DEVELOPMENT OF SCENARIOS FOR FUTURE AGRICULTURAL WATER MANAGEMENT IN SOUTH AFRICA

Report to the
Water Research Commission

by

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Executive Summary

The challenges of feeding South Africa's growing population in a climate-altered, resource-constrained future are substantial. The sustained availability of sufficient and clean freshwater presents one of the greatest risks to South Africa, and the global economy at large. Demand for water in South Africa is projected to increase with economic growth, increased urbanisation, higher standards of living, and population growth. Climate change impacts could exacerbate existing water-related challenges, and create new ones through increased rainfall variability, including more frequent extreme weather events (droughts and floods), changing rainfall seasonality; and overall warming, leading to greater surface water losses to the atmosphere. This would affect a wide range of economic sectors and livelihoods, impact on the development of infrastructure and catchment management, and demand management into the future.

Poor management of water resources threatens the resource base on which agriculture depends; therefore, there is a need to conserve water by creating and managing alternative water sources based on scenarios for future agricultural water use, and other benefits. This project aims at suggesting and developing scenarios for future agricultural water management, despite the natural and unnatural hazards that could unfold in the future. This will be addressed through key objectives such as the identification of the forces that will drive scenarios, and the effects of those forces on scenario building for future agricultural water management.

The scenarios will provide stakeholders and policymakers in South Africa's water sector with valuable insights to strengthen decision-making and counter undesirable trajectories of change in order to achieve food security, the continued relevance of the agricultural sector, and ongoing agricultural development in South Africa.

Research Contextualisation

The research addresses a very serious issue relating to future agricultural water management in South Africa. It has guided the development of scenarios necessary to identify feasible prospects for agricultural water management within the political, social, economic and natural environment.

Research Objectives

The main aim of this research was to develop scenarios that will impact on agricultural water management in South Africa. These scenarios considered the social dynamics (including issues such as poverty, employment, demographic changes, security, etc.); the economic dynamics (including food production, industry, mining, global markets, and trends, etc.), the ecological dynamics (including land degradation, climate change, and variability, etc.), and the political dynamics (including political stability and policy).

- *The secondary objectives of the project were to:*
- *Determine the current status of agricultural water management in South Africa.*
- *Review and provide critical analysis of current social, political and ecological scenarios.*
- *Identify socio-, environmental and economic indicators to measure different scenario outcomes. These indicators were sub-categorised into ten drivers (capitals): human, social, cultural, political, institutional, economic/financial, environmental, technological and infrastructure.*
- *Develop a dynamic decision support tool based on real-time indicator values and changes.*
- *Recommend policy and action plans for sustainable agricultural water management, based on the main scenarios.*

Research Approach

The techniques to obtain and analyse information and data in this study were analytical, theoretical, and descriptive. Both deductive logic and inductive reasoning were applied to analyse the data and information, and to develop the scenarios. This approach started with the identification of predetermined clusters and drivers and their critical uncertainties. The drivers were categorised under cluster headings (social, technological, human, ecological, economic, natural, global, and political). Comprehensive scenarios were then generated based on the impact and degree of uncertainty of the identified drivers.

The approach followed for the development of a mathematical tool for scenario building was based on systems thinking. This is one of the most innovative tools available for identifying drivers of change, and thereby informing policies and strategies around water planning in the face of uncertainties and a constantly changing socio-economic and ecological environment. Systems thinking has been proven to be very useful in water and catchment management planning, because it can inform policymakers and all stakeholders in the water and agricultural sectors about the current water situation in the country, and provide valuable insights to support future water policies, especially regarding the agricultural sector and agricultural development in South Africa.

Research Methodology

This research was completed in four phases namely:

Phase 1: *Comprehensive literature study and review of current water management policies, regulations and scenarios. Detailed reports on literature and current water related acts, policies and regulations at international, regional and national level are reported in Chapters 3 and 4.*

Phase 2: *Expert interviews and participatory workshops. Methods that were used to gather information include: interactive workshops, semi-structured interviews, and two national symposia from target groups such as Department of Human Settlements, Water and Sanitation (DHSWS); Department of Agriculture Land Reform and Rural Development (DALRRD); Department of Environment, Forestry and*

Fisheries (DEFF); National Disaster Management Centre (NDMC); South African Weather Services (SAWS); Agricultural Business Chamber (Agbiz), captains of industries; African Farmers Association (AFASA); AgriSA; National African Farmers Union (NAFU); academia and other organisations and water users. Results from individual consultations and expert discussions provided the research team the confidence that the methodological direction taken was best-suited to this research.

Phase 3: *Scenario development based on qualitative and stakeholder inputs. Information obtained during phase 2 was used to develop scenarios based on the two-axes method. These scenarios were tested with experts during the national symposia, and a water symposium organised by AgriSA in the Western Cape. The feedback was incorporated prior to the development of the final scenarios.*

Phase 4: *A modelling framework for scenario development tool. The mathematical model is based on systems thinking approach and the principle of system dynamics. The data from the Breede river catchment was used to test the tool for robustness.*

Phase 5: *Final reporting and scenario testing. Final testing of the scenarios was done at the national symposium. Various stakeholders participated in the symposium, and post-symposium feedback was used to finalise the scenarios.*

Project Outcome

We developed four potential scenarios ranging from a best-case to a worst-case (Z) scenario. These scenarios are at the strategic level and will impact directly on future water management. The best-case scenario is only possible if private sector, the Government, and society together take full and joint responsibility for future water management.

The worst-case scenario is looming on the horizon if the gap between the “haves” and “have-nots” continue to increase; and, if an environment for job creation and economic development is overshadowed by political opportunism, social unrest and social intolerance; and, if society and government does not eradicate the culture of corruption in all walks of life; and, if service delivery at all governance levels continues to fail because of incompetency and negligence. Delivery of clean and sufficient water and the maintenance and management of water infrastructure is particularly critical and strategic in avoiding a worst case scenario. An intermediate Frustration scenario is where the Government remains pegged down in political struggles, political conflict, and poor service delivery at a local level at the cost of sustainable and efficient developmental programmes. In this scenario the private sector is still efficient and actively involved in economic development, but, together with civil society, is growing increasingly more frustrated with the Government. Our feedback and results indicated that we currently find ourselves in the Frustration scenario with a tendency to shift towards the Traditional and Z scenarios if the private sector withdraw its investments. The Traditional scenario is where the Government becomes more autocratic, driving nationalisation and the implementation of *policies that centralise water management and interfere with the free-market system. That includes the introduction of rules and regulations to control society and limit the influence of the private sector. The Covid-19 pandemic currently serves as an instigator to propel South Africa from the Frustration to the Traditional and most-possibly the Z scenario. If that happens, the private sector will expand to other investment regions and cease further investment in South Africa.*

On the positive side is that signals for a positive scenario became evident with a common realisation that sustainable water management depends on good governance, coordination and cooperation in the water sector. The Minister of Human Settlement, Water and Sanitation showed commitment for increased efficiency in the department and is already involved in discussions with the private sector and other stakeholders. Building on such initiatives should open the pathway for a positive water management scenario.

***Red flags** are those drivers that will have an immediate effect and potentially cause a dramatic shift to a negative scenario. Numerous red flag drivers are identified but the four most important red flag drivers are highlighted here.*

*The **first red flag** is the absence of a social pact between the major stakeholders, i.e. the Government, agribusiness, farmers, farm workers and society at large. The distrust between the Government and the commercial farming sector, and the negative statements from certain political leaders are issues that need to be addressed. This is also characterised by an increased gap between white commercial farmers and black farmers in agriculture as well as the increased gap between the "haves" and "have nots" in society as a whole.*

*The **second red flag** is the capacity of government and more specific provincial and local government to efficiently govern and provide services with the albatross of corruption and self-enrichment around the neck of some leaders and officials; and some elements in the private sector also participating in corrupt activities. This distracts attention from good governance, and forces some leaders and officials to focus on protecting their patronage networks and their own interest, instead of on the needs of the state or province or municipality. This is especially relevant at municipal level where water quality and water availability is determined by proper service delivery and the maintenance of water infrastructure. Poor governance at municipal level is also driving frustration within the citizenry and the increased levels of intolerance.*

*The **third red flag** is centred around the economy and its resilience to withstand the negative impacts of, firstly, the 2015-2019 drought, and, secondly, the 2020-2021 Covid-19 pandemic. Millions of people have lost their jobs, and the Government has provided social grants to support the poorest of the poor; but this cannot continue indefinitely. The Government borrowed money to manage the pandemic, and that needs to be paid back at some stage.*

*The **fourth red flag** is the absence of successful land and water reform. Few of the land reform projects are successful, due to various reasons. The lack of progress in land and water reform sends out a negative message to citizens, and commercial farmers are blamed for not making land available for land reform (which is not the case since the Government already holds titles for millions of hectares of unproductive land). Learning from the example of Zimbabwe, it is clear that the lack of progress with successful land and water reform hold the potential to fast-track South Africa to the Z scenario.*

In three of the four scenarios agriculture will be on the losing end. Agriculture makes use of surplus water after domestic, business, mining and energy water allocations. The negative image of agriculture amongst the average person in South Africa also contributes towards additional challenges for water management in the agricultural sector. Only the positive best case scenario outcome will benefit agriculture (read food security) and the country at large.

Main recommendations

*Scenarios provide a look into **possible** futures, and the development of scenarios is senseless if potential solutions are **then** not investigated and provided. Although the focus of this research was not on the development of **solutions** for water management, but rather on the development of scenarios, some solutions and action plans are also suggested in summarised format in Chapter 10. The solutions are grouped into action plans or strategies for the Government; municipalities, as water services agencies; private sector businesses and industry; civil society as water users; and farmers. The recommendations are also grouped according **to** the 10 clusters, with the most prominent recommendation for each cluster as follows:*

***Human cluster:** The appointment of qualified and experienced staff at all governance levels within all organisations having a stake in water management, water distribution and water use. Organisations must initiate and implement focused training and education programmes to educate individuals in water management issues. The focus should be to educate the critical number of hydrologists and engineers required for water management and planning at all governance levels.*

***Social cluster:** The development of a social pact between all stakeholders to work together, not only in the water sector but in all aspects of societal interaction. Governance sectors **are** probably the most important driver.*

***Cultural cluster**: **The d**river identified as **most** important within the cultural cluster is the societal consciousness of the importance of water as a strategic natural resource. In addition, leaders, water managers, water users, scientists, and others need to make a paradigm shift **to** view and treat water as a flux and not a stock.*

Political cluster: *The political cluster is closely linked to the social and cultural clusters in* ***that*** *leaders influence the way* ***members of*** *society act and react toward**s** each other. The social pact mentioned under the social cluster is not possible without the support and positive example of political leaders. Policy addressing* ***the rectifying*** *of land and water rights* ***is*** *equally important**,** and if land and water reform fails, one would see a* ***Z*** *scenario sooner than later.*

Economic/financial cluster*: The major driver in the economic cluster focuses on the investment in water infrastructure and new technology at all levels of governance. Also important is the acknowledgement that water is an economic driver**,** and the realisation that South Africa is already economically constrained because* ***it*** *is**, for additional** reasons**,** also water constrained.*

Infrastructure cluster: Key success factors here are the m*aintenance of current water infrastructure**,** and timely and innovative construction of future water infrastructure development with consideration of population growth and climate change.*

Technology cluster*:* ***New technologies that will be*** *a key driver for sustainable water management include* ***those designed and implemented around*** *water saving**,** water harvesting, new water, dual reticulation system**s**, conservation and precision agriculture, early warning, monitoring and remote sensing.*

Natural resources cluster: *South Africa is an arid country with a water constrained economy**,** and we need to treat water as a flux and not as a stock. Climate change and climate extremes, together with population growth**,** negatively affect the water supply/demand ratio. All water management organisations and water users need to protect and preserve water sources – groundwater and surface water – with vigilance through the prevention of water pollution and land and wetlands degradation; the implementation of "new water technology"**;** conservation agriculture**;** water saving technology**;** and water harvesting**,** amongst other interventions.*

Organisations cluster: *Organisations dealing with water management and distribution need to be* ***properly*** *funded**,** and staffed with expert and qualified staff. Key organisations are Department of Human Settlement, Water and Sanitation (DHSWS**;** Catchment Management Agencies (CMAs)**;** Water User Organisations (WUAs)**;** Water Supply Agencies (WSAs) (municipalities)**;** and farmers' organisations that lobby for farmers at all levels.*

Institutions cluster: *Institutions deal with the way organisations interact with each other**,** and the regulations required for sound management. South Africa has**,** in general**,** excellent laws and regulations**,** but implementation, enforcement and adherence to laws and regulations is a key requirement for a positive scenario in water management.*

Recommendations for further research

The system dynamics model developed as part of the research utilised data from the Breede river catchment and further research is required to test the model for robustness and application in other catchments and the use of the model at national level. In addition, the model should be developed to become more user-friendly and available for drought monitoring and early warning.

The action plans proposed in the final chapter of the report need to be prioritised and reviewed with additional contributions from the different stakeholders.

The "too little" (drought), "too much" (floods) and "too bad" (water pollution) need to be prevented and managed in a coordinated manner. Drought management, for example, is managed by different departments with Disaster Management responsible for coordination. The Department of Agriculture, Rural Development and Land Reform (DARDLR) is primarily responsible for agricultural drought, Department of Human Settlement, Water and Sanitation (DHSWS) is primarily responsible for hydrological drought (rivers, dams, groundwater), Department of Environment Forestry and Fisheries (DEFF) is responsible for drought affecting eco-systems, land degradation; and the South African Weather Service (SAWS) is also located in DEFF; finally, the Department of Coordination and Traditional Affairs (COGTA) through the municipalities are responsible for domestic water supply. Each of these departments hosts its own drought monitor and early warning information system with little or no integration. The recently developed national drought plan for South Africa proposes an integrated drought mitigation unit as part of the National Disaster Management Centre. Further research is required to determine the best placing of such a unit, its functions and operational requirements.

Conclusion

The results of the project have already created an awareness of potential water management scenarios through the different stakeholder consultations, symposia, peer reviewed publications, and media coverage. Two post graduate students qualified – one with a master's degree and one with a PhD. However, further publications and training are required to obtain full advantage of the contents of this report. We recommend a post-project training and education programme with the following objectives:

- *Training and education of students in scenario building methods.*
- *Training and education of students in the development of scenarios through mathematical modelling.*
- *Sharing of information with water management stakeholders.*
- *Sharing of information with policymakers and decision-makers in the water sector.*

This report contains a wealth of information. If all stakeholders seriously consider the potential scenarios, and implement the necessary recommendations, it will have a positive impact on future water management in the agricultural sector, and prevent the Z scenario being realised.

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Abbreviations

AFASA	African Farmers Association of South Africa
Agbiz	Agricultural Business Chamber
AgriSA	Farmer representative organisation at national level
APAP	Agricultural Policy Action Plan
ARC	Agricultural Research Council
BAU	Business as Usual
BBBEE	Broad Based Black Economic Empowerment
CLD	Causal Loop Diagrams
COGTA	Department of Local Governance and Traditional Affairs
DALRRD	Department of Agriculture, Rural Development and Land Reform
DDMC	District Disaster Management Centre
DEFF	Department of Environmental, Forestry and Fisheries
DMU	Drought Mitigation Unit
DWS	Department of Human Settlement, Water and Sanitation
EWS	Expropriation without Compensation
IBT	Inter-Basin Transfer
IWRM	Integrated Water Resource Management
JDMC	Joint Drought Mitigation Committee
KPA	Key Performance Area
NAFU	National African Farmers' Union
NDMC	National Disaster Management Centre
NDMU	National Drought Mitigation Unit
NDP	National Development Plan
NGO	Non-Governmental Organisation
NGOs	Non-Governmental Organisations
NJDMC	National Joint Drought Mitigation Committee
NWRS	National Water Resources Strategy (NWRS
PDMC	Provincial Disaster Management Centre
PDoARD	Provincial Department of Agriculture and Rural Development
PM	Participatory Modelling
SADC	South Africa Development Community
SASA	South African Satellite Agency
SAWS	South African Weather Service
SD	System Dynamics
SDM	System Dynamics Modelling
SFD	Stock and Flow Diagram
SFDs	Stock and Flow Diagrams

SIP	Strategic Infrastructure Project
TSRC	Total surface resource capture
WMA	Water Management Agency
WSA	Water Service Authority
WUO	Water User Organization
WWF	World Wide Fund

List of Units

Kg	Kilogram
km^2	Square Kilometre
L	Litre
mm	Millimetre
m^3	Cubic metre
ppm	Parts per million
t	Ton
^{O}	Degree
^{O}C	Degree Celsius
%	Percent

Glossary of Terms

Capacity: A combination of all the strengths and resources available within a community, society or organization that can reduce the level of risk, or the effects of a disaster. Capacity may include physical, institutional, social or economic means as well as skilled personal or collective attributes such as leadership and management. Capacity may also be described as capability (UNISDR, 2004).

Capacity Building: Efforts aimed to develop human skills or societal infrastructures within a community or organization needed to reduce the level of risk. In extended understanding, capacity building also includes development of institutional, financial, political and other resources, such as technology at different levels and sectors of the society (UNISDR, 2004).

Climate Change: The climate of a place or region is changed if over an extended period (typically decades or longer) there is a statistically significant change in measurements of either the mean state or variability of the climate for that place or region. Changes in climate may be due to natural processes or to persistent anthropogenic changes in atmosphere or in land use (UNISDR, 2004). The definition of climate change used in the United Nations Framework Convention on Climate Change (UNFCCC) is more restricted, as it includes only those changes, which are attributable directly or indirectly to human activity (UNFCCC, 2008). According to the UNDP (2008) climate change refers to deviations from natural climatic variability observed over time that are attributed directly or indirectly to human activity and that alter the composition of the global atmosphere. Both the UNFCCC and the UNDP use the definition that attributes climate change to human activity. In the context of this study the UNFCCC and UNDP definitions hold.

Clusters Clusters according to this study represent the categorisation of the drivers of change. Ten clusters were identified and used in this study. These clusters include social, cultural, human, natural, economic, technological, infrastructural, institutional, organisational and political.

Coping Capacity: The means by which people or organizations use available resources and abilities to face adverse consequences that could lead to a disaster. In general, this involves managing resources, both in normal times as well as during crises or adverse conditions. The strengthening of coping capacities usually builds resilience to withstand the effects of natural and human-induced hazards (UNISDR, 2004).

Desertification: The process of land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities (UNDP, 2008).

Disaster: A serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources. A disaster is a function of the risk process. It results from the combination of hazards, conditions of vulnerability and insufficient capacity or measures to reduce the potential negative consequences of risk (UNISDR, 2004).

Disaster Management: The IDRM (IDRM International, 2009) explains DM by noting that there could not be a single organization solely responsible for all aspects of disaster management. The management task is to bring together, in an integrated organizational structure, the resources of many organizations that can take appropriate action in times of disasters. UNDHA (1999) defines DM as the body of policy and administrative decisions and operational activities which pertain to the various stages of a disaster at all levels.

Disaster Risk Management: The systematic process of using administrative decisions, organization, operational skills and capacities to implement policies, strategies and coping capacities of the society and communities to lessen the adverse impacts of natural hazards and related environmental and technological disasters. This comprises all forms of activities, including structural and non-structural measures to avoid (prevention) or to limit (mitigation and preparedness) adverse effects of hazards (UNISDR, 2004). IDRM (2009) describe DRM as a development approach to disaster management, this focuses on underlying conditions of the risks, which lead to disaster occurrence. The objective is to increase capacities to effectively manage and reduce risks, thereby reducing the occurrence and magnitude of disasters.

Disaster Risk Reduction: The conceptual framework of elements considered with the possibilities to minimize vulnerabilities and disaster risks throughout a society, to avoid (prevention) or to limit (mitigation and preparedness) the adverse impacts of hazards, within the broad context of sustainable development.

The disaster risk reduction framework is composed of the following fields of action (Living With Risk, 2002):

- Risk awareness and assessment including hazard analysis and vulnerability/capacity analysis.
- Knowledge development including education, training, research and information.

- Public commitment and institutional frameworks, including organisational, policy, legislation and community action.
- Application of measures including environmental management, land-use and urban planning, protection of critical facilities, application of science and technology, partnership and networking, and financial instruments.

Early warning systems including forecasting, dissemination of warnings, preparedness measures and reaction capacities.

Droughts: A deficiency of precipitation from expected or "normal" that, when extended over a season or longer period of time, is insufficient to meet demands. This may result in economic, social, and environmental impacts. It should be considered a normal, recurrent feature of climate. Drought is a relative, rather than absolute, condition that should be defined for each region. Each drought differs in intensity, duration, and spatial extent (Knutson *et al.,* 1998). The UNDP (2008) defines drought as the naturally occurring phenomenon that exists when precipitation has been significantly below normal recorded levels, causing serious hydrological imbalances that adversely affect land resource production systems.

Drought Impact: A specific effect of drought. People also tend to refer to impacts as *"consequences"* or *"outcomes."* Impacts are symptoms of vulnerability (Knutson *et al.,* 1998).

Drivers of change Drivers are fundamental agents of environmental change that are external to a particular system. These are factors that influence the functioning of the system.

Dry period: Refers to a period of below mean precipitation where vegetation and water resources are impacted negatively. The dry period is not as serious as drought.

Early warning: The provision of timely and effective information, through identified institutions, that allows individuals exposed to a hazard to act to avoid or reduce their risk and prepare for effective response. Early warning systems include a chain of concerns, namely: understanding and mapping the hazard; monitoring and forecasting impending events; processing and disseminating understandable warnings to political authorities and the population, and undertaking appropriate and timely actions in response to the warnings (UNISDR, 2004).

Ecosystem: A complex set of relationships of living organisms functioning as a unit and interacting with their physical environment (UNISDR, 2004). The boundaries of what could be called an ecosystem are somewhat arbitrary, depending on the focus of interest or study. Thus, the extent of an ecosystem may range from very small spatial scales to, ultimately, the entire Earth (IPCC, 2001).

Environment: The combination of external physical conditions that affect and influence the growth, development and survival of organisms. This includes all of the biotic and abiotic factors that act on an organism, population, or ecological community and influence its survival and development. *Biotic* factors include the organisms themselves, their food and their interactions. *Abiotic* factors include such items as sunlight, soil, air, water, climate and pollution. Organisms respond to changes in their environment by evolutionary adaptations in form and behaviour (UNDP, 2008).

Environmental Degradation: The reduction of the capacity of the environment to meet social and ecological objectives, and needs. Potential effects are varied and may contribute to an increase in vulnerability and the frequency and intensity of natural hazards. Some examples are: land degradation, deforestation, desertification, wild fires, loss of biodiversity, land, water and air pollution, climate change, sea level rise and ozone depletion (UNISDR, 2004).

Farming System: A farming system is defined as a population of individual farm systems that have broadly similar resource bases, enterprise patterns, household activities and constraints, and for which similar development strategies and interventions would be appropriate. Depending on the scale of the analysis, a farming system can encompass a few dozen or many millions of households (FAO, 2001).

Forecast: Definite statement or statistical estimate of the occurrence of a future event (UNESCO, WMO).

Hazard: A potentially damaging physical event, phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation. Hazards can include latent conditions that may represent future threats and can have different origins: natural (geological, hydro-meteorological and biological) or induced by human processes (environmental degradation and technological hazards). Hazards can be single, sequential or combined in their origin and effects. Each hazard is characterised by its location, intensity, frequency and probability (UNISDR, 2004). Hazard in the context of this study refers to drought caused by hydro-meteorological elements causing dry periods such as lack of precipitation, high temperatures, high winds and evapotranspiration.

Hazard Analyses:	Identification, studies and monitoring of any hazard to determine its potential, origin, characteristics and behaviour (UNISDR, 2004).
Hydro-meteorological Hazards:	Natural processes or phenomena of atmospheric, hydrological or oceanographic nature, which may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation (UNISDR, 2004). Drought is a hydro-meteorological hazard, but in the context of this study only the term "*hazard"* is used.A system is an organised set of detailed methods, procedures and routines created to carry out a specific activity. It is a purposeful structure that consists of interelated and interdependent elements that continously influence each other to maintain their activity and system existence in order to achieve the system main goal.
Information Management and Communication System:	An information system, togther with knowledge and communication system, is a system with the capability to provide answers to questions of "where", "who", "when", "what", "how" and "why" (Business dictionary, 2018:1; Banks, 2002:195). The UNISDR (2013), termed the system an Information and Knowledge Management for Disaster Risk Reduction and defined it as a system that enables and sustains informed decision-making for managing disaster risk and an essential for coordinated action. The NDMF (2005:63) defines an information management and communication system as a system with geographical information systems for mapping and information display application and has capabilities to acquire, sort, store and analyse data for the purposes of targeting information for primary interest groups.
Land degradation:	The reduction or loss in arid, semi-arid and dry sub-humid areas of the biological or economic productivity and complexity of rain-fed cropland, irrigated cropland, or range, pasture, forest and woodlands. Land degradation results from a process or combination of processes, including those arising from human activities and habitation patterns that include: (i) soil erosion caused by wind and/or water, (ii) deterioration of the physical, chemical and biological or economic properties of soil and (iii) long-term loss of natural vegetation (UNDP, 2008).
Livelihood:	The means for securing the necessities of life so that individuals, households and communities can sustain a living over time, using a combination of social, economic, cultural and environmental resources (UNDP, 2008).
Mitigation:	Structural and non-structural measures undertaken to limit the adverse impact of natural hazards, environmental degradation and technological hazards (UNISDR, 2004).

Natural hazards: Natural processes or phenomena occurring in the biosphere that may constitute a damaging event. Natural hazards can be classified by origin namely: geological, hydro-meteorological or biological. Hazardous events can vary in magnitude or intensity, frequency, duration, area of extent, speed of onset, spatial dispersion and temporal spacing (UNISDR, 2004).

Natural resources: Non-renewable resource such as minerals, fossil fuels and fossil water, and renewable resources such as non-fossil water supplies, biomass (forest, grazing resources) marine resources, wildlife and biodiversity.

Preparedness: Activities and measures taken in advance to ensure effective response to the impact of hazards, including the issuance of timely and effective early warnings and the temporary evacuation of people and property from threatened locations (UNISDR, 2004).

In the context of this study preparedness refers to the *"readiness"* of the agricultural sector or individual farmers or communities to overcome the negative impacts of drought.

Relief/Response: The provision of assistance or intervention during or immediately after a disaster to meet the life preservation and basic subsistence needs of those people affected. It can be of an immediate, short-term, or protracted duration (UNISDR, 2004).

In the context of this document relief refers to measures such as subsidies for fodder purchases, interest subsidies or soft loans, extension of debt repayments, or any other measure that support the agricultural sector, communities or farmers in order to financially survive the negative impacts of drought. Relief and response in this context do not include risk reduction measures for future droughts.

Resilience/resilient: The capacity of a system, community or society potentially exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure. This is determined by the degree to which the social system is capable of organizing itself to increase its capacity for learning from past disasters for better future protection and to improve risk reduction measures (UNISDR, 2004).

In the context of this study resilience refers to the capacity of agriculture, farmers or communities to withstand the negative effects of drought without any additional support. The term capacity is also used in the study in the same context.

Risk: The probability of harmful consequences, or expected losses (injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human-induced hazards and vulnerable conditions (UNISDR, 2004).

Conventionally risk is expressed by the notation; Risk = Hazards x Vulnerability. Some disciplines also include the concept of exposure to refer particularly to the physical aspects of vulnerability. Beyond expressing a possibility of physical harm, it is crucial to recognize that risks are inherent or can be created or exist within social systems. It is important to consider the social contexts in which risks occur and that people therefore do not necessarily share the same perceptions of risk and their underlying causes.

Risk Assessment/Analysis: A methodology to determine the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability that could pose a potential threat or harm to people, property, livelihoods and the environment on which they depend. This study also includes resilience or coping capacity as part of risk (UNISDR, 2004). Knutson *et al.* (1989) define drought risk analysis as "the process of identifying and understanding the relevant components associated with drought risk as well as the evaluation of alternative strategies to manage that risk".

The process of conducting a risk assessment is based on a review of both the technical features of hazards such as their location, intensity, frequency and probability; and also, the analysis of the physical, social, economic and environmental dimensions of vulnerability and exposure, while taking particular account of the coping capabilities pertinent to the risk scenarios.

Small-scale farmers: Small-scale farmers are by definition those farmers in transition between subsistence and commercial farmers. They are normally too small to apply modern technology and to mechanise and most of their inputs are labour intensive yet they already produce surplus food and fibre for the market (Jordaan & Jooste, 2003).

Subsistence farmers: Individuals farming with livestock, horticulture or any system but they do not produce any surplus. Agriculture is a livelihood means and subsistence farmers utilise products only for personal and their own livelihood means. This group of farmers do not produce any surplus food for the market (Jordaan & Jooste, 2003).

Sustainable development:	Development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Sustainable development is based on socio-cultural development, political stability and decorum, economic growth and ecosystem protection, which all relate to disaster risk reduction (UNISDR, 2004).
Vulnerability:	The conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards (UNISDR, 2004).

1 INTRODUCTION

The challenges of feeding South Africa's growing population in a climate-altered, resource-constrained future are substantial. The availability of freshwater presents one of the greatest risks to South Africa and the global economy at large. Demand for water in South Africa is projected to increase with economic growth, increased urbanisation, higher standards of living, and population growth. Climate change impacts could exacerbate existing water-related challenges and create new ones through increased rainfall variability including more frequent extreme weather events (droughts and floods), changing rainfall seasonality and overall warming leading to greater surface water losses to the atmosphere. This would affect a wide range of economic sectors and livelihoods, impact on the development of infrastructure and catchment management, and demand management into the future. Poor management of water resources threaten the resource base on which agriculture depends, therefore, there is a need to conserve water by creating and managing alternative water sources through the development of scenarios for future agricultural water use and other benefits This project aims at suggesting and developing scenarios for future agricultural water management despite natural and unnatural hazards which pose as challenges to this development. These aims will be addressed through key objectives such as identification of scenario driving forces and the effects of these driving forces on scenario building for future agricultural water management. An important tool that can be used is the development of knowledge base scenarios developed through structured research, which included an extensive participative process from different stakeholders involved in the agricultural sector and other water-related sectors. The scenarios will provide stakeholders and policy-makers in South Africa's water sector with valuable insights to strengthen decision-making and to counter undesirable trajectories of change to achieve food security, continued relevance of the agricultural sector and agricultural development in South Africa. Various authors have already looked into this topic, therefore, the focus of this report is a review of current literature. The format of the report consists of the title, authors, publication date and the executive summary regarding the need for water management as well as the effects of climate change on agriculture and possible future scenarios for the development and management of water use.

1.1 Motivation for the study

The challenges of feeding South Africa's growing population in a climate-altered, resource-constrained future are substantial. The availability of freshwater presents one of the greatest risks to South Africa and the global economy at large. The World Economic Forum's (WEF) Global Risk Report (2021) list climate and water crisis amongst the top priority global risks in terms of impact, and likelihood (See Table 1.1). Infectious diseases is listed for the first time because of the Covid-19 pandemic.

Table 1.1: Top priority risks according to likelihood and impact

Ranking	Likelihood	Impact
1	Extreme weather	Infectious diseases
2	Climate action failure	Climate action failure
3	Human environmental damage	Weapons of mass-destruction
4	Infectious diseases	Biodiversity loss
5	Biodiversity loss	Natural resource crisis
6	Digital power concentration	Human environmental damage
7	Digital inequality	Livelihood crisis

Source: WEF, 2021

Demand for water in South Africa is projected to increase with economic growth, increased urbanisation, higher standards of living, and population growth. Climate change impacts could exacerbate existing water-related challenges and create new ones through increased rainfall variability including more frequent extreme weather events (droughts and floods), changing rainfall seasonality, and overall warming leading to greater surface water losses to the atmosphere. South Africa depends mainly on surface water resources for most of its urban, industrial, and irrigation requirements. The use of water is dominated by irrigation, amounting to over 60% of the total water use in the country, the bulk of which is used consumptively. However, with the amount of water that agriculture uses, it forms a key, but a small part of the South African economy, contributing only between 2-2,6% of the Gross Domestic Product (GDP) (DAFF, 2018). In addition, the agro-processing industry, which is dependent on irrigation, makes up 20% of South Africa's GDP and is an important source of foreign exchange earnings. It is also a crucial source of employment, particularly in rural areas, employing 15% of the labour force. The challenge is to produce more food with the same amount or less water. Therefore, it is essential to enhance the productivity of water, which improves the competitive advantage of agriculture in a global economy.

Water availability affect a wide range of economic sectors and livelihoods. For instance, the 2015 drought experienced in South Africa wreaked havoc on crops and livestock production. SA is the major producer of maize in Africa with an average production of nearly 13 million tons per annum. The impact of drought in the central parts of South Africa is dramatic and has a direct impact on food prices and food security in SA and even SADC. Figure 1.3 illustrates the impact of drought on maize production with maize production far below the trend line during drought years. These are evident in 1972, 1982, 1983, 1991, 1994, 2005 and 2015.

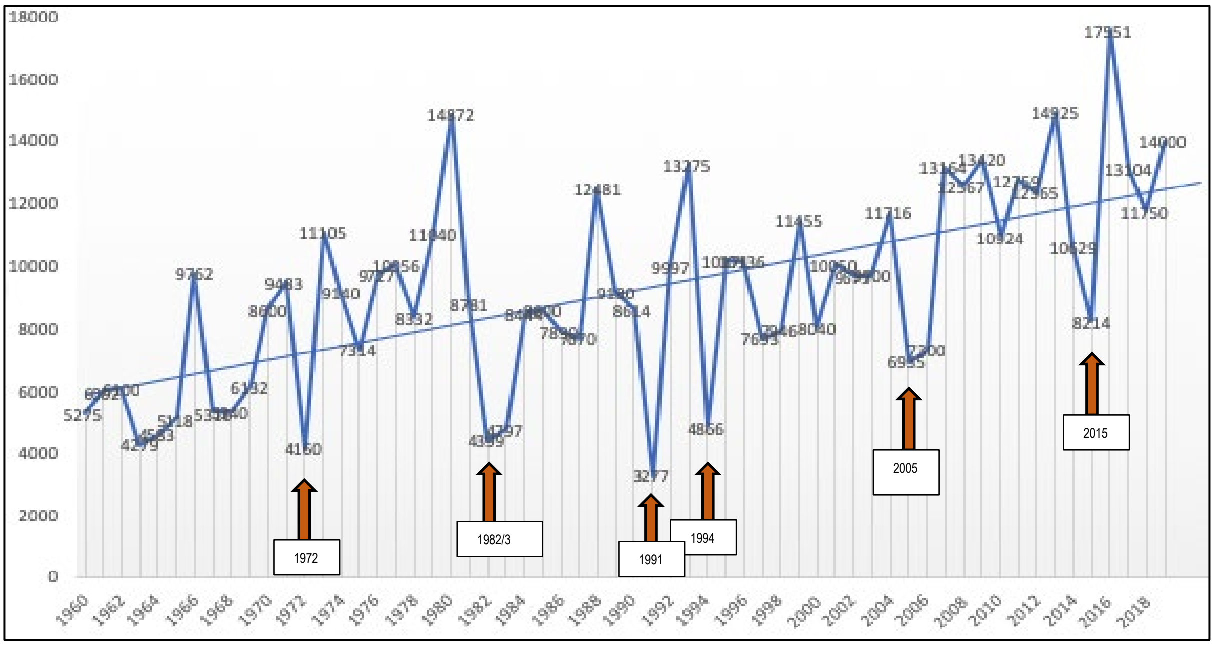

Figure 1.1: Historical maize (ton '000) production and trend
(Source: Jordaan et al., 2019; Data from SAGIS, 2019)

Agriculture is also facing increasing competition from domestic and industrial users. Water requirements for urban and domestic use account for nearly 30%, with the remainder being used for mining, bulk industries and as cooling water for power generation. Water quality has deteriorated in the rivers receiving large quantities of effluent. Some rivers with relatively high salinity (brackish) water occur in the dryer parts of the country. Major sources of pollution of surface waters are agricultural drainage and runoff, urban runoff and effluent return flows, industry, mining and rural settlements with insufficient sanitation services. The most important of these are currently insufficiently treated urban effluent and acid mine drainage. Pollution of groundwater mainly results from mining activities and human settlements. Water is also extensively re-used in South Africa, adding nearly 20% to the yield available from the surface water resources.

The National Development Plan 2030 clearly states that food, fuel and water are interconnected, particularly in the context of climate change and their impact on one another. Social development and economic growth are key national and regional priorities (SADC, 2004; NPC, 2011). Socio-economic development depends on the effective deployment of resources, particularly water, with water resources being required for basic human needs and water security being critical for agricultural and industrial development (United Nations, 2003). Therefore, research and focused monitoring is required to support the development of tools, approaches and case studies that will inform water planning in the context of long-term climate change. An important tool that can be used is the development of knowledge base scenarios developed through structured research, which included an extensive participative process from different stakeholders involved in the agricultural sector and other water-related sectors. These scenarios will provide stakeholders and policy-makers in South Africa's water sector with valuable insights to strengthen decision-making and to counter undesirable trajectories of change to achieve food security, continued relevance of the agricultural sector and agricultural development in South Africa.

During the transition to democracy in 1994 scenario planning played a very important role in helping different decision-makers understand the overall complexity arising from a highly polarized society. Scenario planning was a core element in a USAID project recently completed in the Limpopo and Okavango River Basins. As the consequences of the worst El Nino drought event in living memory become manifested, the potential role for scenarios again comes to the fore. South Africa is already transitioned to a fundamental water constrained national economy. Agriculture is a major user of the national water budget, generating an important component of overall food security in the country. Work recently concluded by DFID suggests that South Africa, along with other water constrained countries in the SADC region, can no longer have national water security, national food security and national energy security, simultaneously. These will need to be collectively sourced at regional rather than at the national level. This has strategic-level implications for the sovereign integrity of the state. Just as scenarios informed the CODESA process, carefully crafted scenarios are capable of informing the decision-making that will soon be required regarding national versus regional self-sufficiency in water, energy and/or food.

1.2 Project Contextualisation

The project addressed a very serious issue relating to future water management in South Africa. It should assist stakeholders to identify feasible prospects for agricultural water management within the political, social, economic and natural environment based on scenarios developed. The outcome from this project should (i) inform policy and decision making at national level, (ii) lead to human capital development in the water and agricultural sciences sectors, (iii) lead to the development of a framework for future water management which will serve as guidance for economic development, that is intrinsically linked to water management. As part of the project, (i) capacity building was also be achieved through the numerous participatory workshops and two national symposia, (ii) student training and education by the graduation of one Master student and one PhD student, and (iii) knowledge dissemination through curricula development of new and current University modules. The students actively contributed to the outcome of the project.

Governmental departments assisted with the information included Department of Agriculture, Rural Development and Land Reform, Department Housing, Water and Sanitation, Department of Environment, Forestry and Fisheries, the National Disaster Management Centre, Provincial Disaster Management Centers, the South African Weather Service and the Western Cape Department of Agriculture, Rural Development and Land Reform. Industry collaborating partners included African Farmers Association (AFASA), National African Farmers Union (NAFU), AgriSA and its regional structures and Agribusiness SA (Agbiz SA) and its affiliates (agricultural businesses in SA).

Participatory workshops with stakeholders provided the ideal opportunity for knowledge dissemination and exchange.

1.3 Outcomes and Impacts

The main outcomes of the research are the different scenarios, which provide the framework for policy and recommendations for action plans that should be developed for future agricultural water management in South Africa. To develop the scenarios, the following were achieved:

1.3.1 Specific Outcomes

- Critical analysis and documentation of the current status quo of the agricultural water management in South Africa and Southern African Development Countries (SADC). (We cannot manage our water resources in isolation in SA) *(Chapter 2)*
- Development of scenarios for population demographics, technological development, agriculture, and food production, global change, and climate change in South Africa and SADC within the political, social, economic, and natural environment. Water is a trans-boundaries issue. Issues such as population movement, economic development, food production, political stability, and security are all closely interdependent in SADC; so we need to consider scenarios for SA that consider SADC scenarios.
- Development of a concept for a computer-based dynamic, integrated decision support tool to allow for consideration of changing indicators for the different sectors (natural, economic, social, and political environment). The development of such a tool will allow decision and policymakers to make dynamic adjustments based on real-time changes and immediately view potential scenario outputs.
- The scenario development addressed some of the WRC lighthouse terminologies that include (a) water sensitive design systems and technology, (b) climate change impacts, (c) water-food-energy nexus, (d) green technology and green villages, and (e) water governance.
- Recommendations as output for the national water budgeting and sustainable use and allocations to different sectors to maintain economic viability under three different scenarios. (best case, worst case and most probable) ***(Chapter 10)***

1.3.2 Secondary Outcomes Achieved

Some of the secondary outcomes achieved are:

- Awareness-raising among different stakeholders, i.e. water users and agro-processing sector through eight consultative workshops and two national symposia
- Communication of outcomes through documentation, publications, conferences (local and international), and reports.

  - Presentation at AgriSA national water management symposium on 26 August 2019
  - Presentation at DMISA national conference 18 and 19 September
- Training and education of students. Two students graduated; one student with a Master's degree and a PhD candidate ready to hand in thesis in 2021.

1.3.3 Potential Impact

- The proposed scenarios highlight the red flags as an early warning for incorrect policy and implementation.
- The proposed scenarios provide guidelines for policy and action plans for sustainable water management
- The framework for a dynamic decision support tool based on real-time indicators provides the content and indicators for the future development of a decision support tool. This framework is based on identified drivers and the scenarios developed is a major outcome of this project.
- The proposed scenarios development can be used as a means of preventing conflict through informed and timely decision making in that it serves as an early warning signal to decision-makers.
- Development of policies for a more efficient water management system with consideration of different scenarios.
- Policymakers will be able to make a more informed decision on water management
- Collaborating partners already secured and identified for this project are all the important role players in agriculture (AgriSA, Agbiz, DAFF, DWS) and they will be well informed about the scenarios through the participatory workshops and two national symposia.

1.4 Structure of Report

This report consists of 10 Chapters and one attachment numbered as chapter 11.

Chapter 1 is the introduction and the following are discussed in chapter 1:

- Motivation to the study.
- Contextualisation.
- The objectives of the study.
- Outcomes and impacts.
- Knowledge dissemination and uptake.

Chapter 2 describes the methodology followed to identify drivers for future scenarios, and the approach to develop the systems analytic programme. The following are discussed in chapter 2:

- Aim of research

- Methodological approach
- Driver identification approach
- Modelling approach
- Scenario development approach
- Project Implementation

Chapter 3 is an annotated bibliography literature dealing with water management. The following are discussed in Chapter 3:

- Relevant global literature
- Relevant literature with a focus on SADC
- Relevant literature with a focus on South Africa

Chapter 4 is a literature study on policies and regulations dealing with water and water management in SADC and South Africa. The following is discussed in Chapter 4:

- SADC regional water policy.
- South African National Water Act 36 of 1998.
- National Water resources strategy (NWRS), 2013.
- Water for growth and development framework.
- Draft position paper for water allocation in South Africa: Towards a framework for water allocation planning, 2005.
- South African production strategy.
- Integrated growth and development plan.
- Draft irrigation strategy for South Africa, 2015.
- Draft policy framework on irrigation for South Africa: Focus on revitalisation of irrigation.
- Medium-term strategic framework (MTSF), 2014-2019.
- Comprehensive rural development strategy.
- War on poverty.
- Critical analysis of policies and strategies.

Chapter 5 is a discussion of the clusters and associated drivers used for scenario building. The following are discussed in Chapter 4:

- Scenario planning and drivers of change.
- Definition of scenario planning.
- History of scenario planning.
- Theory and methodologies of scenario planning.
- Water resource planning and management under uncertainty.
- Drivers for scenario development.

- Agricultural water use drivers:

Chapter 6 provides the results from consultative workshops and discussions. The following is discussed in Chapter 6:

- Methodological approach to scenario building
- Participatory stakeholder workshops
- Feedback from stakeholder workshops

Chapter 7 is a discussion of the conceptual modelling and system dynamics approach the following is discussed in chapter 7:

- Participatory modelling with system dynamics
- Results from system dynamics modelling
- Integrating the conceptual models
- Discussion of results

Chapter 8 focuses on the application of the conceptual modelling and provides a simulation for the coupled water-food systems in South Africa using the Breede river catchment as case study. The following is discussed in chapter 8:

- Methodological approach to modelling
- Input data and parameterisation
- Model testing and sensitivity analysis
- Policy scenarios
- Modelling results
- Discussion of results

Chapter 9 provides consolidated and final recommendations for future agricultural water management in South Africa. The systems dynamic modelling results, as well as the results discussed in Chapters 7 and 8, support the final scenarios. The following is discussed in Chapter 9:

- Scenario building process
- Decide drivers of change
- Consolidated agricultural water management scenarios
- Current position
- Red flags

Chapter 10 focus on the recommendations, conclusions and study limitations as follows:

- Paradigms of water resource management

- Potential actions and strategies to enable the *"strive for the best-case scenario"* and *"avoid the z-scenario"*

Appendix A provides project implementation details. The following is highlighted in the Appendix.

- Project timelines
- Project outcomes as per contract
- Innovation
- Capacity building
- Community development
- Project Management
- Finances
- Limitations of the study
- Follow up recommendations
- Recommendations for further research

1.5 Conclusion

This chapter provides background information toward the motivation and contextualization of the project with a summary of the project outcomes and the report structure. Details regarding project implementation, contractual commitments such as knowledge dissemination, innovation, capacity building, institutional development and recommendations for further research is addressed in Attachment A.

1.6 References

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2 THE METHODOLOGICAL APPROACH TO SCENARIO BUILDING

2.1 Introduction

The management of water issues for sustainable development requires the adoption of a long-term view to account for the changes in some of the hydrological and social processes and time necessary for investments in water projects to start yielding benefits to the economy. Projections of trends in human activities may produce legitimate results over the short-term, but may ultimately become unreliable over medium to long-term periods (Gallopín & Rijsberman, 2000). Fundamental uncertainties are brought about both by the limited understanding of human and ecological processes and by the intrinsic indeterminism of intricate dynamic systems. Furthermore, social developments in the future will depend on human choices which are yet to be made (Gallopín et al., 1997). Water must be regarded, both in its natural form and in balancing competing demands upon it domestic, agricultural, industrial, and environmental in a way that ensures the sustainability of the resource (Cosgrove & Rijsberman, 1998).

The approach followed in this study deliberately focused first on developing qualitative scenarios, which allowed for the incorporation of the many social, economic, ecological, technological, infrastructural, political, institutional, organisation and cultural factors that are considered to play a major role in shaping water use management in the future. The qualitative scenarios were subsequently be modelled quantitatively. The development and discussion of qualitative scenarios served as a platform for consultation among many stakeholders from different disciplinary backgrounds and different stakeholder perspectives (Farmers, farmers' organisation, political analysts, government organisation, etc.).

Policy development on its turn requires contributions from scientific experts and non-experts (Turner, 2016). This study followed the approach noted by Turner (2016) in selecting the participants for the consultative workshops and national symposia making the participants as diverse as possible. Participatory planning is important for policy development and implementation because it takes into account the views of stakeholders who are most likely to be affected by the policies.

Mathematical simulation models were used subsequently to analyse the consistency and coherence of the qualitative scenarios, explore some of the consequences, and help fill in some of the gaps. The scenarios evolved in at least five rounds of development, discussion, feedback, and subsequent improvement, in the interaction between the project team, stakeholders, scenario developers, modellers, reviewers, and the reference group for the project. We adopted the approach of smaller workshops with different stakeholders to introduce the project and also capture independent views.

According to Gallopín (2012), scenario development typically involves the following elements: characterization of the current situation, with a diagnosis of the starting state of the scenarios, focused on the focal issue or problem under consideration (water in this case), identification of major driving forces that represent the key factors, trends or processes that influence the situation, focal issue or decisions that propel the system forward and condition the story's outcome. Some of these forces are invariant (e.g. they apply to all scenarios) and to a large extent predetermined (Shiklomanov, 1997). Some of the driving forces may represent critical uncertainties, the resolution of which can fundamentally alter the course of events. These driving forces (or drivers, for short) influence but do not completely determine the future (Gallopín, 2012). Thus, while the initial state of the drivers is the same in all scenarios, the trajectory of the system follows a different course in each one. The formulation of the plot, the current state, driving forces, strategic invariants, and critical uncertainties form the backbone of the scenarios. In addition, all scenarios unfold according to an internal logic (the plot) that links the various elements (Gallopín, 2012).

The Participatory Modelling (PM) approach based on the principles of system thinking was selected as the most appropriated modelling technique to determine qualitative outcomes quantitatively. The PM approach uses systems dynamics modelling technique in which stakeholders or experts participate to some degree in different stages of the process, including problem definition, system description, identification of policy levers, model development, and/or policy analysis (Stave, 2010). The approach is based on the notion that people who reside and work in a system may be better informed about its processes and probably have observed phenomena that would not be captured by scientists (Voinov & Bousquet, 2010). Several scholars and experts who have used the PM approach have highlighted several benefits of modelling with stakeholders. These include facilitating and structuring discussion between scientists and stakeholders, the clarification of stakeholders' mental models, creating an environment for social learning, and increasing the credibility of model outputs and legitimacy of management decisions (Kotir *et al.,* 2017). Jointly developed models have the advantage of helping stakeholders with problem definition and evaluation of possible management or policy options (Bhaduri *et al.,* 2011).

2.2 Aim of the Research

The main aim of this research was to develop scenarios for agricultural water management in South Africa. These scenarios should consider the social dynamics (including issues such as poverty, employment, demographic changes, security, etc.), economic (including food production, industry, mining, global markets, and trends, etc.), ecological (including land degradation, climate change, and variability, etc.), political (including political stability and policy).

The secondary objectives of the project were to:

- recommend some policy and action plans for sustainable agricultural water management based on four main scenarios,
- determine the current status of agricultural water management in South Africa,

- review and provide critical analysis of current social, political and ecological scenarios
- identify socio, environmental and economic indicators to measure different scenario outcomes. These indicators were sub-categorised in ten drivers (capitals) namely, human, social, cultural, political, institutional, economic, environmental, technology and infrastructure, and
- to develop the framework for a dynamic decision support tool based on real-time indicator values and changes.

2.3 Methodological Approach

This study made use of the intuitive logic approach, first developed by Pierre Wack in 1985 and later improved by SRI, Global Business Network, and Shell (Ratcliffe, 2000; Shadbolt *et al.,* 2017). This approach has been widely used and has become a very important tool for policy planning in different areas (Goodwin & Wright, 2010). This approach generally starts with the identification of predetermined drivers (referred to as clusters and drivers in this study) and their critical uncertainties (Shadbolt *et al.,* 2017). The drivers are then categorised under headings (social dynamics, technological, human, ecological, economic, natural, global factors, and political), then different clusters are constructed between elements in each discipline (Ratcliffe, 2000). Comprehensive scenarios are developed from each specified scenario dimension that is generated based on the impact and degree of uncertainty of the identified drivers (Goodwin & Wright, 2010, Shadbolt *et al.,* 2017).

Proper scenario planning usually takes time and several sessions (workshops) are required (Konno *et al.,* 2014). In this study, several consultative workshops and two national symposia directly contributed to the building of scenarios. This study used the approach outlined in Table 2.1:

Table 2.1: Scenario planning approach

Steps	Approaches/Strategies
Step 1: Issues Identification	This session challenges stakeholders to strategically think, analyse, and identify key issues/uncertainties that would shape the water sector in South Africa by 2030.
Stage 1:	Key stakeholders were tasked with identifying key issues facing the water sector in South Africa within a broader context of important capitals (social dynamics, economic, cultural, human, technological, institutional, ecological, infrastructural, and global factors.)
Stage 2:	Several small groups were created from the larger group and assigned each a capital for deliberation in great detail to list all the issues associated with that capital, to identify and prioritise key issues related to the capital.
Stage 3:	All issues generated by each group were put together and key issues were identified that could shape the future of the water sector in South Africa by 2030.
Step 2: Scenario Identification	This session has stakeholders working in a group to determine possible uncertainties that can happen to influence the water sector in South Africa.
Stage 1:	Small groups were created and each group identified a set of uncertainties regarding the water sector. Each group discussed debate and deliberated on these uncertainties and how they might occur and influence the water sector and its effects on the agricultural sector in South Africa.

Steps	Approaches/Strategies
Stage 2:	Uncertainties were ranked based on their expected influence and potential impact on the agricultural sector. The uncertainties were further grouped and plausible scenario themes developed.
Step 3: Scenario Validation	This step involved presenting the selected scenarios and validating them against the general objectives.
Stage 1:	General discussions took place regarding the possibility and plausibility of the proposed scenarios and validation of assumptions. After the various discussions and debates, four scenarios were selected.

Source: Adapted from Shadbolt et al. (2017).

2.4 Driver Identification Approach

Ten clusters were identified from literature with each having its influence on resource management in South Africa. The ten clusters that have varying influences and impacts on agricultural water management are:

- Natural/Ecological cluster*
- Social cluster
- Economic Cluster
- Cultural cluster
- Human cluster
- Infrastructural Cluster*
- Political cluster*
- Technological cluster*
- Institutional cluster*
- Organisational cluster*

All the clusters with an asterisk were determined from literature as the clusters with the biggest influence in water resource management. So before the clusters and drivers were submitted to stakeholders for discussion, these clusters were marked as those to be those which need special attention. A total of 62 drivers were also identified under each of the ten clusters as the drivers which will influence change in water resource management in South Africa. The list of all the drivers and clusters was submitted for discussion among different stakeholders and review through expert consultations. Stakeholders and experts in the agricultural and water sectors were permitted to propose alternative clusters and drivers which they thought will have the biggest influence in water resource management and were not listed in the document presented to them. The objective of the expert consultations after different stakeholder workshops was to validate the degree of importance of each cluster and driver of change and to gain an informed opinion on the likelihood of the drivers and clusters influencing agricultural water resource management in the future.

2.5 Modelling Approach

The past few decades have seen system dynamics modelling (SDM), based on the notion of systems thinking (Forrester, 1961; Sterman, 2000), emerges as an innovative approach that facilitates a holistic analysis of complex human-environmental systems, such as water resource systems and agricultural development (Simonovic, 2009). Recently, several studies have applied the SDM approach to developing system dynamics and simulation models in various river basins or watersheds around the world (see Dawadi & Ahmad, 2013; Gohari *et al.,* 2013; Mirchi & Watkins, 2013; Niazi *et al.,* 2014 and Chapman & Darby, 2016, etc.). The diversity of SMD applications contributed to an improved understanding of the dynamic behaviour of water systems, but there is still a need for dynamic models that adequately integrate various physical, social, and economic factors and feedback processes that determine the current and future dynamics of water resources management systems.

Systems thinking is one of the most innovative tools necessary for identifying drivers of change, policies, and strategies that will inform water planning in a face of uncertainties and a constantly changing socio-economic and ecological environment. Systems thinking can be very useful in water planning because it will inform policymakers and all stakeholders in the water and agricultural sectors about the current water situation in the country and provide valuable insights to support future water policies especially regarding the agricultural sector and agricultural development in South Africa. System dynamic modelling can provide a learning tool for policy-makers to improve their understanding of the long-term dynamic behaviour of the water agricultural sectors and as a decision support tool for exploring plausible policy scenarios necessary for sustainable water resource management and agricultural development.

2.6 Scenario Developing Approach

According to Gallopín (2012), scenario development typically involves

- characterization of the current situation,
- a diagnosis of the starting state of the scenarios,
- focused on the focal issue or problem under consideration (water in this case),
- identification of major driving forces that represent the key factors,
- trends or processes that influence the situation, focal issue or decisions that propel the system forward, and
- condition the story's outcome.

Some of these forces are invariant (e.g. they apply to all scenarios) and to a large extent predetermined (Shiklomanov, 1997). Some of the driving forces may represent critical uncertainties, the resolution of which can fundamentally alter the course of events. These driving forces (or drivers, for short) influence but do not completely determine the future. Thus, while the initial state of the drivers is the same in all scenarios, the trajectory of the system follows a different course in each one. The formulation of the plot, the current state, driving forces, strategic invariants, and critical uncertainties form the backbone of the scenarios. In addition, all scenarios unfold according to an internal logic (the plot) that links the various elements (Gallopín, 2012).

Scenarios are narrative descriptions of a possible state of affairs or development over time, which can be useful to communicate speculative thoughts about future developments to elicit discussion and feedback and to stimulate the imagination (Warfield, 1996; Claassen *et al.,* 2012). Scenarios are developed to achieve the desired outcome in an uncertain future (Metzner & Reger, 2004; Claassen et al., 2012). To deal with the future, we need to deal with possibilities. Scenario planning is a future technique used for medium to long-term strategic analysis and planning. It is used to develop policies and strategies that are robust, resilient, flexible, and innovative. Scenarios are plausible alternative futures of what might happen under particular assumptions. By focusing on key drivers, complex interactions, and uncertainties, scenario building generates the futures within which we can assess alternative mitigation strategies. For the scenario planning process to be successful, the scenarios must be developed in line with certain principles, whatever methodology is used. Scenarios must be plausible, internally consistent, based on rigorous analysis and engaging and compelling.

Before starting to build scenarios, it is important to clarify the purpose of the work and agree on how the scenarios will be used. Interviewing those who have commissioned the work and other senior stakeholders is a very useful part of the scoping process. It will help ensure that a clear idea of what the work should achieve is shared by the commissioning group and will help give a sense of how scenarios might be used in practice.

Scenarios should be developed in a workshop setting by a small to a large team, representing a wide range of expertise drawn from different backgrounds. Participation should be made of a mixture of subject matter experts (academics, NGOs, and business professionals), policymakers, and planners who will subsequently use the scenarios. Linking scenarios into a national process at the country level may require a target number of stakeholders to be involved.

Work on identifying major drivers, trends, and events were initiated ahead of the first workshop; this was an opportunity to draw on relevant horizon scanning work and other analysis. This work was synthesised into a format that could be accessed easily by workshop participants, either as preparatory material or at the workshop itself.

2.7 Implementation

This research was completed in 4 phases namely:

- Phase 1: Comprehensive literature study and review of current water management policies and regulations and scenarios.
- Phase 2: Expert interviews and participatory workshops

- Phase 3: Scenario development based on qualitative and stakeholder inputs
- Phase 4: A modelling framework for computer-based scenario development tool
- Phase 5: Final reporting and scenario testing

2.7.1 Phase 1: Comprehensive literature study and review of current water management policies, regulations, and scenarios.

These included:

- A review of literature on the historical development and changes as relates to water
- Evaluation of current policies in place related to water management
- Review of National Development Plan and the South African Water Act
- Status of the water user associations, policy, and plans for all the water users
- Benchmark with other countries with similar structure, i.e. Australia.
- A review of climate change adaptation plan developed by Environmental Affairs
- A review of the current drought management plan? National drought development plan.
- Other related WRC reports related to the study

Main activities during phase 1 were desk top literature study and face-to-face discussions with experts plus an inception workshop with the research team and other experts.

See Chapter 3 for a report on the literature.

2.7.2 Phase 2: Expert Interviews and Participatory Workshops

The knowledge base for the development of the scenarios was developed through structured research, which included an extensive participative process as suggested by Claassen *et al*. (2011). Participatory research comprises a range of methodological approaches and techniques, all to transfer knowledge and information from the researcher to research participants and *vice-versa*. Research participants are often community members or community-based organisations. In participatory research, participants influence the research agenda, the process, and actions. Most importantly, participants themselves are the ones who analyse and reflect on the information generated, to influence the findings and conclusions of the research process. Participatory research involves inquiry, but also action. People not only discuss their problems and challenges; they also think about possible solutions to them and actions which need to be taken. We experienced this in our research in that the contents and structure of workshops were adapted over time.

Methods that were used to gather information include; interactive workshops, semi-structured interviews and two national symposia from target groups such as academia, Department of Human Settlements, Water and Sanitation (DHSWS), Department of Agriculture Land Reform and Rural Development (DALRRD), Department of Environment, Forestry and Fisheries (DEFF), National

Disaster Management Centre (NDMC), South African Weather Services (SAWS), Agribusiness Chamber (Agbiz), captains of industries, African Farmers Association (AFASA), AgriSA, National African Farmers Union (NAFU) and other organisations and water users. The following specific groups were targeted:

The summary of the workshops conducted is shown in Table 2.2.

Table 2.2: Summary of consultative workshops

#	Organisation	Place	Date	# people participated	Profile of attendees
1	AgriSA	Stellenbosch plus virtual	12 Sept 2018	7	Executive plus provincial representatives for WC, NC, EC
2	NAFU	Pretoria	14 Nov 2018	7	Senior Executive
3	AFASA	Pretoria	20 Nov 2018	6	Senior Executive
4	National Symposium	Pretoria	29 Nov 2018	44	Representatives from various stakeholder organisations
5	WC workshop	Cedara	3 April 2019	23	Experts and officials in the agricultural sector, water management sector, and environmental management sector.
6	Mpumalanga Agri	Mbombela	24 July 2019	11	Water management officials, commercial farmers (irrigation; dryland; extensive)
7	Agri WC	Stellenbosch	29 July 2019	12	Water management officials, commercial farmers (irrigation; dryland; extensive)
8	AFASA (members)	Phutaditjhaba	31 July 2019	16	AFASA provincial farmer leader, subsistence farmers, small scale farmers, and new land reform beneficiaries
9	AgriNC	Upington	2 Oct 2019	8	Commercial farmer leaders (Irrigation, extensive livestock)
10	National Symposium 2	Virtual / Pretoria	24 Nov 2020	39	Experts and officials in the agricultural sector, water management sector, and environmental management sector.

These workshops were important because the current and future agricultural trends in South Africa were highlighted, gaps in current water policies were identified, the future of water management and agricultural development were discussed, and various drivers of change and clusters were discussed and selected from the viewpoint of commercial and smallholder farmers. More stakeholder workshops have been planned for 2020 with farmers and experts in the agricultural and water sectors across different provinces in South Africa but the Covid-19 lockdown prevented further workshops. The profile of the participants ranged from agricultural economists, disaster managers, water modellers, commercial farmers, smallholder farmers, senior researchers, and bankers all over South Africa.

The structure of the workshops promoted discussion and proper interaction between experts and attendees. Experts provided informative presentations, which were followed by small group discussions and a final feedback session. This method stimulated and informed active debate, which provided important insight for scenario building.

The first national symposium provided a national platform where results from workshops were presented and discussed. The main aim of the national symposium was to bring all the relevant stakeholders together in a working and interactive environment where all stakeholders could share, discuss and debate the future of agriculture and water management in South Africa. The national symposium served as a platform for all stakeholders to compare notes and contribute to the development of scenarios for future agricultural water management in South Africa.

The symposium was introduced by Prof. Andries Jordaan (Project leader), whereby he gave a background and context of the research project. He also highlighted the importance for South Africa to develop agricultural water management scenarios.

Me. Chantell Ilbury (project team member) from the Mindofafox delivered a presentation on the art of scenario building and its value for policy development. Her presentation highlighted the scenario building process and how it can contribute to the development of better policies in the future.

The keynote speech was delivered by Dr Frans Cronje, CEO South African Institute for Race Relations (IRR). Dr Cronje presented the future scenarios for South Africa and how it will impact on agriculture. He presented the future of the South African economy and highlight key aspects and areas that will be affected should certain key decisions/policies be made. His presentation also highlighted the political climate in South Africa and how it might change during the 2019 elections and how it will affect the country. His presentation also examined the socio-economic situation of the country and how things might change in the future and the people that might be affected the most.

Prof. Tony Turton (project team member) also delivered a presentation on the future challenges for agricultural water management in South Africa. His presentation examined the paradigm of scarcity and paradigm of abundance and he argued the fact that we should manage water as a flux and not a stock. He further argued that South Africa must invest in technologies that will enhance efficient water desalination and water recycling.

Prof. Sue Walker (project team member) from ARC also delivered a presentation on climate extremes and climate change impact on future agricultural scenarios. Her presentation examined the effects of climate change and climate variation on water availability in the future and how it will affect agriculture.

Dr John Purchase of Agbiz SA gave his contribution by thanking the project team members for the brilliant initiative and pledged the support of Agbiz to the project.

Presentations were also delivered by members of AFASA, Free State. They gave a situation report on the state of small and emerging farmers in the Free State and water distribution and use in the Province. Each participant was handed a questionnaire in the morning which contained the identified clusters (10) and drivers of each cluster. Participants were asked to allocate a score to the drivers and clusters. See the results report in Chapter 7.

See Chapter 6 for results from the consultative workshops

2.7.3 Phase 3: Scenario Development Based on Qualitative and Stakeholder Inputs

Phase 3 of the project entails the modelling of scenarios using system dynamics and it is discussed in detail in a later chapter. The following are the key issues we consider before the scenario development process:

- Is the purpose of the project clear and agreed upon by all involved?
- How will the scenarios be used in practice?
- Can the scenarios help stimulate discussion and build consensus with key stakeholders?
- What is the time frame for the scenarios – 2030 in this case?
- Who will participate?
- Is there sufficient expertise?
- Is there sufficient buy-in from key stakeholders?
- What underpinning analysis will be used to inform the scenario-building?
- Has this been made available to participants in advance?
- What methodology is most appropriate?
- How will the scenarios be communicated?

It was important to avoid falling into the trap of developing three or four scenarios that broadly correspond to the status quo. Such an approach would increase the risk that the extreme scenarios are rejected. Instead, it was important to explore a range of plausible futures, each of which has both positive and negative aspects; this assisted in the identification of risks and provided a more robust way of testing strategies. The literature mentioned three important methodologies that can be considered namely:

- Two axes method
- Branch analysis method
- Cone of plausibility method

We selected the two axes method for this project.

A combination of Schwartz (1991) and Shell (2003) approaches to scenario building and others identified in the literature was used in this study. Schwartz (1991) suggests a 6-step process for the development of scenarios namely:

- identifying focal questions;
- identifying key forces;
- deciding on driving forces;
- ranking of driving forces;

- selecting the scenario logic; and
- fleshing out the scenarios.

Claassen *et al.* (2012) recommends that the analysis should be framed around a focal question during phase 1 of the scenario building process. The Shell (2003) approach, on the other hand, followed a flow path, which includes preparation, pioneering, map-making, navigation, and reconnaissance as a framework.

Meinert & Sacha (2014) recommended a practical way to develop scenarios, which was followed in this project. The Meinert and Sacha six-step implementation is as follows:

- Decide drivers of change and assumptions
- Bring drivers together into a viable framework
- Produce 7-9 initial mini-scenarios
- Reduce to 4 scenarios
- Draft the scenarios
- Identify the issues arising

The project team followed a slightly different approach than what was proposed by Meinert & Sacha (2014) in that the framework was conceptualised before the identification of drivers.

2.7.4 Phase 4: Modelling Framework for Computer Based Scenario Development Tool

The framework was based on indicators or drivers that can be adjusted in real-time to provide different scenario outcomes. The value of such a tool is that it should be able to provide early warning for timely decision making at the national level. The real-time dynamic scenarios can be used by the government, industry, students for research, captains of industry, and policymakers.

2.7.5 Phase 5: Final Reporting and Scenario Testing

The final phase was the wrap-up phase and included the second national water scenario symposium during which time selected experts gave presentations and final comments on the draft scenarios. The national conference provided an opportunity for final inputs and discussions of the draft scenarios. The framework for the dynamic scenario tool was also to be finalised and presented at the conference.

2.8 Conclusion

The structuring of the different phases and the sequence of workshop discussions together with the two national symposia assisted the research team to create a good understanding of the perceptions, fears and expectations of people with different backgrounds and expertise. The phasing of the project also contributed to the efficient management of the project.

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3 ANNOTATED BIBLIOGRAPHY

In this section, the literature of international relevance is reviewed. This is to provide the readers with information regarding the state of research at the international and national level and the lessons that can be learned.

3.1 Relevant Global Literature

The World Bank (2016). **High and Dry: Climate Change, Water and the Economy**

The impacts of climate change will be channelled primarily through the water cycle, with consequences that could be large and uneven across the globe. Water-related climate risks cascade through food, energy, urban, and environmental systems. Growing populations, rising incomes, and expanding cities will converge upon a world where the demand for water rises exponentially, while supply becomes more erratic and uncertain. If current water management policies persist, and climate models prove correct, water scarcity will proliferate to regions where it currently does not exist, and will greatly worsen in regions where water is already scarce. Simultaneously, rainfall is projected to become more variable and less predictable, while warmer seas will fuel more violent floods and storm surges. Climate change will increase water-related shocks on top of already demanding trends in water use. Reduced freshwater availability and competition from other uses – such as energy and agriculture – could reduce water availability in cities by as much as two-thirds by 2050, compared to 2015 levels.

Economic growth is a surprisingly thirsty business. Water is a vital factor of production, so diminishing water supplies can translate into slower growth that clouds economic prospects. Some regions could see their growth rates decline by as much as 6% of GDP by 2050 as a result of water-related losses in agriculture, health, income, and property – sending them into sustained negative growth. Economic modelling suggests that bad water management policies can exacerbate the adverse growth impacts of climate change, while good policies can go a long way towards neutralizing them. Some regions stand to see growth accelerate as much as 6% with better water resource management. The impacts of water mismanagement are felt disproportionately by the poor, who are more likely to rely on rain-fed agriculture to feed their families, live on the most marginal lands which are more prone to floods, and are most at risk from contaminated water and inadequate sanitation. Ensuring a sufficient and constant supply of water under increasing scarcity will be essential to achieving global poverty alleviation goals.

Changes in water availability and variability can induce migration and ignite civil conflict. Food price spikes caused by droughts can inflame latent conflicts and drive migration. Where economic growth is impacted by rainfall, episodes of droughts and floods have generated waves of migration and statistical spikes in violence within countries. In a globalized and connected world, such problems are impossible to quarantine. And where large inequities prevail, people move from zones of poverty to regions of prosperity which can lead to increased social tensions.

Water management is crucial in determining whether the world achieves the Sustainable Development Goals (SDGs) and aspirations for reducing poverty and enhancing shared prosperity. Water is the common currency which links nearly every SDG, and it will be a critical determinant of success. Abundant water supplies are vital for the production of food and will be essential to attaining SDG 2 on food security; clean and safe drinking water and sanitation systems are necessary for health as called for in SDGs 3 and 6, and water is needed for powering industries and creating the new jobs identified in SDGs 7 and 8. None of this is achievable without adequate and safe water to nourish the planet's life-sustaining ecosystem services identified in SDGs 13, 14, and 15.

Water is to adaptation what energy is to mitigation, and the challenges the world will face in adapting to water issues are enormous. It calls for recognizing the interlinkages between water for food, energy, cities, and the environment through an "*expanded water nexus*," which acknowledges that the fortunes of these sectors are tied through a common dependence on water. The costs of policy inaction are high, and prudent stewardship of water resources will pay large dividends. Although significant challenges exist, the right actions need not be costly. Thoughtful policies and well-placed investments can yield large benefits in improved welfare and increased economic growth. Three overarching policy priorities can help lead countries down the road to water-secure and climate-resilient economy. None of these will be a panacea, however, just as there is no one-size-fits-all solution. In practice, hybrid solutions will be needed, determined by country and regional risks and circumstances.

Optimizing the use of water through better planning and incentives. Building climate-resilient economies that can develop and grow in a warming world will require better ways of *allocating scarce water resources across sectors* to higher-value uses. This could be achieved through planning and regulation or using market signals through instruments such as prices and permits. In both cases, there would need to be adequate safeguards to assure access to poor households and farmers as well as the environment. None of this will be easy. It will call for establishing credible institutions, policies, and legal systems that can facilitate transfers of water in ways that benefit all parties to the transaction. Economic instruments such as water permits and prices can be valuable for promoting improved environmental stewardship of water resources, but they are also the most misunderstood due to anxieties of elite capture, denial of services to the poor, and the complex social and cultural values of water. Much depends upon how such policies are implemented and enforced. In countries where water is deemed to be free, the poor are unserved or under-served and are compelled to pay a much higher price than the rich for each drop of water. As a consequence, free water is typically costly for the poor as well as harmful to the environment.

Water *efficiency must also increase within sectors*. This calls for the creation and adoption of new water-saving technologies, incentives, education, and awareness. Approaches are already available, such as Climate Smart Agriculture (CSA) or Sustainable Agricultural Intensification (SAI), that allow farms to maintain or even increase yields while reducing their energy and water footprint. Similar approaches exist for significant water savings in the energy sector through improved efficiency. However, the adoption of these solutions is slow, hesitant, and below desired levels. The constraints most often lie in misaligned incentives. For instance, a large proportion of the benefits of approaches such as CSA are public, while technology adoption costs are private. This requires sharper incentives for technology uptake that might require a change in the subsidy regime, public investments in infrastructure or extension services, selective forms of crop insurance, and increasing access to credit. There are opportunities to alter behaviour and change thirsty consumption patterns through education, contextual cues, and using social norms to signal consent or disapproval. The tools based on these behavioural nudges do not displace existing policy approaches that target incentives; rather, they complement and enhance them. Some of these approaches may cost little to implement because they depend on nuances in messaging and policy design, while others may entail longer periods of engagement, especially when changes in attitudes and values are involved.

Where appropriate, expand water supply and availability. This includes investments in storage infrastructure such as dams that make water available when it is needed; water recycling and reuse; and where viable, desalination. While expanding the water supply will be vital in some countries, particularly the driest regions, these tools must be used with caution. Other tools like groundwater recharge and wetlands preservation may offer lower risk, lower costs, and higher returns than other policy approaches. Historically, when supply is increased without corresponding safeguards to manage use, demand rises to meet the new level of supply, resulting in a higher level of water dependence in often arid areas. To be effective, these interventions must be accompanied by policies to promote water efficiency and improve water allocation across sectors.

Reducing the impact of extremes, variability, and uncertainty. A final set of interventions requires "*waterproofing*" economies to limit the impact of extreme weather events and rainfall variability. Increasing storage capacities and water reuse systems will go a long way towards building resilience. Better urban planning, risk management, and citizen engagement will likewise reduce the exposure of cities to flood risk. In rural areas, expanding crop insurance programs can protect farmers against rainfall shocks. Large capital investments such as seawalls, levees, and dams, meanwhile, can protect coastal cities from storm surges and floods. As the precise impacts of climate change are uncertain and large investments are costly and irreversible, their siting and design must be carefully chosen to minimize regret.

Smart water policy is fundamental to smart climate policy and smart development policy. While adopting policy reforms and investments will be demanding, the costs of inaction are far higher. The future will be thirsty and uncertain, but with the right reforms, governments can help ensure that people and ecosystems are not left vulnerable to the consequences of a world subject to more severe water-related shocks and adverse rainfall trends.

Ertug-Ercin, A. & Hoekstra, Arjen Y. (2010). **Water footprint scenarios for 2050: A global analysis**

This study develops water footprint scenarios for 2050 based on several drivers of change: population growth, economic growth, production/trade pattern, consumption pattern (dietary change, bioenergy use), and technological development. The objective of the study is to understand the changes in the water footprint (WF) of production and consumption for possible futures by region and to elaborate on the main drivers of this change. In addition, we assess virtual water flows between the regions of the world to show dependencies of regions on water resources in other regions under different possible futures. We constructed four scenarios, along with two axes, representing two key dimensions of uncertainty: globalization versus regional self-sufficiency, and economy-driven development versus development driven by social and environmental objectives. The study shows how different drivers will change the level of water consumption and pollution globally in 2050.

The presented scenarios can form a basis for a further assessment of how humanity can mitigate future freshwater scarcity. The authors showed with this study that reducing humanity's water footprint to sustainable levels is possible even with increasing populations, provided that consumption patterns change. This study can help to guide corrective policies at both national and international levels and to set priorities for years ahead to achieve sustainable and equitable use of the world's freshwater resources.

Piao, S., Ciais, P., Huang, Y., Shen, Z., Li, J., Zhou, L., Liu, H., Ma, Y., Ding, Y., Friedlingstein, P., Liu, C., Tan, K., Yu, Y., Zhang, T. & Fang. (2010). **The impacts of climate change on water resources and climate change in China**

China is the world’s most populous country and a major emitter of greenhouse gases. Consequently, much research has focused on China’s influence on climate change but somewhat less has been written about the impact of climate change on China. China experienced explosive economic growth in recent decades, but with only 7% of the world’s arable land available to feed 22% of the world’s population, China’s economy may be vulnerable to climate change itself. We find, however, that notwithstanding the clear warming that has occurred in China in recent decades, current understanding does not allow a clear assessment of the impact of anthropogenic climate change on China’s water resources and agriculture and therefore China’s ability to feed its people. To reach a more definitive conclusion, future work must improve regional climate simulations – especially of precipitation – and develop a better understanding of the managed and unmanaged responses of crops to changes in climate, diseases, pests, and atmospheric constituents.

Strayer, D.L.. & Dudgeon, D. (2010). **Freshwater biodiversity conservation: recent progress and future challenges**

Freshwater habitats occupy, 1% of the Earth’s surface, yet are hotspots that support, 10% of all known species, and, more of vertebrate species. Freshwaters also are hotspots for human activities that have led to widespread habitat degradation, pollution, flow regulation, and water extraction, fisheries overexploitation, and alien species introductions. These impacts have caused severe declines in the range and abundance of many freshwater species so that they are now far more imperilled than their marine or terrestrial counterparts. Here, we review progress in the conservation of freshwater biodiversity, with a focus on the period since 1986, and outline key challenges for the future. Driven by rising conservation concerns, freshwater ecologists have conducted a great deal of research over the past 25 years on the status, trends, autecology, and propagation of imperilled species, threats to these species, the consequences of biodiversity loss for ecosystem functioning, metapopulation dynamics, biodiversity hotspots, reserve design, habitat restoration, communication with stakeholders, and weaknesses of protective legislation.

Nevertheless, *existing* efforts might be insufficient to stem the ongoing and coming multitude of freshwater extinctions. We briefly discuss 4 important challenges for freshwater conservation. First, climate change will imperil both freshwater species and human uses of freshwater, driving engineering responses that will further threaten the freshwater biota. We need to anticipate both ecological and human responses to climate change, and to encourage rational and deliberate planning of engineering responses to climate change before disasters strike. Second, because freshwater extinctions are already well underway, freshwater conservationists must be prepared to act now to prevent further losses, even if our knowledge is incomplete, and engage more effectively with other stakeholders. Third, we need to bridge the gap between freshwater ecology and conservation biology. Fourth, we suggest that scientific societies and scholarly journals concerned with limnology or freshwater sciences need to improve their historically poor record in publishing important papers and influencing practice in conservation ecology. Failure to meet these challenges will lead to the extinction or impoverishment of the very subjects of our research.

Vörösmarty, C.J., McIntyre, B., Gessner, M.O., Dudgeon, D., Prusevich, A., Green, P., Glidden, S., Bunn, S.E., Sullivan, C., Liermann, C.R. & Davies, P.M. (2010). **Global threats to human water security and river biodiversity**

Protecting the world's freshwater resources requires diagnosing threats over a broad range of scales, from global to local. Here we present the first worldwide synthesis to jointly consider human and biodiversity perspectives on water security using a spatial framework that quantifies multiple stressors and accounts for downstream impacts. We find that nearly 80% of the world's population is exposed to high levels of threat to water security. Massive investment in water technology enables rich nations to offset high stressor levels without remedying their underlying causes, whereas less wealthy nations remain vulnerable. A similar lack of precautionary investment jeopardizes biodiversity, with habitats associated with 65% of continental discharge classified as moderately to highly threatened. The cumulative threat framework offers a tool for prioritizing policy and management responses to this crisis and underscores the necessity of limiting threats at their source instead of through costly remediation of symptoms to assure global water security for both humans and freshwater biodiversity.

Rockström, A., Falkenmark, Karlberg, L., Hoff, H., Rost, S. & Gerten, D. (2006). **Global Hydrological Cycles and World Water Resources**

Water is a naturally circulating resource that is constantly recharged. Therefore, even though the stocks of water in natural and artificial reservoirs are helpful to increase the available water resources for human society, the flow of water should be the main focus in water resources assessments. The climate system puts an upper limit on the circulation rate of available renewable freshwater resources (RFWR). Although current global withdrawals are well below the upper limit, more than two billion people live in highly water-stressed areas because of the uneven distribution of RFWR in time and space. Climate change is expected to accelerate water cycles and thereby increase the available RFWR. This would slow down the increase of people living under water stress; however, changes in seasonal patterns and increasing probability of extreme events may offset this effect. Reducing current vulnerability will be the first step to prepare for such anticipated changes.

Lienert , J., Manstadt, J. & Truffer, B. (2006). **Future Scenarios for a Sustainable Water Sector: A Case Study from Switzerland**

Uncertainties about the long-term prospects of urban water management systems have increased substantially over the past decade due to an increasing variety of regulations, technologies, and demand structures. In Switzerland, this uncertainty is mirrored by growing difficulties of utility managers and (waste) water scientists to agree on shared strategies: Water professionals demand support for pressing management problems, while researchers fundamentally question the longer-term sustainability of the established water management system. To re-establish shared orientation, we conducted a foresight study for the Swiss (waste) water sector in 2004. Based on interviews with 29 experts from Swiss water management and research to collect 56 drivers of change, a team of 17 experts developed three scenarios: (A) regional mergers of water utilities leading to enhanced professionalism in the sector, (B) consequent material flows management leading to a radically restructured urban water management system, and (C) generalized financial crisis leading to a breakdown of centralized utility services. These scenarios helped to identify shared research priorities. We conclude that scenario analysis is a powerful tool for framing long-term strategies, defining priorities, and integrating different interests in the multidisciplinary contexts of sustainability science, which are marked by high uncertainties and concern a wide range of stakeholder groups.

Rijsberman, F.R. (2006). **Water Scarcity: Fact or fiction?**

It is surprisingly difficult to determine whether water is truly scarce in the physical sense at a global scale (a supply problem) or whether it is available but should be used better (a demand problem). The paper reviews water scarcity indicators and global assessments based on these indicators. The most widely used indicator, the Falkenmark indicator, is popular because it is easy to apply and understand but it does not help to explain the true nature of water scarcity. The more complex indicators are not widely applied because data are lacking to apply them and the definitions are not intuitive. Water is physically scarce in densely populated arid areas, Central and West Asia, and North Africa, with projected availabilities of less than 1000 m3/capita/ year. This scarcity relates to water for food production, however, and not to water for domestic purposes that are minute at this scale. In most of the rest of the world water scarcity at a national scale has as much to do with the development of the demand as the availability of the supply. Accounting for water for environmental requirements shows that abstraction of water for domestic, food, and industrial uses already has a major impact on ecosystems in many parts of the world, even those not considered ''water-scarce''. Water will be a major constraint for agriculture in the coming decades and particularly in Asia and Africa, this will require major institutional adjustments. A ''soft path'' to address water scarcity, focusing on increasing overall water productivity, is recommended.

Kumar, M.D. & Singh, O.P. (2005). **Water Resource Management**

The argument that economies that face acute water scarcity problems can and should meet their water demand for food through cereal imports from water-rich countries; and that virtual water trade can be used to achieve water securities has become dominant in global water discussions. Analysis of country-level data on renewable freshwater availability and net virtual water trade of 146 nations across the world shows that a country's virtual water trade is not determined by its water situation. Some countries have the advantage of high "economic efficiency" in food production and have surplus water, but resort to food import, whereas some water-scarce countries achieve high virtual water trade balances.

Further analysis with a set of 131 countries showed that virtual water trade increased with an increase in the gross cropped area. This is because of two reasons: First, when access to arable land increases, the ability to utilize available blue water for irrigation increases. Second, increasing access to arable land improves the access to water held in the soil profile as "free good", a factor not taken into account in assessing water availability.

Hence, many of the humid, water-rich countries will not be in a position to produce surplus food and feed the water-scarce nations; and virtual water often flows out of water-poor, land-rich countries to land-poor water-rich countries. This means that "distribution of scarcity" and "global water use efficiency", are goals that are difficult to achieve through virtual water trade in a practical sense. For a water-poor, but land rich country, virtual water import offers little scope as a sound water management strategy as what is often achieved through virtual water trade is improved "global land-use efficiency".

The important policy inferences emerging from the analyses are two: First, assessing the food security challenges posed to nations in the future purely from a water resource perspective provides a distorted view of the food security scenario. National policies on food security should take into account "access to arable land" apart from water availability. Second, analysis of water challenges posed by nations purely from the point of view of renewable water availability and aggregate demands will be dangerous. Access to water in the soil profile, which is determined by access to arable land, would be an important determinant of effective water availability.

Varis, O., Kajander, T. & Lemmelä, R. (2004). **Climate and water: From Climate models to Water Resources Management and vice versa**

This article reviews the recent developments in the functional chain from climate models to climate scenarios, through hydrology to water resources management, design, and policymaking. Although climate models, such as Global Circulation Models (GCMs) continue to evolve, their outputs remain crude and often even inappropriate to watershed-scale hydrological analyses. The bridging techniques are evolving, though. Many families of regionalisation technologies are under progress in parallel. Perhaps the most important advances are in the field of regional weather patterns, such as ENSO (El Niño-Southern Oscillation), NAO (North Atlantic Oscillation), and many more. The gap from hydrology to water resources development is by far not that wide. Traditional and contemporary practices are well in place.

In climate change studies, the bottleneck is not in this link itself but the climatic input. The tendency seems to be towards integrated water resources assessments, where the climate is only one among many changes that are expected to occur, such as demography, land cover and land use, economy, technologies, and so forth. In such a pragmatic setting a risk-analytic interpretation of those scenarios is often called for. The above-outlined continuum from climate to water is a topic where the physically-based modellers, the empiricists, and the pragmatists should not get restricted to their way of thinking. The issues should develop hand in hand. Perhaps the greatest challenge is to incorporate and respect the pragmatic policy-related component to the two other branches. For this purpose, it is helpful to reverse the direction of thinking from time to time to start – instead of climate models – from practical needs and think how the climate scenarios and models help really in the difficult task of designing better water structures, outline better policies and formulate better operational rules in the water-field.

Amell, N.W. (2004). **Climate change and global water resources: SRES emissions and socio-economic scenarios**

In 1995, nearly 1400 million people lived in water-stressed watersheds (runoff less than 1000 m^3/capita/year), mostly in Southwest Asia, the Middle East and around the Mediterranean. This paper describes an assessment of the relative effect of climate change and population growth on future global and regional water resource stresses, using SRES socio-economic scenarios and climate projections made using six climate models driven by SRES emissions scenarios. River runoff was simulated at a spatial resolution of 0.5×0.5° under current and future climates using a macro-scale hydrological model, and aggregated to the watershed scale to estimate current and future water resource availability for 1300 watersheds and small islands under the SRES population projections. The A2 storyline has the largest population, followed by B2, then A1 and B1 (which have the same population). In the absence of climate change, the future population in water-stressed watersheds depends on population scenario and by 2025 ranges from 2.9 to 3.3 billion people (36–40% of the world's population). By 2055 5.6 billion people would live in water-stressed watersheds under the A2 population future, and “only” 3.4 billion under A1/B1.

Climate change increases water resource stresses in some parts of the world where runoff decreases, including around the Mediterranean, in parts of Europe, central and southern America, and southern Africa. In other water-stressed parts of the world – particularly in southern and eastern Asia – climate change increases runoff, but this may not be very beneficial in practice because the increases tend to come during the wet season and the extra water may not be available during the dry season. The broad geographic pattern of change is consistent between the six climate models, although there are differences of magnitude and direction of change in southern Asia.

By the 2020s there is little clear difference in the magnitude of impact between population or emissions scenarios, but a large difference between different climate models: between 374 and 1661 million people are projected to experience an increase in water stress. By the 2050s there is still little difference between the emissions scenarios, but the different population assumptions have a clear effect. Under the A2 population between 1092 and 2761 million people have an increase in stress; under the B2 population, the range is 670-1538 million, respectively. The range in estimates is due to the slightly different patterns of change projected by the different climate models. Sensitivity analysis showed that a 10% variation in the population totals under a storyline could lead to variations in the numbers of people with an increase or decrease in the stress of between 15% and 20%. The impact of these changes on actual water stresses will depend on how water resources are managed in the future.

Pimentel, D., Berger, B., Filiberto, D., Newton, M., Wolfe, B., Karabinakis, E., Clark, S., Poon, E., Abbett, E. & Nandagopal, S. (2004). **Water Resources: Agricultural and Environmental Issues**

The increasing demands placed on the global water supply threaten biodiversity and the supply of water for food production and other vital human needs. Water shortages already exist in many regions, with more than one billion people without adequate drinking water. In addition, 90% of the infectious diseases in developing countries are transmitted from polluted water. Agriculture consumes about 70% of freshwater worldwide; for example, approximately 1000 litres (L) of water are required to produce 1 kilogram (kg) of cereal grain, and 43,000 L to produce 1 kg of beef. New water supplies are likely to result from conservation, recycling, and improved water-use efficiency rather than from large development projects.

Renault, D. (2002). **Value of Virtual Water in Food: Principles and Virtues**

The value of virtual water of a food product is the amount of water per unit of food that is or that would be consumed during its production process. Five principles for assessing the value of virtual water are proposed. The first one considers common standard values per food product; which is appropriate for global studies on trade. The second one considers the marginal water requirements for an alternative production close to the consumption site. The third one introduces the nutritional equivalence between food products. The fourth one focuses on the substitution (or reallocation) to transform virtual water imports into real water savings. The fifth underlines the need for historical studies to account for the gain of productivity and deflated values of virtual water.

The application of these principles illustrates some important features of virtual water. Virtual water trade is shared evenly between energetic products, fat products, and protein products. Virtual water trade not only generates water savings for importing countries but also global real water savings due to the differential in water productivity. Food storage also generates real water savings in time. The value of virtual water in sea products is globally significant, accounting for 8% of the total. Impacts of diet changes on water requirements for food are significant but the gain in water productivity in food production is more influential. Assuming that the gain in water productivity reaches 50% of yield growth, we estimate that in Europe 15, water requirements for food per capita and per day have declined in real value from 5 400 litres in 1961 down to 3 600 litres in 2000. This conservative assumption on water productivity shows that at least 1 800 litres per day per capita has been saved since 1961, thanks to agricultural productivity.

Savenije, H.H.G. (2000). **Water scarcity indicators; the deception of the numbers**

The water scarcity indicators that are presently used to indicate the level of water shortage in the different parts of the world suffer from serious flaws. First of all, they are limited to “blue” water only, neglecting the important contribution that “green” water makes to global food production. Secondly, they are based on averages and hence hide the very important temporal and spatial variations of the water resources, which are often the determining factors for water scarcity. Subsequently, they do not consider climatic differences, differences between primary and secondary uses, or the effect of life-styles. A contentious issue is how to distribute the water resources over the different countries sharing a river. How it is done is not at all clear and will require an objective key for allocation among riparians. A new approach is needed to develop indicators that take these aspects into account.

Postel, S.L. (2000). **Entering an Era of Water Scarcity: The Challenges Ahead**

Freshwater is a renewable resource, but it is also finite. Around the world, there are now numerous signs that human water use exceeds sustainable levels. Groundwater depletion, low or non-existent river flows, and worsening pollution levels are among the more obvious indicators of water stress. In many areas, extracting more water for human uses jeopardizes the health of vital aquatic ecosystems. Satisfying the increased demands for food, water, and material goods of a growing global population while at the same time protecting the ecological services provided by natural water ecosystems requires new approaches to using and managing freshwater. In this article, I propose a global effort (1) to ensure that freshwater ecosystems receive the quantity, quality, and timing of flows needed for them to perform their ecological functions and (2) to work toward a goal of doubling water productivity. Meeting these challenges will require policies that promote rather than discourage water efficiency, as well as new partnerships that cross-disciplinary and professional boundaries.

3.2 Relevant Literature with Focus on SADC

The main objectives of Southern African Development Corporation (SADC) are to achieve development, peace, and security, and economic growth, to alleviate poverty, enhance the standard and quality of life of the peoples of Southern Africa, and support the socially disadvantaged through regional integration, built on democratic principles and equitable and sustainable development. It is of interest to note that high economic activities in the region increase the consumption of natural resources, there is also an increase in energy and water demand for industrial use. Civil societies call for restrictions and regulations of water use by industry while the government is challenged to consider water-use trade-offs. This section provided a review of relevant literature on water-related issues and management in the region. Specific reference is made to agriculture.

Dabrowski, J.M., Masekoameng, E. & Ashton, P.J. (2009). **Analysis of virtual water flows associated with the trade of maize in the SADC region: Importance of scale**

The concept of virtual water encourages a country to view crops in terms of the amount of water required to produce those crops, to implement trading policies that promote the saving of scarce water resources. Recently, increased attention has focused on partitioning the virtual water content of crops into green and blue water (derived from rainfall and irrigation, respectively) as the latter has higher opportunity costs associated with its use and therefore impacts directly on scarcity. Maize is the most important crop traded within the SADC region. South Africa is the largest producer and exporter of maize, with the majority of its exports destined for other SADC countries. In comparison to other SADC countries, South Africa produces maize relatively efficiently, with low virtual water content and a high green (868 $m^3\ t^{-1}$) to blue (117 $m^3\ t^{-1}$) water ratio. The blue water content is however higher than for maize produced in all other SADC countries, except for Namibia (211 $m^3\ t^{-1}$). Current trade patterns, therefore, result in a net expenditure of blue water (66×106 m^3), almost all of which is exported by South Africa (65×106 m^3).

South Africa is one of the most water-scarce countries in the region and analysis of virtual water flows indicates that current SADC maize trading patterns are influenced by national productivity as opposed to water scarcity. The virtual water content of maize was estimated for each of South Africa's nineteen Water Management Area's (WMA) and used as a proxy to represent water use efficiency for maize production. The virtual water content varied widely across all of the WMAs, ranging from 360 m^3 t^{-1} in the Usutu Mhlatuze to 1000 m^3 t^{-1} in the Limpopo. A comparison of the virtual water content and production of maize (expressed as a percentage of the total national production) identified those WMAs where maize production is highly water inefficient (e.g. Lower Orange and Limpopo WMAs). Results suggest that, while a national estimate of the virtual water content of a crop may indicate a relatively efficient use of water, an analysis of the virtual water content at smaller scales can reveal the inefficient use of water for the same crop. Therefore, analysis of the virtual water content of crops and trading of agricultural products at different spatial scales (i.e. regional, national, and WMA) could be an important consideration within the context of water allocation, water use efficiency, and alleviation of water scarcity.

Douglas, J.M. & Hilmy, S. (2008). **Micro-agricultural water management technologies for food security in Southern Africa: Part of the solution or a red herring?**

This paper is based on a review of experiences with a wide range of micro-agricultural water management technologies in sub-Saharan Africa with a special emphasis on southern Africa. The major finding of the study is that these technologies have the potential to make major contributions to improving food security, reducing rural poverty, and promoting broad-based agricultural growth. However, there are serious policy impediments to successfully scaling out the use of these technologies at both national and regional levels. The paper makes seven specific policy recommendations whose implementation would enable the promotion of wider uptake.

Jewitt, G. (2006). **Integrating blue and green water flows for water resources management and planning**

The *"Green Water"* approach, where flows of water vapour in the form of transpiration, interception, and evaporation from the soil and vegetation are considered green water and runoff and groundwater recharge is considered blue water, has been an extremely useful illustrative concept in many situations where the role of land use in water resources management needs to be highlighted. The approach has been the subject of much interest in recent years, particularly in semi-arid and arid regions where Green Water Flows dominate the hydrological cycle. However, there are limits to the concept of informing water resources management and planning. In this paper, these limits are explored through case studies of commercial afforestation and runoff harvesting in the SADC region. Issues highlighted include the degree of simplification of the hydrological cycle in many green water-focused studies, appropriate spatial and temporal scales for the consideration of low flows and the uncertainty regarding the storage of water in the soil profile and the generation of flows from saturated and unsaturated soil water. It is concluded that rather than focusing on green or blue water flows, it is the hydrological linkages between these and their representation in water resources management and planning that needs the most attention.

Pallet, J. (ed.), Heyns, P., Falkenmark, M., Lundqvist, J. *et al.* (1997). **Sharing water in Southern Africa**

The theme of the book is sharing and managing water resources in Southern Africa (i.e. the 12 SADC member countries). The introduction gives an overview of the contents of each chapter. Key issues like water as a natural resource, its availability (as influenced by climatic factors), water uses, and related problems (water stress, population growth, urbanisation, and others), water shared within a river basin, and between countries are addressed in the various chapters. The last chapters are devoted to the management of water resources: Management principles, levels of management, the involvement of the private sector and NGOs, the role of Agenda 21 of the United Nations Conference on the Environment and Development, and the Helsinki Rules, and supply versus demand management. The text and the many-colored illustrations are supplemented by a useful glossary, bibliographical references, and an index.

3.3 Relevant Literature with Focus on South Africa

In this last section, special reference is made to studies done in South Africa. As was done in the previous sections, we arranged the studies in sequence based on the date of publication. The list of publications cited in this section is not exhaustive and more can be added. Important however is to note the number of publications with a futuristic outlook already. That will assist with the preparation of the different workshops and symposia planned during this project.

Cronje, F. (2017). **A Time Traveller's Guide to South Africa in 2030**

Taking cognisance of the changes that have taken place in the country since 2014, this book introduces four brand new scenarios for South Africa one year after the 2029 election. The first of these, the Rise of the Right, suggests that the state will grow more powerful and authoritarian and use that authority to force pragmatic economic policies along the lines of the model followed by Lee Kuan Yew in Singapore and Paul Kagame in Rwanda.

By the early 2020s, South Africa emerges as a stable and increasingly prosperous society – a remarkable turnaround that shapes the evolution of high-growth economies across the continent. The second scenario is titled the Tyranny of the Left. In this scenario, the state also becomes extremely authoritarian but uses that power, not for reform but to extort wealth out of the tax base and the private sector while suppressing political dissent and civil rights. Land and businesses are nationalised and property rights destroyed. South Africa collapses into the grip of a cruel dictatorship and all hope for a better future is lost. The third scenario is titled The Break-up. In this scenario the state weakens as the economy stalls, and, amidst rising levels of internal conflict, South Africans drift apart into enclaves. Behind their high walls, the more prosperous enclaves become de-facto private countries with high standards of living. But, outside the walls, the rural poor fall under the control of tribal leaders, while an emerging gang culture becomes the de-facto government in urban slums. As South Africans turn away from one another the country splinters irreparably along lines of race and class. The fourth scenario is titled the Rise of the Rainbow. In this future, the ruling party and the opposition enter into a coalition and allow the private sector to take the lead in returning economic growth rates to levels upwards of 5% as unemployment rates fall, living standards increase, and South Africa emerges, against all the odds, as a free, open, stable, and prosperous society.

Ogungeji, A.A. & Jordaan, H. (2017). **A simulation study on the effect of climate change on crop water use and chill unit accumulation**

Climate change and its impact on already scarce water resources are of global importance, but even more so for water-scarce countries. Apart from the effect of climate change on water supply, the chill unit requirement of deciduous fruit crops is also expected to be affected. Although research on crop water use has been undertaken, researchers have not considered the future climate. They also have focused on increasing temperatures but failed to relate temperature to chill unit accumulation, especially in South Africa. With a view of helping farmers to adapt to climate change, in this study we provide information that will assist farmers in their decision-making process for adaptation and the selection of appropriate cultivars of deciduous fruits. Crop water use and chill unit requirements are modelled for the present and future climate. Results show that irrespective of the irrigation system employed, climate change has led to increases in crop water use. Water use with the drip irrigation system was lower than with sprinkler irrigation as a result of efficiency differences in irrigation technologies. It was also confirmed that the accumulated chill units will decrease in the future as a consequence of climate change. To remain in production, farmers need to adapt to climate change stress by putting in place water resources and crop management plans. Thus, producers must be furnished with a variety of adaptation or management strategies to overcome the impact of climate change.

Ogundeji, A.A., Jordaan, H. & Groenewald, J. (2017). **Economics of climate change adaptation: a case study of Ceres – South Africa**

Climate change and its impact on already scarce water resources are important issues being publicly debated in the world today. Water resources are of more concern because changes in the water supply will affect the water availability for household use, agricultural practices, and the vast industrial water demand. With the view of helping farmers to adapt to climate change, the Ceres Dynamic Integrated Model was developed to simulate the impacts and evaluate different adaptation strategies thereof. The results show that a substantial change can be expected in the profile of the farming community. However, with adaptation, the welfare of the farmers can be improved. Depending on the availability of funds to make farm dams available for farmers, access to farm dam capacity and winter water allocations as well as increasing water-use efficiency are potential adaptation options for the farmers. Improved water management practices that increase the productivity of irrigation water use may provide a significant adaptation potential under the future climate. Therefore, farmers must be equipped with a collection of management or adaptation tools to overcome slight climatic differences.

WWF-SA (2017). **Scenarios for the Future of Water in South Africa**

Water directly affects South Africa's socio-economic development, but it is becoming an increasingly scarce resource. Based on current usage trends, South Africa is expected to face a water deficit of 17% by 2030, and this shortage will only be worsened by climate change. Because water is a shared resource, we are all at risk; therefore, it is critical to understand our impact on water and incorporate water management into our daily lives. To address these issues, the World Wide Fund for Nature – South Africa (WWF-SA), supported by The Boston Consulting Group (BCG), hosted a "Future of Water" workshop in South Africa on January 31, 2017. A diverse group of key stakeholders from the public, private, and social sectors gathered to discuss specific scenarios. Workshop participants proposed four primary goals.

MAIN GOALS

- Become a **water-conscious country** with sufficient knowledge and skills in the water sector;
- Implement **strong water governance** with resilient stakeholder partnerships that advance the more explicit second phase of the National Development Plan to achieve water security under climate change;
- Manage **water supply and demand** regulations more rigorously and protect water resources;
- Become a **water-smart economy** and a leader in Africa in commercializing low-water technologies for industry and agriculture.

Six "no regret" actions that will have high impact and be feasible to implement have emerged from discussions. These actions could significantly shape the future of water in South Africa:

- ACTION 1: Improve social awareness on the criticality of water scarcity, at schools, businesses, and communities, through campaigns and social media platforms.
- ACTION 2: Develop skilled jobs, new enterprises, and capabilities to effectively maintain green and grey water infrastructure across South Africa, and reduce losses.
- ACTION 3: Pilot innovative co-financing to maintain and protect ecological (green) infrastructure e combating further unnecessary water loss from alien vegetation.
- ACTION 4: Implement the water pricing model to strategically differentiate tariffs in the face of continuous water demand growth, urbanization, and population growth.

- ACTION 5: Commercialize and implement at scale water re-use and improved irrigation efficiency technologies.
- ACTION 6: Increase access to information to share a clearer understanding of water users' impact on water and to advance collective action.

Collective action plays a vital role in building a sustainable water future for all stakeholders. By collaborating to mitigate risks, seize opportunities, as well as preserve and maintain this valuable shared resource, we can create a water-secure future for South Africa. These actions focus on what can be achieved in partnerships between civil society, the public, and private sectors. A massive drive is also required to improve performance in public sector water institutions and local government.

Turton, A. (2015). **Sitting on the Horns of a Dilemma: Water as a Strategic Resource in South Africa**

South Africa is a water-constrained country with a vital need to conserve, manage, and expand its limited water resources as efficiently as possible. Since 1994, however, strategic planning has deteriorated, along with operational efficiency. Under the supposed imperatives of 'transformation', skilled engineering and other professional staff have been driven out of water boards (responsible for bulk water supply) and municipalities (charged with local reticulation and often also with waste management). Municipalities are now discharging around 4 billion litres of untreated or partially treated sewage into the country's rivers and dams every day. The Government refuses to admit the extent to which water quality has deteriorated, and a public health crisis now looms. Various reforms are feasible, but the ruling party shows little willingness to allow practical reality to prevail over its transformation ideology.

Musvoto, C., Nortje, K., De Wet, B., Mahumani, B.K., Nahman, A. (2015). **Imperatives for an agricultural green economy in South Africa**

Globally, there are social, economic, and environmental challenges related to sustainable development; these challenges include climate change, the need to feed a rapidly increasing population, high rates of poverty, and environmental degradation. These challenges have forced us to rethink how development takes place, resulting in the emergence of the concept of a 'green economy'. A green economy results in improved human well-being and social equity, while significantly reducing risks to the environment. It is based on principles that integrate social, economic, and environmental considerations. South Africa has adopted the principle of green economic growth, and agriculture is one of the sectors that will drive this growth. Agriculture could address some of the sustainable development problems, but there are challenges related to resource availability, environmental impacts of agriculture, and climate change. For agriculture to support a green economy it has to be productive, contribute to economic growth, and not undermine the environment, social and cultural systems. The information base and policies required to support a green economy in general, and/or an agriculture-supported green economy have not yet been developed, as the green economy is an emerging concept in South Africa as well as globally. The generation of such information requires analysis and synthesis of green economy principles and agricultural imperatives into generic principles and practices for facilitating agriculture's contribution to the green economy. This paper conducts this analysis and synthesis and highlights the defining aspects of an agricultural green economy.

Goldblatt, A. (2015). **Agriculture: Facts and Trends in South Africa**

This report provides a snapshot of the overwhelming evidence that we need for better environmental practices if we want to ensure ongoing productive agricultural systems and food security in South Africa. It also serves to underpin WWF's drive to promote the protection of natural ecosystems, which produce the critical goods and services that underpin agricultural practices in the country. We have not attempted to specify every issue but rather aimed to provide a broad view of the negative impacts of agricultural development that is focused on maximum productivity by exploiting natural resources while disregarding the complex hidden costs – financial and otherwise – of food production. It also highlights some of the best-practice solutions we need to follow if we want to meet our growing demand for food and fibre – one of the key challenges of the 21st century. The information has been compiled from diverse and reliable sources to construct a vivid picture of the state of our agricultural resources. It is intended to stimulate debate and catalyse collaboration throughout the agricultural value chain.

Cronje, F. (2014). **A Time Traveller's Guide to South Africa for the next 10 years**

This book published by Frans Cronje produced four scenarios for South Africa. The first of these was the Wide Road and suggested that the African National Congress (ANC) would stage an internal reformation and, amidst massive popular support, introduce reforms to turn the South African economy around. Economic growth rates would exceed 5% by 2019, and South Africa would emerge as one of the world's most exciting emerging markets. In the second scenario, the Narrow Road, a desperate government would follow the example of the Asian Tiger economies to suppress civil rights to force a series of pro-investment reforms against the wishes of a rebellious and hostile public. Economic growth rates would again exceed levels of 5%, and South Africa would play a prominent role in shaping the evolution of increasingly authoritarian high-growth economies across the African continent. In the third scenario, the Rocky Road, the government would reject the need for economic reform, become incredibly corrupt, and turn to destroy South Africa's democracy in a bid to cling to power. The country would sink into recession amidst staggering corruption and terrible civil rights abuses. The fourth scenario, the Toll Road, suggested that infighting would see the government fail to introduce economic reforms, but also fail in destroying South Africa's democracy. Support for the once-dominant ANC would sink rapidly in major urban areas as the economy was brought to its knees. Massive protests would sweep the country and South Africa would enter a new and ultra-volatile era of coalition politics.

Cilliers, J. & Hedden, S. (2014). **Parched prospects – The emerging water crisis in South Africa**

South Africa is facing a potential water crisis. This paper proposes aggressive measures to close the gap between demand and supply. South Africa is over-exploiting its freshwater resources and water could be a large constraint on the implementation of the National Development Plan. Using the International Futures forecasting system, this paper model and forecasts water demand and supply until 2035, the period covered by the National Water Resource Strategy 2013. The authors' research finds that the gap between demand and supply increases and that the solutions proposed by the Department of Water Affairs and Sanitation will not close the gap without additional, aggressive measures. The authors propose such measures for each sector of demand and each source of water supply.

Department of Water Affairs (2013). **National Water Resource Strategy – Water for an Equitable and Sustainable Future**

The NWRS2 builds on the first NWRS published in 2004. The purpose of the NWRS2 is to ensure that national water resources are protected, used, developed, conserved, managed and controlled efficiently and sustainably towards achieving South Africa's development priorities equitably over the next five to 10 years. This Strategy responds to priorities set by the Government within the National Development Plan (NDP) and the National Water Act imperatives that support sustainable development. The NWRS2 acknowledges that South Africa is a water-stressed country and is facing several water challenges and concerns, which include security of supply, environmental degradation and resource pollution, and the inefficient use of water. In the context of the need for growth, equity and protection of water resources, this Strategy identifies three broad objectives: water supports the development and the elimination of poverty and inequality; water contributes to the economy and job creation; and water is protected, used, developed, conserved, managed and controlled equitably and sustainably. The response to the strategic context and the imperatives set out above are delivered through strategic themes, which discuss in detail the context and challenges, key principles to be sustained, objectives of that particular theme, and then propose strategic actions to achieve the stated objectives.

The most important consideration in all themes discussed is that water is scarce and it requires careful management to enable the provision of basic water services and equitable allocation while meeting the needs of inclusive economic growth without threatening the integrity of aquatic ecosystems. The water resources planning, infrastructure, and development theme indicate that surface water sources are limited in many catchments, as indicated by Reconciliation Strategies, and that infrastructure and the costs of construction and maintenance are prohibitive. South Africa has to prioritise, considering the mix of options available to supply the huge water demands for equitable allocation for development and economic growth. The country will thus consider other potential sources, which include water re-use, desalination, groundwater utilisation, water conservation, and water demand management measures, rainwater harvesting, recovering water from acid mine drainage, and the import of water-intensive goods.

The NWRS2 continues to state that these measures will augment the available water resources to support the key developmental objectives of the country. One of the objectives is the equitable allocation of water resources. The Strategy recognises that how water was allocated in the past was unequal and favoured only the white section of the population in South Africa. The National Development Plan (NDP) and the National Water Act (NWA) collectively inform the intended means to redress past imbalances in the manner in which water was allocated. While some municipalities and other institutions have begun to address the challenge of water loss, the NWRS2 emphasises that effort must be intensified with specific targets set to reduce water loss. Water conservation and water demand management measures will have multiple benefits in terms of the postponement of infrastructure augmentation, mitigation against climate change, support to economic growth, and ensuring that adequate water is available for equitable allocation. This requires appropriate institutional arrangements and effective governance.

The management and implementation of water strategies require competent and accountable management. The Strategy outlines the institutional arrangements that will be established or strengthened to coordinate activities related to efficient water resource management within a defined geographical area or catchment boundary. The institutions will be required to perform their duties within a developmental management approach that values the involvement of all stakeholders in defining strategies and plans for management within their defined areas. Smart business approaches will be promoted within the total water value chain management and water footprint.

The NWRS2 is developed within a changing environment and acknowledges that monitoring and collecting relevant data will not only affect the accurate assessments of the status of water resources and the magnitude of water problems but will vastly improve planning and policy formulation processes. National water legislation (Section 68 of Water Services Act) requires the Minister to maintain a national information system to record and provide data on the development, implementation, and monitoring of national policy. The monitoring should not be done only for the sake of our national concerns, but also in response to our obligation within international river basins. Approximately 60% of the streamflow in rivers is shared through trans-boundary water systems.

South Africa should ensure that Integrated Water Resources Management (IWRM) is 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. A repository of water resource intelligence will facilitate better interpretation and response to the challenges associated with changing hydrological patterns, climate change, groundwater reserves, and innovative responses for reference to the country and neighbouring states with whom we share river basins. The NWRS2 also strongly promotes technology and innovation to contribute to effective and efficient water management solutions that respond to the needs for water security and sustainability for individuals, communities, productive and strategic water use as well as ecosystem services. The research and innovation conducted by the WRC and other research bodies in areas such as wastewater treatment, water quality and water ecosystems, skills and capacity within the sector, climate change, and water conservation and water demand management approaches have influenced the themes and interventions contained in this Strategy.

The regulation of the sector to ensure that standards are set and maintained and that there is compliance with the regulatory provisions is a key focus of the Strategy. The achievement of all the country and sector goals must be sustained within an environment that protects the integrity of the National Water Act and all other legislation that has an impact on water resource management.

Claassen, M., Funke, E. & Nienaber, S. (2013). **Scenarios for the South African Water Sector in 2025**

In 2008 the Water Research Commission initiated a project to develop 'Water Sector Institutional Landscape in 2025 Scenarios'. The aim was to build knowledge about key drivers and uncertainties related to the future of the South African water sector. A diverse group of stakeholders contributed to the development of the drivers, which translated into different scenarios and associated stories that have potential implications for social and economic development, as well as for the management of water resources and water services. The four scenarios were derived from a matrix with two axes that represent the ability of the decision-making paradigm of water institutions to deal with complexity, and the reconciliation of environmental, social and economic demands of present and future generations (sustainability).

The Wise Tortoise scenario describes a sector that deals with complexity and is sensitive to sustainability issues, whereas the Ignorant Ostrich scenario describes the opposite conditions. The Greedy Jackal and Busy Bee scenarios describe the other combinations of the key drivers. The scenarios provide stakeholders and policy-makers in South Africa's water sector with insights to strengthen decision-making and to counter undesirable trajectories of change. The knowledge will empower role players in the water sector to engage in participative governance by equipping them with insights into potential futures that the South African water sector may face. This paper reports on the process to develop these scenarios for the South African water sector institutional landscape in 2025, presents the key forces, introduces the stories, and reflects on the use of scenarios in the water sector.

DEA (Department of Environmental Affairs) (2013). **Climate Change Implications for the Water Sector in South Africa**

Because of South Africa's generally arid to semi-arid climate, rainfall and river flow are unpredictable in time and unevenly distributed in space, with only 12% of the land area generating 50% of potentially available surface water resources. Decadal rainfall variability also results in extended periodic dry and wet periods across the country. Surface water resources were already over-allocated by the year 2000 in five of the nineteen water management areas.

Demand for water is expected to increase with economic growth, increased urbanisation, higher standards of living, and population growth. Climate change impacts could exacerbate existing water-related challenges and create new ones through increased rainfall variability including more frequent extreme weather events (droughts and floods), changing rainfall seasonality, and overall warming leading to greater surface water losses to the atmosphere. This would affect a wide range of economic sectors and livelihoods, impinge on the development of infrastructure and catchment management, and demand management into the future.

Current national water planning contingencies provide assurance of water supply (based on surface water resources) from 91% (for agricultural use) up to as high as 99.5% for key strategic uses under historic patterns of rainfall variability. Groundwater resources are not currently fully integrated into the national water strategy, though these currently provide about 10% of national needs, being primarily used for irrigation. A key concern for the water sector is, therefore, whether future rainfall variability will exceed patterns based on the historical record. Current modelling of future climate is uncertain with respect to rainfall variability and seasonality change, but more certain about warming projections. Consequently, a scenario-based approach is a viable way forward with respect to exploring adaptation options for this sector and the cross-sectoral and economic implications. Climate modelling approaches provide guidance on the likely range of change in rainfall and temperature that must be further translated using hydrological modelling approaches of projected impacts on surface water flows and availability. Based on LTAS Phase 1 findings (see climate trends and scenarios technical report), South Africa's climate future up to 2050 and beyond can be described using four fundamental climate scenarios at a national scale, with different degrees of change and the likelihood that capture the impacts of global mitigation and the passing of time.

- **warmer (<3°C above 1961-2000) and wetter** with greater frequency of extreme rainfall events.
- **warmer (<3°C above 1961-2000) and drier**, with an increase in the frequency of drought events and a somewhat greater frequency of extreme rainfall events.
- **hotter (>3°C above 1961-2000) and wetter** with a substantially greater frequency of extreme rainfall events.
- **hotter (>3°C above 1961-2000) and drier**, with a substantial increase in the frequency of drought events and greater frequency of extreme rainfall events.

Projections for national runoff range from a 20% reduction to a 60% increase by as early as mid-century based on an unmitigated global emissions pathway. However, if global emissions are constrained to stabilise at 450 ppm CO2, these changes are projected to lie between a 5% decrease and a 20% increase in annual runoff. Sub-nationally, projected changes range from increases along the eastern seaboard and central interior to decreases in much of the Western Cape. Areas showing the highest risks of extreme runoff related events include KwaZulu-Natal, parts of southern Mpumalanga and the Eastern Cape. Other areas show neutral to a reduced risk of extreme runoff events, except for the central and lower Orange River region. Specific areas of high risk, where cumulative negative climate change impacts are likely to occur (including increased evaporation, decreased rainfall, and decreased runoff), include the southwest of the country, the central-western parts, and to some extent the extreme north. Under all four future medium and long-term climate scenarios a higher frequency of flooding and drought extremes is projected, with the range of extremes exacerbated significantly under the unconstrained global emissions scenario.

Specific provisions for climate change have not yet been made in most of the water resources reconciliation studies in South Africa, these being the primary tool for strategic water resource planning to at least 2030 in South Africa. However, this planning capacity will be a key capability

for adaptation planning under ongoing and future climate change. To build resilience to climate change in the water sector it would be beneficial if resource planners could develop adaptive responses that do not foreclose future options, thus retaining the ability to respond to a wide range of climate outcomes, monitor indicators so that changes can be observed with increasing certainty, and adopt flexible planning to allow appropriate responses as conditions change.

Adaptation response strategies for the water sector can usefully be identified at distinct governance levels. At a national scale, the development of strategic intent and an enabling framework for adaptation would help to ensure a coherent national response. At a sub-national or system scale, key institutions could usefully engage in prioritising and allocating resources to adaptation interventions that adequately reflect the conditions at that scale. At sub-catchment or municipal scale, the design of local implementation actions would be facilitated by responding to local challenges, resources, and capacities.

The following priority functions would be beneficial to the DWA: policy review for enabling flexible frameworks, flexible and robust infrastructure planning, resources directed at maintaining and rebuilding ecological infrastructure in vulnerable systems, institutional oversight to ensure water-related institutions build adaptive management capacity, effective information management and maintenance of monitoring and evaluation systems, and sustainable and locally accessible financial management.

Research and focused monitoring is required to support the development of tools, approaches, and case studies that inform water planning in the context of long-term climate change. This includes understanding how climate-driven changes in water resources availability or demand may constrain or enable different development pathways in different parts of South Africa, particularly in terms of agricultural production and energy generation. Also, there is value in exploring the implications of long-term hydrological change on the ecological reserve (including the appropriate definition of the reserve) and associated issues of catchment management approaches that are needed to maintain the ecological reserve in different systems.

Key decisions in development planning would benefit from considering the implications of a range of possible climate-water futures facing South Africa. Under a wetter future scenario, trade-offs in water allocation between sectors are likely to be less restrictive, providing greater scope for urban-industrial economic growth and water provision for an intensive irrigated agricultural production model. Under a drier future scenario, significant trade-offs are likely to occur between developmental aspirations, particularly in terms of the allocation between agricultural and urban-industrial water use, linked to the marginal costs of enhancing water supply. These constraints are most likely to be experienced in central, northern, and south-western parts of South Africa. This scenario has significant social, economic, and ecological consequences by restricting the range of viable national development pathways.

Pelser, A. & Redelinghuys, N. (2009). **Towards A 10-Year Review of the Population Policy Implementation in South Africa (1998-2008) – Population, Environment & Development**

The increasing pace of human-induced environmental change has a negative impact on the health and well-being of many South Africans, strains the human development of our country at large, and threatens to relegate the goal of "sustainable development" to an elusive and non-attainable pipe dream. The pressure on economic development, social services, and environmental resources, particularly access to freshwater and land, will continue to mount in the coming years. Challenging realities in the form of high levels of poverty, unemployment, the growing number of informal dwellings, rising consumption, increased competition for access to limited resources, indoor air pollution, susceptibility to climate change, gender and racial disparities, looming water deficits, a deteriorating state of the environment, and patchy success in the delivery of services such as water and sanitation, are all increasing the exposure and vulnerability of millions of South Africans to environmental change.

The increased utilisation and overconsumption of natural resources could exacerbate the cycle of poverty, environmental degradation, and ultimately impact negatively on human development. The poor are becoming more and more dependent on an environment that is increasingly stressed or unable to meet the demands of those who directly depend upon it for their daily survival. The growing quest for land, housing units and services places major demands and stresses on, not only the natural environment but also on urban authorities who find it increasingly difficult to meet the demand for human development. The backlog – and in many cases deterioration – in service delivery at the particularly municipal level is testimony to the fact that human capacity in critical areas is seriously lacking. Although significant progress has been made towards human well-being and development in some areas since the mid-1990s, the paper reveals several key challenges at the interface of population, environment, and development, which will unleash new dynamics in the medium to long term.

Our future well-being and development initiatives will increasingly be determined by how successfully we manage our impact on the environment and ecological systems we depend on. Now, more than ever before, the government will have to be firm and decisive in implementing, monitoring, and evaluating the many environmental policy instruments at our disposal. Without preventative or mitigatory actions, the impact of climate change will be potentially significant, leading to a drastic decline in overall human well-being in South Africa. The demand for energy has to be balanced with the need to minimize the damaging impact of energy generation upon human health and the environment in

South Africa and, therefore, renewable and clean energy will have to contribute more substantially than ever before to the country's energy mix. Conditions that threaten food security must be identified, targeted, and addressed. The drivers of biodiversity loss require a greater commitment of resources, stricter enforcement of regulation, and a stronger, integrated approach to turn the tide and to ensure sound ecosystem functioning that is a prerequisite for sustainable development, health, and human well-being. The overall deterioration of freshwater sources and the looming water deficit facing the country demand immediate intervention. Lastly, human capacity required for the implementation of policy initiatives at the population, environment, and development interface, needs to be strengthened and increased.

Policy Co-ordination and Advisory Services (PCAS) (2008). **South Africa Scenarios 2025: The Future we chose?**

Scenarios are constructed stories about a particular point in the future and some informed speculation on ways that might lead us there. Scenarios help us to put future goals and plans into perspective by thinking of ways to better the nation in terms of what should or should not be embarked on. This article focuses on debates and discussions of the challenges South Africa might face after 30 years of democracy.

The scenario building process involved various participants from diverse fields who were able to identify 24 'variables' as key shapers of our reality, which need to be understood to construct views of the future. The 24 variables are:

- World economic growth;
- Terms of trade;
- African economy;
- South African economic growth;
- Transformation of the economy;
- Global politics;
- Content and form of South African politics;
- Crime;
- Corruption;
- Civil society and social cohesion;
- The youth;
- Inequality;
- Poverty;
- Urbanization;
- Food security issues;
- The capacity of the state;
- Local/Provincial government;

- Skills and education;
- Infrastructure;
- Health (including HIV and AIDS);
- Energy/oil prices;
- The natural environment/climate change;
- Technology;
- Migration and demographics.

These variables led to the identification of seven Key Driving Forces (KDFs) which are trends of what is likely to shape South Africa in the next couple of years. The KDFs are:

- KDF 1: Shifts in global economic power;
- KDF 1: Shifts in global political power;
- KDF 3: Resource constraints;
- KDF 4: South Africa's economic growth;
- KDF 5: Governance;
- KDF 6: Social fabric.

Three Scenarios were looked at:

- **Scenario 1**: *not yet Uhuru* – A Government strongly committed to accelerating economic growth struggles in the face of deteriorating global conditions and severe ecological challenges…
- **Scenario 2:** *Nkalakatha* – Determined to play a more central role in the economy, the Government prioritises poverty reduction and skills enhancement by articulating a national vision and fostering partnerships…
- **Scenario 3**: *Muvhango* – Despite an initial resurgence of the economy, and positive world conditions, the Government battles to govern well…

Department of Water Affairs (2010). **Governing Board Induction Manual: Overview of the South African Water Sector**

South Africa is a semi-arid, water-stressed country, with an average rainfall of about 450 mm, which is well below the world average of about 860 mm per year. Water availability across the country is faced with three major challenges:

- Uneven spatial distribution and seasonality of rainfall (43% of the rain falls on 13% of the land)
- Relatively low stream flow in rivers most of the time, which limits the proportion of streamflow that can be relied upon for use, and
- Location of major urban and industrial developments remote from the country's larger watercourses, which necessitates large-scale transfers of water across catchments.

About 70% of South Africa's gross domestic product is supported by water from the Limpopo, Inkomati, Pongola, and Orange Rivers, which collectively drain two-thirds of the land area. Judicious joint management of these rivers with the relevant neighbouring countries is therefore of paramount importance to South Africa. Although the National Government is the public trustee of the nation's water resources and the Minister is ultimately responsible for implementing water legislation, the management of water resources will take place at a regional scale in 19 Water Management Areas (WMAs) that cover the entire country.

The total natural runoff flowing along our rivers towards the sea amounts to some 50 billion cubic metres per year (on average), of which nearly 10% originates in Lesotho. Of the total runoff, a yield of some 14 billion cubic metres is available for use through dams, basin transfers, and other water resource developments throughout the country. This is currently adequate to meet the country's total annual water requirement, which in 2000 was estimated at 13,28 billion cubic metres. Prior to 1998, the management of water resources was mainly demand-driven, with emphasis on the development of new water resources in response to the socio-economic needs of the time and in line with the greatest perceived overall benefit. The new water management policy has a different emphasis; the National Water Act (No 36 of 1998) is concerned with (amongst other things) efficiency and sustainability of water use, redressing past imbalances with regard to access to water for all South Africans, and reserving sufficient water to maintain the natural environment.

The assurance of water supply for the future is not a problem unique to South Africa. It is estimated that by 2025, at least 3,5 billion people (nearly 50% of the world's population) will face water scarcity. In South Africa, it is estimated that, based on current usage trends, water demand will exceed the availability of economically usable freshwater resources by 2025. The continuing trend in industrialization and urbanization of the population is expected to place further pressure on the country's sources of water supply unless appropriate corrective action is taken.

DEA (Department of Environmental Affairs) (2009). **Long Term Adaptation Scenarios for South Africa – Together developing adaptation responses for future climates**

This study aims to explore the systemic implications of three distinct adaptation scenarios for South Africa. These scenarios are summarised briefly below.

It should be noted that, while in two of these scenarios a clear distinction has been made between a warmer and **wetter** and a warmer and **drier** future world the reality of climate change impact on South Africa is likely to be more complex, in several ways. Firstly, as the climate warms its plausible that different regions within South Africa could simultaneously become wetter (on the east coast in particular) while other regions become drier (in the Northern Cape for instance). Secondly, it is plausible, South Africa could move between a dry and wetter future from year to year. While uncertainty over the impact of climate change on precipitation in particular persists, these scenarios nonetheless provide a useful heuristic device to explore possible future climates and their impact on South Africa.

- **Scenario one:** Global emissions goal met/ a warmer but drier climate in South Africa [Temperature increase of <3°C in RSA and drier]: characterised by an increase in the frequency of drought events. In this scenario, the limited availability of water intersects with growing demand in both agriculture (for irrigation) and urban areas (driven by population increase) resulting in price rises. The affordability of water drives a transformation in approaches to rural economic growth, water-efficient urban design, and the development of new models for managing food security.
- **Scenario two:** Global emissions goal met/ a warmer but wetter climate in South Africa [Temperature <3°C in RSA and wetter]: characterised by a greater frequency of extreme rainfall events. In this scenario infrastructure and the property is threatened and poor communities suffer as flooding increases in frequency and severity. These phenomena negatively impact human health, while the increasing variability of rainfall creates a shifting pattern of agricultural production. To adapt flood resilience and socially sensitive settlements are prioritised as infrastructure design is rethought. Simultaneously, approaches to the conservation of natural resources evolve further, as do innovative approaches to incentivising effective ecosystem management.
- **Scenario three:** Global emissions goal not met/a hotter climate in South Africa [A hotter scenario of >3°C in RSA]: characterised by a rapid shift in the frequency of extreme weather events, variability in precipitation and more significant impacts from fire and sea-level rise. To cope with this radically new and variable climate the predictive power of early warning systems is prioritised as the weather becomes increasingly volatile. Urban spaces are reconfigured to preserve water and shield South Africans from the intense heat. Approaches to organising labour and conservation are radically rethought as traditional models are not effective in a radically hotter climate. In the face of sea-level rise, managed retreat from less populated coastal areas is considered as a policy response.

Across the scenarios explored, this report concludes that increasing individual and community resilience to climate change cannot be separated from basic developmental interventions. The first and ‘no-regret option’ for policymakers to adapt to climate change should be based on doing the basics better. Economically active, educated, and healthy South Africans will have a greater capacity to avoid and recover from climate events. Fulfilling the NDPs objectives of providing basic life opportunities and improving the welfare of the general population should be a major building block to any response to climatic change. A critical component of human wellbeing is healthy ecosystems and so ‘no-regret’ options should include maintaining and restoring ecosystems through approaches like an ecosystem-based adaptation.

Water for growth and development framework**. (**Undated). **Water for Growth and Development in South Africa**

The Department of Water Affairs and Forestry (DWAF) has embarked upon a process to develop a framework that will set in motion a course of action to ensure that there is sufficient water, in both quantitative and qualitative terms, to support South Africa's path of growth and development. There must be sufficient water for the country to achieve its 6% economic growth target. At the same time, every person in South Africa must have access to potable water. These two goals must be achieved by not compromising the ecological sustainability of the resource. The Department has also embarked upon rigorous water assessment studies referred to as Reconciliation Strategies to achieve the reconciliation of supply and demand for both water-scarce areas as well as those experiencing relatively high levels of demand (DWAF, 2005).

These strategies aim to ensure the supply of water at adequate levels of assurance within the constraints of affordability and appropriate levels of service to users and protection of current and possible future water resources. Thus far, six strategies have been undertaken in the major urban centres and in July 2008, the Department commissioned reconciliation strategies for every town in the country, due to be completed by 2011. Water scarcity has been identified in major urban centres. These major urban areas anchor the country's economy, and the Department has reached a point where it knows that it must invest heavily in the diversification of its water mix to avert serious water shortages that could impact adversely on our economy. In addition to the traditional augmentation schemes, there are two major ways that water supplies can be augmented. These are the treatment of effluent and the desalination of seawater for productive use, thereby rendering primary water sources for domestic use. A key principle behind assuring local water supplies is that the water supply should be as close to the end-user as possible, avoiding the unnecessary intensification of costs associated with the transportation of water.

The Department also appreciates that whilst it invests in schemes to assure water supply, it is also required to strengthen its focus on water conservation and water demand management, especially since a very basic cost analysis shows that there is a greater return on investment through water loss control and water use efficiency measures than supply-side interventions. A major source of water loss is aging infrastructure exacerbated by poor operations and maintenance at a municipal level and analysis shows that this state of affairs is a multi-faceted problem including a lack of managerial and technical skills and funding. The Department will strengthen its efforts to support this sector in a bid to reverse this dire situation; it becomes an even more crucial intervention when one factor in the pollution of water sources due to faulty wastewater treatment works. The notion of water for development alludes to the role of water in the alleviation of poverty and people's constitutional rights to have access to a source of safe and reliable drinking water. The Department is deeply concerned about the persistent backlogs in particular parts of the country although it has achieved the Millennium Development Goal of halving, "by the year 2015... the proportion of people who are unable to reach or to afford safe drinking water" in 2005.

The Department is also very aware of the anomalies in water distribution, where people reside adjacent to water sources and yet have no access to these. The Department will achieve the target of ensuring that every person has access to a safe and reliable supply of drinking water although it has to reconsider how this can be achieved. The Department recommends that the service backlogs, which are predominantly situated in KwaZulu-Natal, Eastern Cape, Limpopo, and the North West province, are prioritised and addressed through a combination of short-term interventions such as rainwater harvesting, exploring further options of supply communities from available sources and the further Water for Growth and Development Framework exploitation of groundwater sources, which may necessitate a policy change. Ultimately, a balance needs to be struck between large and small-scale infrastructure projects. Where a community can be serviced by existing large-scale infrastructure, this should happen with immediate effect. Where a community cannot be serviced by a large-scale infrastructure project due to the cost of such an intervention (for example, pumping water to mountaintop communities at higher altitudes), then small-scale schemes must be planned and implemented. Where large-scale infrastructure could solve local water scarcity, such as the De Hoop Dam, the necessary planning and resourcing must be undertaken and interim measures introduced to compensate for the long lead-times. The Department should also prioritise schemes in areas with resource development potential that coincide with areas with high service backlogs. It will also support sector plans where water use for growth purposes can simultaneously support water use for development purposes. The Department will seek out and support interventions that support the dual goals of water for growth and development as one goal should not be at the expense of the other.

Water for Growth points to the relationship between water availability and the forms of economic activity that are dependent on the available water supply of varying levels of quality depending on the technologies being used. The Department's position is that it would like to support the country's economic growth target of 6% but this cannot be at the expense of the ecological sustainability of the resource or people's primary needs. It wishes to be responsive to the needs of the different economic sectors and this can only be achieved if these sectors factor in water implications (supply and impact of use) at the outset. Rather than being an add-on or afterthought, the Department sees the need for water to be mainstreamed and placed at the nucleus of all planning decisions, whether these be within the public or private sector. Water can only support economic growth, without compromising primary needs or ecological sustainability if, and only if, its availability is adequately factored in.

Apart from ensuring water availability for growth purposes, the Department is very mindful of water use behaviour that impacts negatively on both water resource quantity and quality. It is currently exploring a potential mix of mechanisms to change this behaviour, which includes regulatory instruments, market-based instruments, self-regulation, and awareness and education, and it will match appropriate mechanisms to mitigate offending behaviour. The Department is satisfied that it is taking the required course of action to ensure that it has the right kind of information at its disposal to make better informed and calculated decisions and trade-offs with respect to water in support of cross-sectoral planning and development initiatives. The rolling out of the Reconciliation Strategies to all parts of the country will ensure that the Department can anticipate and address future demand without any one area of water need – social, economic, and ecological – being compromised.

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4 WATER MANAGEMENT IN SADC AND SOUTH AFRICA

4.1 Introduction

The challenges of feeding South Africa's growing population in a climate-altered, resource-constrained future are substantial. The availability of freshwater presents one of the greatest risks to South Africa and the global economy at large. Demand for water in South Africa is projected to increase with economic growth, increased urbanisation, higher standards of living, and population growth. Climate change impacts could exacerbate existing water-related challenges and create new ones through increased rainfall variability including more frequent extreme weather events (droughts and floods), changing rainfall seasonality, and overall warming leading to greater surface water losses to the atmosphere. This would affect a wide range of economic sectors and livelihoods, impact on the development of infrastructure and catchment management, and demand management into the future. Poor management of water resources threaten the resource base on which agriculture depends, therefore, there is a need to conserve water by creating and managing alternative water sources through the development of scenarios for future agricultural water use and other benefits. This project aims at suggesting and developing scenarios for future agricultural water management despite natural hazards that pose challenges to this development.

South Africa is increasingly integrated across sectors with the rest of SADC and it has an important interest in a climate-resilient SADC. This is increasingly important in terms of regional food security, extreme event responses, and climate change adaptation in the face of increased climate variability where SADC will experience more extreme dry spells. It is therefore important to understand how climate risks can be shared in SADC through trade, information sharing, and technology transfer amongst other factors. SADC countries differ dramatically in terms of economic development, infrastructure development, resource availability, and climatic conditions. It is therefore important that countries take note of climate risks such as drought risk and how drought can impact the different sectors in a specific country.

South Africa is inextricably linked to SADC through various means including the migration of people, trade of goods, services and energy, food supply, regional climatic conditions, transboundary water resources, and others. The availability of water underpins the socio-economic fabric of society in SADC. Rapid urbanisation is taking place in South Africa but SADC as a region remains rural-based and heavily dependent on agriculture. Water is a scarce resource in South Africa and its neighbouring countries. Low coverage of water supply and sanitation facilities for urban poor people has a significant impact on public health. South Africa has the lowest per capita freshwater available in SADC with only 843 m^3 per person per annum compared to the arid Namibia with 2674 m^3 per person per annum (WWF, 2016). It is expected that Malawi and South Africa will face absolute water scarcity by 2025 due to mainly population growth, while Lesotho, Mauritius, Tanzania, and Zimbabwe are likely to be water-stressed

(Hirji, Mackay & Maro, 2002). The WWF (2016) calculated that national demand for water will increase to 17 700 million m^3 by 2030 due to population growth and industrial development.

South Africa has international obligations under the National Water Act to ensure the sustainability of water flows across international borders. Sixty% of the river basins in South Africa include flow to or from a neighbouring country (WWF, 2016). The Karoo aquifer sequence on the Kalahari is a major transboundary resource shared with Namibia and Botswana. The Inkomati and Limpopo rivers flow into Mozambique and the Limpopo is also shared with Zimbabwe. The headwaters of the Orange-Senqu are in Lesotho and the Vaal-Orange rivers downstream are shared with Namibia.

4.2 SADC Regional Water Policy

The water resources of the SADC region are vital for sustainable economic and social development of the region. Apart from sustaining a rich diversity of natural ecosystems, the region's water resources are critical for meeting the basic needs related to water supplies for domestic and industrial requirements, and sanitation and waste management for about 200 million people. In addition, there is a need for increasing food security through better management of rain-fed and irrigated agriculture, aquaculture, and livestock production; and improving access and availability of cheap energy through hydropower. Despite the importance of water in the region, there is, presently, no long-term policy and strategy for the development and management of the region's water resources, and in particular the management of transboundary watercourse systems.

The SADC region has 15 major river basins which are transboundary or watercourses shared by two or more countries. They range from the large Congo River Basin (3,800,000 square kilometres), the Zambezi River Basin (1,400,000 square kilometres covering eight SADC Member States) to the Umbeluzi River Basin (5,500 square kilometres) shared by only two countries. Thus one of the characteristic features in the region is shared watercourse systems, with complex water rights and potential conflicts over-utilisation of the shared resources. This common heritage also presents tremendous opportunities for cooperation in managing the shared resources for regional economic development and regional integration.

Since the mid-1990s the SADC Member States have engaged in wide-ranging and intense consultations on the development of the water sector in the region. This has brought about a heightened awareness of the importance of water for socio-economic development, regional integration, and poverty reduction. However, there are several institutional, technical, economic, social, and environmental factors that, to one degree or another, still constrain effective management of the region's water resources. These include:

- Weak legal and regulatory framework.
- Inadequate institutional capacities of national water authorities, and regional or river basin organizations.
- Weak policy framework for sustainable development of national water resources.

- Poor information acquisition, management, and dissemination systems.
- Low levels of awareness, education, and training with respect to economic, social, environmental, and political issues related to water resources development and management.
- Lack of effective public participation by all stakeholders particularly women and the poor.
- Infrastructure is inadequate and unable to meet the growing demands for service.

These issues are being addressed through several programmes and projects that form part of the Regional Strategic Action Plan for Integrated Water Resources Development and Management in the SADC Countries (RSAP-IWRM) which is now a component of the Regional Indicative Strategic Development Plan (RISDP). The RSAP is implemented by the SADC Secretariat through the Directorate of Infrastructure and Services" Water Division (DIS-WD). However, water resources development in the region still faces many challenges including the following:

- ***A mismatch between water availability and demand.*** Areas of highest water demand happen to be in the water-scarce semi-arid zones of the region. This poses a challenge in terms of the allocation of available water resources to various users, particularly concerning transboundary water resources.
- ***High variability of available water resources***, which impacts on reliability. Investments in storage dams, inter-basin transfers, and large scale water distribution networks are needed to ensure water security for multi-purpose uses under varying climatic and hydrological conditions.
- ***Shared watercourses*** that cut across political jurisdictions and cover several countries with different socio-economic conditions and complex water rights serve as a potential source of conflict unless managed in a coordinated, integrated, and equitable manner. At the same time, shared watercourses serve as potential sources of regional cooperation and economic integration.
- ***Widespread poverty in the region.*** UN and World Bank studies indicate that several SADC countries have the lowest human development indices in the world; it is estimated that about 70% of the population in the region lives below the international poverty line of US$ 2 per day.
- ***Weak inter-sectoral linkages and coordination,*** which hampers comprehensive and integrated development.
- ***Low access to safe drinking water and adequate sanitation,*** primarily as a result of inadequate infrastructure, and poor operation and maintenance of facilities.
- ***Weak policy linkages at regional and national levels,*** particularly weak implementation mechanisms at the national level, such that plans at the regional level do not have an effective impact at the national level.
- ***Sharing benefits of water allocation, between the Watercourse States,*** taking account of historically uneven development of water resources requiring joint assessment, planning, and understanding of resource availability ***and utilisation.***
- ***Poorly developed formal dispute resolution mechanisms***, particularly the delay in the establishment of the SADC Tribunal.
- ***The prevalence of HIV/AIDS,*** with the associated challenges for the capacity, sensitivity, and requirements to water resources management in the region.

This document presents the Regional Water Policy for the SADC region which is aimed at providing a framework for sustainable, integrated and coordinated development, utilization, protection and control of national and transboundary water resources in the SADC region, for the promotion of socio-economic development and regional integration and improvement of the quality of life of all people in the region. The policy was formulated through a highly participatory and consultative process, implemented over 12 months, involving diverse stakeholders including senior government officials from ministries dealing with economics, law, water resources, agriculture, energy, and environment. Other stakeholders included academic and research institutions, private companies, consultants in various disciplines, as well as representatives of local and regional NGOs, and community leaders.

Policy Principles

The policy framework for the regional water policy is anchored by the following pronouncements which the SADC Member States have formulated over the years:

- SADC Declaration and Treaty (Declaration by the Heads of State or Government of Southern African States "Towards the Southern African Development Community" "Towards the Southern African Development Community" adopted in Windhoek, Namibia, on 17 August 1992, and the Treaty of the Southern African Development Community, which entered into force on 30 September 1993). The original Declaration calls upon all countries and people of Southern Africa to develop a vision of a shared future, a future within a regional community that will ensure economic well-being, improvement of the standards of living and quality of life, freedom and social justice and peace and security for the peoples of Southern Africa.
- The Southern African Vision for Water, Life, and Environment adopted in March 2000, aimed at "equitable and sustainable utilisation of water for social and environmental justice, regional integration and economic benefit for present and future generations". Water is therefore seen as a driving force to a better future for the peoples of Southern Africa.
- The Revised SADC Protocol on Shared Watercourses, which entered into force in September 2003, whose overall objective is "to foster closer cooperation for judicious, sustainable and coordinated management, protection and utilisation of shared watercourses and advance the SADC agenda of regional integration and poverty reduction".
- The "Dublin Principles" of integrated water resources management (IWRM) (enunciated in the 1992 Dublin Statement on Water and Sustainable Development promulgated by the International Council of Water and Development) commonly accepted as representing best water resources management practice.

The Policy Principles for Water Resources Management for the SADC region, taking into account the above policy pronouncements, are as follows:

- Recognition of water as an instrument for peace, cooperation, and regional integration
- Effective public consultation and involvement of users.
- Focus on integrated, people-centred planning.
- Further development of SADC water resources through the joint planning and construction of strategic water infrastructure, to rectify historical imbalances and promote water supply for irrigation and poor communities.

- Efficient use of water through demand management, conservation, and re-use, and the efficient use of water for agriculture.
- Recognition of the environment as a legitimate user of water, as well as a resource base.
- The protection of the environment through appropriate user charges and the enforcement of "the polluter pays" principle, taking into account equity and social justice.
- Integration of water supply, sanitation, and health and hygiene education programmes.
- Capacity building to ensure that managers of water, waste, and sanitation have the requisite knowledge and tools.
- Ensuring that waste is safely managed close to the point of generation.
- Preventing the export (and import) of harmful waste across the national and regional boundaries.
- Gender mainstreaming and addressing HIV/AIDS in water resources management at all levels.

Policy Structure

The policy has nine thematic areas which address the water resources management issues and challenges outlined in paragraphs 3 and 4, or are aimed at optimising the development opportunities. The main policy areas are:

- ***Regional Cooperation in Water Resources Management:*** including policy provisions on the water for regional integration and socio-economic development; cooperation in water resources management of shared watercourses; inter-sectoral and international cooperation; and the harmonisation of national policies and legislation.
- ***Water for Development and Poverty Reduction:*** containing policy provisions on water for basic human needs and industrial development; water for food and energy security.
- ***Water for Environmental Sustainability:*** containing policy provisions on water and the environment, water quality management, and control of alien invasive species in watercourses.
- ***Security from Water-related Disasters:*** including policy provisions covering people's protection from water-related disasters; disaster prediction, and management and mitigation.
- ***Water Resources Information and Management:*** covering data and information acquisition and management; and information sharing.
- ***Water Resources Development and Management:*** including policy provisions on a river basin approach; integrated planning; dams and dam management; water demand management; and alternative sources of water
- ***Regional Water Resources Institutional Framework:*** including policy provisions covering institutional arrangements at regional and national levels and for Shared Watercourse Institutions (SWCIs).
- ***Stakeholder Participation and Capacity Building:*** including provisions focusing on participation and awareness creation; capacity building and training; gender mainstreaming; and research, technology development, and transfer.
- ***Financing integrated water resources management in the region.***

Policy Statements

Based on the above policy structure, and guided by the policy principles already outlined, the policy statements are grouped under each thematic area and sub-theme. The policy statements are stated below:

(a) Regional Cooperation in Water Resources Management.

Water for Economic Integration

- Water resources shall be developed and managed in an integrated manner to contribute to regional and national economic integration and development based on balance, equity and mutual benefit for all Member States
- The Southern African Vision for Water, Life and the Environment shall be the reference point for the water resources contribution to achieving regional integration, development and poverty eradication

Water for Peace

- Regional Cooperation in shared watercourses shall be guided by the Revised SADC Protocol on Shared Watercourses.
- Watercourse States shall participate and co-operate in the planning, development, management, utilization, and protection of water resources in the shared watercourses
- The Member States shall endeavour to promote and exploit opportunities for joint water resources development in shared watercourses to consolidate regional cooperation.

Water and Inter-Sectoral Cooperation

The SADC Secretariat, the Member States, and Watercourse Institutions shall ensure the collaboration of all affected sectors in the management of water resources to achieve the goals of regional integration, development, equity, poverty eradication, and sustainability.

Harmonisation of National Policy and Legislation

- The Member States shall promote the harmonisation of its water policies and legislation with the regional water policy.
- National water policy and legislation shall take into account any international and regional conventions, protocols, and policies accepted and/or already adopted by the Member States.

Conflict Management

- Member States shall pursue all avenues of amicable prevention and resolution of conflicts, in accordance with the principles enshrined in the SADC Treaty

- Where an amicable resolution cannot be achieved, conciliation, mediation, and arbitration mechanisms should be pursued, with use of the SADC Tribunal or other recognised international arbitration structures only as a last resort

Water for International Cooperation

SADC shall actively participate in and support other African Initiatives, as well as creating relationships with international initiatives on water resources management.

(b) Water for Development and Poverty Reduction.

Water for Socio-Economic Development

- Water shall be considered as an economic good, which supports cross-sectoral regional economic integration and development, and shall be conserved, developed, and managed to provide economic benefits.
- Water shall be considered as a social good that is essential to human dignity, poverty reduction, and social well-being.
- Water allocation between the Member States, sectors and users shall consider among other things the economic benefits balanced with social obligation and environmental requirements
- Regional water resources management shall consider the concept of comparative advantage in water availability as a means of promoting intra-regional trade and sustainably balancing national water budgets.

Water Supply, Sanitation and Hygiene

- Members States have a social and economic responsibility to ensure sustainable access to safe water supply for basic human needs in their respective countries.
- Member States will prioritise the allocation, access, and utilisation of water resources for basic human needs over any other allocation, access, and utilisation.
- Member States will seek to provide, in addition to clean water for domestic use, water for productive activities to poor and marginalised communities in rural and peri-urban areas to alleviate poverty and to correct imbalances in development.
- To ensure the sustainability of water supply services to all areas, cost recovery will underpin all infrastructural developments and operations, i.e. beneficiaries will pay an appropriate amount towards the cost of providing services taking into account Member States" social responsibilities to the poor.
- Member States will facilitate the provision of sustainable access to adequate sanitation for all rural, peri-urban, and urban households.
- Member States will ensure that provision of sanitation services is integrated into the provision of water supply for basic human needs.
- Public awareness, as well as hygiene education and practice, should be integrated into the provision, operation, and maintenance of water and sanitation facilities.

Water for Food Security

- Member States will promote the attainment of regional food security rather than national self-sufficiency by developing those areas which have a comparative advantage for rain-fed and irrigated agriculture.
- Water resources development for irrigation in commercial agriculture should be planned in coordination with other sectors in the interest of IWRM.
- As a vehicle for promoting reliable food production and enhancing food security, sustainable irrigated agriculture will be promoted in all Member States with suitable water and land resources.
- Member States will promote improved tillage and rainwater harvesting techniques to optimise the use of water by rain-fed agriculture.
- Member States will promote affordable and sustainable techniques for small-scale irrigation as an equitable measure to increase the production of food and cash crops in rural areas for sustainable livelihoods and poverty reduction.
- Member States will promote measures to increase water use efficiency in agriculture. Pricing of irrigation water shall be consistent with the need to provide economic incentives for efficient use.
- Water requirements for livestock watering and maintenance of grazing land shall receive adequate consideration in water resource allocations and management at regional as well as national and local levels.

Water for Energy Development

- Member States will optimise the use of hydro-electricity generation potential to provide cheaper and more environmentally friendly sources of electrical energy to the region.
- Member States will encourage the use of more efficient technologies in the cooling of industrial processes and electric power generation stations.
- Member States will encourage the development of small-scale hydropower to service the energy needs of rural communities.

Water for Industrial Development; Member States may allocate water for industrial requirements at the economic value of the resource.

Water for Sports and Recreation; Water resources allocation at national and regional levels shall consider allocating water for Sport and Recreation.

(c) Water for Environmental Sustainability.

Water and the Environment

- The environment is recognised as a resource base and a legitimate user of water in the SADC region and Member States should take all necessary measures to sustain it.
- Member States should, in their mechanisms for allocating water resources among many users, allocate sufficient water to maintain ecosystem integrity and biodiversity including marine and estuarine life.

Water Quality Management

- SADC should harmonise and uphold common minimum standards of water quality in shared watercourses.
- Member States should individually and collectively adopt the necessary measures to prevent and control pollution (point and non-point sources) of ground and surface waters resulting from inland, coastal, or offshore activities.
- The Member States shall not import pollutants into the region for disposal which can affect watercourses.
- EIA should be a mandatory requirement for development initiatives in the watercourses and Member States are encouraged to undertake Strategic Environmental Assessments where feasible.

Alien Invasive Species; Member States are individually and collectively responsible for the control of alien invasive species with the ultimate aim of eradication of the non-economical ones.

(d) Security from Water-related Disasters

People's Protection from Floods and Droughts

- The Member States shall commit themselves towards the protection of human life, common property, and the environment against the effects of water-related natural and human-induced disasters.
- The SADC Secretariat and SWCIs shall facilitate and coordinate the management of natural disasters at a shared watercourse and regional level.

Disaster Prediction, Planning, and Mitigation

- The SADC Secretariat, the Member States, and SWCIs are committed to improving the region's capacity in predicting water-related disasters associated with floods and droughts through coherent and effective regional and watercourse strategies.
- Management of natural disasters and emergencies require the development and implementation of integrated and coherent regional and watercourse level management plans and procedures.
- Regional disaster management planning shall be aligned with other sector disaster management plans and involve consultation with relevant stakeholders.
- Each Member State must notify and share information with the affected Watercourse States in the event of actual or pending water-related disasters.

(e) Water Resources Information and Management.

Data and Information Acquisition and Management

- The Member States shall establish water resources data and information acquisition and management systems in their territories in an integrated manner at regional, river basin, and national levels to meet all water resources management needs.
- The Member States shall adopt compatible systems for data and information acquisition and management.

Information Sharing

- The Member States shall timeously share relevant available information and data regarding the hydrological, hydro-geological, water quality, meteorological, and environmental condition of shared watercourses.
- The Member States shall ensure that members of the public in the region have access to relevant and understandable information regarding water resources impacting on their health or safety and economic interests.
- SADC, SWCIs as well as the Member States shall establish mechanisms for regular interpretation and dissemination of essential information on water resources so that the public is regularly informed.

Water Resources Assessment; Member States shall adopt common or compatible procedures and methodologies for carrying out regular water resources assessment at regional, river basin, and national levels.

(f) Water Resources Development and Management.

River Basin Approach

- Member States will adopt a river basin or watercourse approach in the planning, development, and management of water resources. This applies in particular to shared watercourses.
- Watercourse States will prepare and implement river basin development plans in a holistic and integrated manner, with the involvement of stakeholders to achieve equitable and efficient utilisation.
- The planning, development, and management of watercourses, particularly in shared watercourses will consider the integrated use of surface and groundwater resources, the reuse of water, proper pollution management, and the provision of environmental requirements.
- Water resource allocation and utilisation will be based on equitable and reasonable mechanisms through negotiations between watercourse States.
- Member States will ensure that major water uses in watercourses, particularly in shared watercourses will be regulated through authorisations such as a system of permits.

Integrated Planning

- Planning, development, and management of water resources in the region should be based on the principles of IWRM and shall take full cognisance of the cross-cutting nature of water.
- Watercourse States shall promote joint planning and implementation of water resources developments within their shared watercourse and transparently notify and/ or engage the other Watercourse States in a dialogue, where such States are not proponents of the project.

Water Demand Management

- When planning the development of water infrastructure and services, the Member States or river basin organisations shall aim to utilise existing capacities more efficiently as part of the process of augmenting water supply.

- Water Demand Management (WDM) will be pursued by the Member States as a fundamental requirement for integrated planning and management of water resources, particularly in shared watercourses.

Alternative Sources of Water; Member States will promote rainwater harvesting and alternative sources of water such as desalination, reuse of water, recycling, and reclamation. Relevant research in this regard should be promoted as and where appropriate.

Dam Development and Management

- Integrated planning, development, and management of dams will be promoted to optimise the use of the water resources, maximise derived benefits (such as hydropower, tourism, flood control, irrigation, water supply) and take both positive and negative externalities into account.
- SADC shall encourage the participation of all stakeholders in decision-making processes for dam development and, where appropriate, with adequate facilitation and empowerment of vulnerable groups to ensure their effective involvement in decision-making.
- Watercourse States will negotiate on operating rules for dams on shared watercourses to optimise the socio-economic and environmental benefits equitably.

Affected Communities

- Watercourse States shall promote the development and implementation of water infrastructure projects through a participatory process, especially of affected communities.
- Member States will put in place proper legislation to ensure/provide for compensation and resettlement of affected communities so that they will not be worse off as a result of the project.

(g) Regional Water Resources Institutional Framework.

SADC Secretariat

- The SADC Secretariat is responsible for promoting and coordinating the implementation of the Regional Water Policy and Strategy and Protocols for the Water Sector in cooperation with other sectors such as health, energy, agriculture, tourism, and environment.
- The SADC Secretariat is responsible for supporting SWCIs and assessing their compliance with and implementation of the Revised Protocol.
- The SADC Secretariat is accountable to the Member States through the Council of Ministers and shall ensure direct coordination with National Water Departments.

Shared Watercourse Institutions (SWCIs)

- Appropriate SWCIs shall be negotiated in all shared watercourses by agreement between the Watercourse States.
- A Watercourse Commission shall be established on each shared watercourse to advise and coordinate the sustainable development and equitable utilisation of the associated water resources for mutual benefit and integration.
- The development of Watercourse Commissions may be phased to enable gradual development of cooperative arrangements and capacity requirements.
- Watercourse Commissions must efficiently and effectively fulfil the institution's responsibilities considering sustainability.
- Watercourse States are encouraged to jointly plan the development of water resources through Watercourse Commissions and to undertake the development and operation of joint water resources infrastructure on behalf of two or more countries for mutual benefit through Water Authorities or Boards.
- Policy and strategy level decision making within SWCIs should be through consensus between the Watercourse States.
- All SWCIs must enable the SADC Secretariat to fulfil its coordination and guidance responsibilities in terms of the Regional Policy and Strategy and the (Revised) Protocol on Shared Watercourses.
- Stakeholder participation in decision making shall primarily be through the Member States" government representatives, while any SWCI shall ensure stakeholder consultation at a joint project level.
- In the interests of IWRM, SWCIs are encouraged to foster cooperative relationships with non-governmental and civil society groupings within the shared watercourse.

Institutional Arrangements at National Levels

- The Member States must create an enabling institutional environment for the effective management of shared watercourses in line with the Revised Protocol and the Regional Policy and Strategy.
- Member States are encouraged to decentralise the management of water and the associated authority to the lowest appropriate level while maintaining appropriate institutional arrangements for the management of shared watercourses.
- The Member States shall develop and implement appropriate institutional arrangements to enhance the participation of NGOs in the planning and management of water resources at national and community levels.

Monitoring and Evaluation; The SADC Water Sector's achievement of its development goals, objectives, strategies, programmes and institutional performance should be assessed through a coherent, transparent, and independent monitoring and evaluation system.

(h) Stakeholder Participation and Capacity.

Participation and Capacity Development

- Water resources development and management at all levels shall be based on a participatory approach, with effective involvement of all stakeholders.
- All stakeholders shall be empowered to effectively participate in the management of water resources at regional, river basin, national, and community levels, particularly in shared watercourses.
- The Member States and SWCIs shall recognize the positive role played by NGOs in water resources management particularly at the community level and shall facilitate their participation in water development and management activities.

Gender Mainstreaming

- Women are recognised as playing a central role in the provision, management, and safeguarding of water and shall be fully involved in the development and implementation of policies, processes, and activities at all levels.
- All SADC Water Institutions shall implement the principles, goals, and objectives of gender mainstreaming in their administration and implementation.

Capacity Building and Training

- All water institutions in the region at various levels shall make all efforts to develop and share the capacity to carry out their mandate efficiently and effectively.
- IWRM and regional integration shall be promoted in water sector education and training.

Research, Technology Development, and Transfer

- A regional perspective for effective and efficient demand-driven water sector research and technology development shall be adopted in the region.
- Notwithstanding considerations of national sovereignty, Member States shall share appropriate water technology and information as a means of building capacity and integration.

(i) Financing Integrated Water Resources Development and Management in the Region.

Financial Sustainability

- The Member States shall ensure adequate financial resources for national as well as regional projects for water resources development and management.
- For water resources, development, and management at the national and regional levels to be financially sustainable, Member States as well as SWCIs shall strive to recover all costs for managing the resources considering the special requirements of the poor and the vulnerable in society.

Cost Reduction; Member States shall institute planning and operational systems to facilitate cost reduction in the management of water resources.

Public-Private Partnerships

- The SADC Secretariat, SWCIs, and the Member States should actively develop partnerships with funding agencies, non-governmental organisations, and private sector bodies to support the development and management of water resources in the region.
- Partnerships between SWCIs or governments and the private sector should be considered where these could contribute to the efficient management of resources and delivery of services, as well as higher inflow of investment capital to the sector.
- SADC shall continue to actively engage donor agencies to finance water development and management in the region.

Implementation of Regional Water Policy. The Regional Water Policy will be implemented through a Regional Water Strategy. An important vehicle for implementing the policy is the existence of well-functioning River Basin Organisations established particularly on shared watercourses, operating under sound legislation, and systems for planning and stakeholder involvement, and embracing the IWRM principles. For the Regional Water Policy to be implemented at the national level, Member States would need to harmonise their policies with this Regional Water Policy. It is also fundamentally important that there should be closer coordination of the Regional Water Policy with other sectoral policies in the SADC, especially the major water use sectors including, trade, agriculture, energy, and environment. Inter-sectoral coordination at SADC level would be an important building block for integrated water resources development and management which is the basis for sustainable development.

4.3 Water Management in South Africa

We cannot deal with agriculture without linking it to water. Agriculture needs water to thrive. As established in the previous deliverable, water is considered as one of the most important substances on earth, of which without it, plants and animals would cease to exist (World Bank, 2016, Australian Government: Department of Health, 2010). If water is not available or insufficient, agriculture will suffer – land and crops. It is for this reason that we will look into the most recent water management plans in South Africa and how different sectors can manage their water systems to avoid water scarcities. While South Africa is known as a water-scarce country (Brown, 2012), there are ways of achieving sustainable water management systems. Proper management of water systems will enhance and promote drought preparedness plans and systems, as well as flood mitigation and other hazards alike. To this effect, South Africa has developed several policies and strategies which have been repealed over the years. Repealing these policy programmes either means that these development plans were not good enough or on the other hand, they were probably not implemented effectively. Although some of these policies and strategies are well developed with regards to agricultural water, there are challenges to structural implementation within the sector that is specific to matters dealing with agriculture. Often, the programmes are too broad and therefore fail to attend to a specific issue. These are the strategies and policies developed by certain departments at the National level in South Africa.

The Department of Human Settlement, Water and Sanitation (DHSWS) (formerly known as the Department of Water Affairs) developed the following:

- The National Water Act, Act 36 of 1998;
- The National Water Resources Strategy, 2nd Edition;
- The Water for Growth and Development Framework;
- The draft position paper for water allocation reform in South Africa: Towards a framework for water allocation planning.

The Department of Agriculture, Land Reform and Rural Development DALRRD) also developed the following policies and strategies:

- The draft National Agriculture Development Strategy;
- The Integrated Growth and Development Plan for Agriculture, Forestry and Fisheries;
- The draft Irrigation Strategy for South Africa;
- The draft Policy Framework on Irrigation for South Africa – focus on revitalization of irrigation;
- The draft strategy document entitled “National guidelines for integrated management of agricultural water use – an integrated approach to the upliftment and local economic development through the transformation of State support for agricultural water use”.
- Draft policy on climate-smart agriculture
- Draft Integrated National Agricultural Drought Management Plan

Other Government policy documents and programmes include the following:

- Medium Term Strategic Framework;
- The Comprehensive Rural Development Strategy;
- War on Poverty.

Through these government policies and programmes, we shall look into the general significance of existing water management plans and critically analyse their effectiveness, but more specifically, in the agricultural sector. The format of the report entails the title of the policy or strategy and executive summary followed by a critical analysis of the programme. In this case, the discussion of the literature will only focus on South Africa.

The main focus of this chapter is to provide a summary of the legal and policy framework water management in SA. The following contains executive summaries and short descriptions of the different acts and policies that impact or might impact on agricultural water management.

4.3.1 National Water Act, Act No 36 of 1998

The National Water Act (Act 36 of 1998) is regarded as amongst the best water acts in the world. The purpose of the act is:

- To provide for fundamental reform of the law relating to water resources;
- To repeal certain laws; and
- To provide for matters connected therewith.

4.3.1.1 The preamble to the Act

- Recognising that water is a scarce and unevenly distributed national resource which occurs in many different forms which are all part of a unitary, interdependent cycle;
- Recognising that while water is a natural resource that belongs to all people, the discriminatory laws and practices of the past have prevented equal access to water, and use of water resources;
- Acknowledging the National Government's overall responsibility for and authority over the nation's water resources and their use, including the equitable allocation of water for beneficial use, the redistribution of water, and international water matters;
- Recognising that the ultimate aim of water resource management is to achieve the sustainable use of water for the benefit of all users;
- Recognising that the protection of the quality of water resources is necessary to ensure the sustainability of the nation's water resources in the interests of all water users; and
- Recognising the need for the integrated management of all aspects of water resources and, where appropriate, the delegation of management functions to a regional or catchment level to enable everyone to participate.

4.3.1.2 Catchment Management Agencies

The National Water Act (36 of 1998) provides for the progressive establishment of Catchment Management Agencies (CMAs) in the 19 Water Management Areas (WMA) throughout South Africa. CMAs will take over responsibility for managing water resources at catchment management level. They are required to do so in cooperation with locals and as such, consult and seek agreement on water-related matters from the various stakeholders and other interested persons. CMAs are tasked to manage water resources and coordinate functions of other water management institutions within WMAs.

CMAs will be governed by a board and will commence functionality once the governing board has been appointed. The governing board must reflect the interests of all relevant sectors, as well as have appropriate expertise, experience, demographic and gender profile. The role of board members is to represent interests, rather than constituencies or organizations, except in the case of mandated representatives of the three spheres of government. Board members are ultimately responsible and accountable for the CMA's implementation of delegated or assigned functions for integrated water resources management, in accordance with the purpose of the Act.

4.3.1.3 Water User Associations

Although water user associations are water management institutions their primary purpose, unlike catchment management agencies, is not water management. They operate at a restricted localised level and are in effect co-operative associations of individual water users who wish to undertake water-related activities for their mutual benefit. A water user association may exercise management powers and duties only if and to the extent, these have been assigned or delegated to it. The Minister establishes and disestablishes water user associations according to procedures set out in the Chapter. A water user association for a particular purpose would usually be established following a proposal to the Minister by an interested person, but such an association may also be established on the Minister's initiative. The functions of a water user association depend on its approved constitution, which can be expected to conform to a large extent to the model constitution in Schedule 5. This Schedule also makes detailed provisions for the management and operation of water user associations. Although water user associations must operate within the framework of national policy and standards, particularly the national water resource strategy, the Minister may exercise control over them by giving them directives or by temporarily taking over their functions under particular circumstances.

4.3.2 National Water Resources Strategy (NWRS) 2013, Second Edition

The NWRS2 builds on the first NWRS published in 2004. The purpose of the NWRS2 is to ensure that national water resources are protected, used, developed, conserved, managed and controlled efficiently and sustainably towards achieving South Africa's development priorities equitably over the next five to 10 years.

This Strategy responds to priorities set by the Government within the National Development Plan (NDP) and the National Water Act imperatives that support sustainable development. The NWRS2 acknowledges that South Africa is a water-stressed country and is facing several water challenges and concerns, which include security of supply, environmental degradation and resource pollution, and the inefficient use of water.

In the context of the need for growth, equity and protection of water resources, this Strategy identifies three broad objectives: (i) water supports development and the elimination of poverty and inequality; (ii) water contributes to the economy and job creation; and (iii) water is protected, used, developed, conserved, managed and controlled equitably and sustainably. The response to the strategic context and the imperatives set out above are delivered through strategic themes, which discuss in detail the context and challenges, key principles to be sustained, objectives of that particular theme, and then propose strategic actions to achieve the stated objectives.

The most important consideration in all themes discussed is that water is scarce and it requires careful management to enable the provision of basic water services and equitable allocation while meeting the needs of inclusive economic growth without threatening the integrity of aquatic ecosystems. The water resources planning, infrastructure, and development theme indicate that surface water sources are limited in many catchments, as indicated by Reconciliation Strategies, and that infrastructure and the costs of construction and maintenance are prohibitive.

South Africa has to prioritise, considering the mix of options available to supply the huge water demands for equitable allocation for development and economic growth. The country will thus consider other potential sources, which include water re-use, desalination, groundwater utilisation, water conservation, and water demand management measures, rainwater harvesting, recovering water from acid mine drainage, and the import of water-intensive goods.

The NWRS2 continues to state that these measures will augment the available water resources to support the key developmental objectives of the country. One of the objectives is the equitable allocation of water resources.

The Strategy recognises that the manner in which water was allocated in the past was unequal and favoured only the white section of the population in South Africa. The National Development Plan (NDP) and the National Water Act (NWA) collectively inform the intended means to redress past imbalances in the manner in which water was allocated.

The perspective of equity in the Strategy is three dimensional and includes (i) equity in access to water services, (ii) equity in access to water resources, and (iii) equity in access to the benefits from water resource use through economic, social and environmental development and management. The Strategy intends to achieve these objectives through the use of the Water Allocation Reform programmes and mechanisms proposed, which include water set aside specifically for (i) redress, (ii) compulsory licensing, (iii) general authorisations, (iv) development support and (v) partnerships to ensure that water is made available to previously disadvantaged groups.

The water resource protection theme emphasises the need to protect our freshwater ecosystems, which are under threat because of pollution from many sources. The need for the determination and preservation of the ecological reserve and the classification of our river freshwater systems will be a priority. This will assist to determine the nature and the extent of pollution to provide appropriate rehabilitation solutions. The Strategy stresses the need for the value of water to be appreciated and for the attitudes and habits of all citizens to change towards water and to work towards its protection. It is reported that climate change will progressively alter the environment in the future and present new challenges. The effects of climate change include higher temperatures, altered rainfall patterns, and increased occurrence of drought and floods. The Strategy proposes the development of adequate capacity within the sector and the country for monitoring and effective detection and adaptation to protect water and to ensure sustainable water supplies into the future.

Reconciliation Strategies project depletion in the water supplies for some water supply systems in the country. In light of the urgency to protect our water resources and the adverse effects of climate change, the NWRS2 submits that water conservation and water demand management should be one of the top priorities, and measures to reconcile demand and supply in order provide for all our goals of a better life for all through job creation and economic growth.

Research published by the Water Research Commission (WRC) in 2013 indicates that Non-Revenue Water (NRW) for urban supply systems over the past six years was at an average of 36.8%, which is equal to 1 580 million m^3/annum from a total urban consumption of approximately 4 300 million m^3/annum. This research also indicates that in many municipal water supply schemes, the figures are even worse, with NRW in some cases up to 90%. The irrigation sector, which uses up to 60% of the country's water resources, accounts for losses of between 35% and 45%.

While some municipalities and other institutions have begun to address the challenge of water loss, the NWRS2 emphasises that efforts must be intensified with specific targets set to reduce water loss. Water conservation and water demand management measures will have multiple benefits in terms of the postponement of infrastructure augmentation, mitigation against climate change, support to economic growth, and ensuring that adequate water is available for equitable allocation. This requires appropriate institutional arrangements and effective governance.

The management and implementation of water strategies require competent and accountable management. The Strategy outlines the institutional arrangements that will be established or strengthened to coordinate activities related to efficient water resource management within a defined geographical area or catchment boundary. The institutions will be required to perform their duties within a developmental management approach that values the involvement of all stakeholders in defining strategies and plans for management within their defined areas. Smart business approaches will be promoted within the total water value chain management and water footprint.

The NWRS2 is developed within a changing environment and acknowledges that monitoring and collecting relevant data will not only affect the accurate assessments of the status of water resources and the magnitude of water problems but will vastly improve planning and policy formulation processes. National water legislation (Section 68 of the Water Services Act) requires the Minister to maintain a national information system to record and provide data on the development, implementation, and monitoring of national policy. The monitoring should not be done only for the sake of our national concerns, but also in response to our obligation within international river basins. Approximately 60% of the streamflow in rivers is shared through trans-boundary water systems. South Africa should ensure that Integrated Water Resources Management (IWRM) is 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.

A repository of water resource intelligence will facilitate better interpretation and response to the challenges associated with changing hydrological patterns, climate change, groundwater reserves, and innovative responses for reference to the country and neighbouring states with whom we share river basins. The NWRS2 also strongly promotes technology and innovation to contribute to effective and efficient water management solutions that respond to the needs for water security and sustainability for individuals, communities, productive and strategic water use as well as ecosystem services.

The research and innovation conducted by the WRC and other research bodies in areas such as wastewater treatment, water quality and water ecosystems, skills and capacity within the sector, climate change, and water conservation and water demand management approaches have influenced the themes and interventions contained in this Strategy.

The regulation of the sector to ensure that standards are set and maintained and that there is compliance with the regulatory provisions is a key focus of the Strategy. The achievement of all the country and sector goals must be sustained within an environment that protects the integrity of the National Water Act and all other legislation that has an impact on water resource management.

The Strategy promotes the development of a clear regulatory framework for water resources and coordinating regulatory standards and processes with other government departments and regulatory institutions. Compliance monitoring and enforcement are some of the priorities identified by the Strategy and legal, financial and forensic capacity will be developed to ensure effective prosecution for the ultimate protection of South African water resources against any illegal action by institutions or persons in contravention of the required quality and quantity standards.

The NWRS2 emphasises that the achievement of the vision and objective will require support by strong institutions, competent and capacitated personnel with the requisite financial resources to implement interventions.

A National Water Infrastructure Investment Framework for the Strategy, contained in the financial chapter, outlines the financial capital required to effectively implement all key programmes. This is done within the context that government, development institutions, the private sector, and other funders will join hands to provide the necessary funding to support water resource management in the country.

The Strategy also defines the skills required to support effective implementation and outlines the strategy that will be adopted to raise skill levels through collaboration and partnership with various training and skills development institutions, including universities, further education & training (FET) colleges and universities of technology. A collective approach will be sustained within the Water Sector Skills Developments Task Team (WSSDTT), which operates under the auspicious of the Water Sector Leadership Group (WSLG), to identify the skills gap, and to develop relevant educational and training material and competencies at different levels.

The significant challenge that has been identified and is acknowledged within the Strategy is the lack of implementation of clearly defined priorities. The NWRS1 outlined some of the key priorities for the water sector, which include water conservation and water demand management, equitable allocation of water resources, appropriate institutional arrangements, and strengthening regulation, but little progress has been made in these areas. There is a need to change the approach to implementation and ensure that priority programmes are given focus and attention. The NWRS2 Implementation Plan thus proposes that key programmes are prioritised, which include water resource protection, infrastructure planning, operation and maintenance, compliance monitoring and enforcement, and institutional arrangements, and that a collective detailed implementation plan is developed in consultation with sector partners to identify roles and set measures to monitor progress.

4.3.3 Water for Growth and Development Framework

The Department of Water and Sanitation (DWS) has embarked upon a process to develop a framework that set in motion a course of action to ensure that there is sufficient water, in both quantitative and qualitative terms, to support South Africa's path of growth and development. There must be sufficient water for the country to achieve its economic growth targets. At the same time, every person in South Africa must have access to potable water. These two goals must be achieved by not compromising the ecological sustainability of the resource.

The Department has also embarked upon rigorous water assessment studies referred to as Reconciliation Strategies to achieve the reconciliation of supply and demand for both water-scarce areas as well as those experiencing relatively high levels of demand. These strategies aim to ensure the supply of water at adequate levels of assurance within the constraints of affordability and appropriate levels of service to users and protection of current and possible future water resources. Until 2008, six strategies have been undertaken in the major urban centres and in July 2008, the Department commissioned reconciliation strategies for every town in the country that was supposed to be completed by 2011. Most towns could not implement and achieve the goals set by these strategies. The 2015/2016 drought impacts were exacerbated as a result of non-compliance with these strategies.

Water scarcity has been identified in major urban centres. These major urban areas anchor the country's economy, and the Department has reached a point where it knows that it must invest heavily in the diversification of its water mix to avert serious water shortages that could impact adversely on our economy. In addition to the traditional augmentation schemes, there are two major ways that water supplies can be augmented. These are the treatment of effluent and the desalination of seawater for productive use, thereby rendering primary water sources for domestic use. A key principle behind assuring local water supplies is that the water supply should be as close to the end-user as possible, avoiding the unnecessary intensification of costs associated with the transportation of water.

The Department also appreciates that whilst it invests in schemes to assure water supply, it is also required to strengthen its focus on water conservation and water demand management, especially since a very basic cost analysis shows that there is a greater return on investment through water loss control and water use efficiency measures than supply-side interventions. A major source of water loss is aging infrastructure exacerbated by poor operations and maintenance at a municipal level and analysis shows that this state of affairs is a multi-faceted problem including a lack of managerial and technical skills and funding. The Department will strengthen its efforts to support this sector in a bid to reverse this dire situation; it becomes an even more crucial intervention when one factor in the pollution of water sources due to faulty wastewater treatment works.

The notion of water for development alludes to the role of water in the alleviation of poverty and people's constitutional rights to have access to a source of safe and reliable drinking water. The Department is deeply concerned about the persistent backlogs in particular parts of the country although it has achieved the Millennium Development Goal of halving, "by the year 2015... the proportion of people who are unable to reach or to afford safe drinking water" in 2005.

The Department is also very aware of the anomalies in water distribution, where people reside adjacent to water sources and yet have no access to these. The Department will achieve the target of ensuring that every person has access to a safe and reliable supply of drinking water although it has to reconsider how this can be achieved. The Department recommends that the service backlogs, which are predominantly situated in KwaZulu-Natal, Eastern Cape, Limpopo, and the North West province, are prioritised and addressed through a combination of short-term interventions such as rainwater harvesting, exploring further options of supply communities from available sources and the further exploitation of groundwater sources, which may necessitate a policy change. Ultimately, a balance needs to be struck between large and small-scale infrastructure projects.

Where a community can be serviced by existing large-scale infrastructure, this should happen with immediate effect. Where a community cannot be serviced by a large-scale infrastructure project due to the cost of such an intervention (for example, pumping water to mountaintop communities at higher altitudes), then small-scale schemes must be planned and implemented. Where large-scale infrastructure could solve local water scarcity, such as the De Hoop Dam, the necessary planning and resourcing must be undertaken and interim measures introduced to compensate for the long lead-times. The Department should also prioritise schemes in areas with resource development potential that coincide with areas with high service backlogs. It will also support sector plans where water use for growth purposes can simultaneously support water use for development purposes. The Department will seek out and support interventions that support the dual goals of water for growth and development as one goal should not be at the expense of the other.

Water for Growth points to the relationship between water availability and the forms of economic activity that are dependent on the available water supply of varying levels of quality depending on the technologies being used. The Department's position is that it would like to support the country's economic growth targets but this cannot be at the expense of the ecological sustainability of the resource or people's primary needs. It wishes to be responsive to the needs of the different economic sectors and this can only be achieved if these sectors factor in water implications (supply and impact of use) at the outset. Rather than being an add-on or afterthought, the Department sees the need for water to be mainstreamed and placed at the nucleus of all planning decisions, whether these be within the public or private sector. Water can only support economic growth, without compromising primary needs or ecological sustainability if, and only if, its availability is adequately factored in.

Apart from ensuring water availability for growth purposes, the Department is very mindful of water use behaviour that impacts negatively on both water resource quantity and quality. It is currently exploring a potential mix of mechanisms to change this behaviour, which includes (i) regulatory instruments, (ii) market-based instruments, (iii) self-regulation, and (iv) awareness and education, and it will match appropriate mechanisms to mitigate offending behaviour.

The Department is satisfied that it is taking the required course of action to ensure that it has the right kind of information at its disposal to make better informed and calculated decisions and trade-offs with respect to water in support of cross-sectoral planning and development initiatives. The rolling out of the Reconciliation Strategies to all parts of the country will ensure that the Department can anticipate and address future demand without any one area of water need – social, economic, and ecological – being compromised.

4.3.4 Draft Position Paper for Water Allocation Reform in South Africa: Towards a Framework for Water Allocation Planning, 2005

As custodians of the national water resource, the Department of Water Affairs and Forestry must promote the beneficial use of water in the best interests of all South Africans. The allocation of water should, therefore promote equity, address poverty, generate economic growth, and create jobs. The water allocation process must also recognise that redressing the effects of previous discriminatory legislation also provides social stability, which in turn promotes economic growth. Moreover, the water allocation process must allow for the sustainable use of water resources and must promote the efficient and non-wasteful use of water.

On the other hand, allocating water without ensuring that all users can use this water productively will limit these benefits. Consequently, water allocation should not only aim at realising the above goals but must work closely with all spheres of government to promote the productive and responsible use of water. Likewise, water allocations should try to minimise the impacts on existing lawful users of water who are already contributing to our development. As such, water allocations should promote shifts in water use patterns that are equitable but also gradual and carefully considered.

This goes well beyond the Department of Water Affairs and Forestry's mandate and requires the active pursuit of those cooperative governance arrangements required to support the productive use of water. In many instances, this will be a difficult and costly process. Accordingly, approaches to water allocation will initially be rolled out in areas experiencing water stress. However, to address the short-term need for equity in other areas, the approaches will include options that promote the beneficial and equitable use of water in all catchments.

Lastly, water allocations should phase in the change of water use entitlements from Existing Lawful Use to Licences under the National Water Act. To address these challenges, the Department of Water Affairs and Forestry has recently commenced a project, with financial assistance from the United Kingdom's Department for International Development, to review existing and develop alternative approaches to water allocation in South Africa. This review proposes a draft framework to address the issues at hand. It considers the issues raised by a wide range of stakeholders during the extensive public consultation process for the Proposed National Water Resource Strategy and during subsequent processes and serves as the basis for specific public consultation around the development of creative solutions for allocating water fairly and equitably into the future.

4.3.5 South African Agricultural Production Strategy: 2011-2025

For the past 2-3 years, amidst a global threat on the availability and affordability of basic food products, plunging most countries into a threatening food crisis, governments debated and relooked at the role agriculture plays both economically and socially. It is argued and further supported by the ANC's Polokwane resolutions, agriculture have a fundamental role to play in industrialisation and development, and that the role of agricultural production lies in: (i) the qualitative and quantitative production of food to ensure national food security, (ii) the economic growth and development of agriculture, and in (iii) rural economic development.

It is within this context that the South African Agricultural Production Strategy seeks to position primary agriculture production to improve the national food safety and security, and agricultural economic output profitably and sustainably, through a qualitative and quantitative improvement of South Africa's agricultural productivity, productive efficiency, trade and regulatory environment for all commodity groups. Given the scope and nature of agriculture and by achieving the aforementioned, rural economic growth and development can be fuelled to increase rural employment, alleviate the plight of the poor, who mostly reside in rural areas and stimulate off-farm industrial development. Investment in non-farm economic activities will also be stimulated due to the primary sector's strong backward and forward linkages.

4.3.6 Integrated Growth and Development Plan

Despite the small direct share of the total Gross Domestic Product (GDP), agriculture, forestry, and fisheries are vital to South Africa and its economy. These sectors furnish some of the most important material needs of South Africans, such as food and fibre, while providing large numbers of jobs and self-employment opportunities. However, the sectors are not fulfilling their potential, particularly in terms of job creation. What constrains these sectors from meeting their potential? Indeed, what accounts for the fact that employment continues to decline, and what can be done about it?

The Integrated Growth and Development Plan (IGDP) has been developed to provide a long-term strategy for the growth and development of South Africa's agriculture, forestry and fisheries sectors, to enable them to address key national priorities and outcomes. The purpose is to develop a common vision encompassing all three sectors and to develop an integrated implementation framework that allows common issues to be addressed in unison, and specific issues to be addressed in separate policies and strategies. The IGDP is furthermore a response of the Minister to the national goals outlined in the Medium Term Strategic Framework (MTSF) document, adopted in July 2009 and stated through the 12 outcomes identified during the January 2010 Lekgotla.

The last half-century has seen substantive shifts in the structure of South Africa's agricultural sector. Farm size has grown, farm numbers have declined and production has increasingly emphasised higher-value commodities, notably a range of horticultural crops. The agricultural sectors' share of GDP has been steadily declining for many decades. From 1965 to 2009, agriculture's share of total GDP declined from over 9% to around 3%. Currently, primary agriculture contributes about 3% to South Africa's gross domestic product (GDP) and about 7% to formal employment. However, there are strong linkages into the economy, so that the agro-industrial sector contributes about 12% of GDP. Given these realities, it is argued within the context of the IGDP that the role of the agricultural sector lies in ensuring national and household-level food security; ensuring social and economic growth and development through job creation; and contributing to rural socio-economic development. The Strategic Plan for South African Agriculture (also known as the 'Sector Plan') was published in 2001 and it presented a shared perspective between the government and industry on strategic issues in the sector. Strategic goals identified in this plan included enhanced access and participation; competitiveness and profitability; and sustainable resource management. A review of the Strategic Plan completed in 2008, identified several ongoing concerns, namely the slow pace of implementation, limited implementation capacity within government and limited coverage, and inadequate funding of some critical programmes. Other factors identified by the review as contributing to the lack of impact of the Strategic Plan included weak implementation capacity and the absence of a comprehensive implementation plan.

Forestry plays an important role in contributing to local and national economic output and social well-being, through the production of timber and non-timber forestry resources from plantation forests, natural forests, and woodlands. Managing forest resources requires flexibility to accommodate the change. This may include pressure to address community needs, incorporation of conservation practices, water catchment management principles, and new commercial and non-commercial opportunities for woodlands, forests, and plantation use. The National Forestry Action Programme (NFAP) was published in 1997, with the expressed purpose of mobilising and organising national and international resources and catalysing action to implement programmes and plans in a coordinated manner. It set out the most important work to be done in the first three years of implementation, identified specific goals for each issue, and provided a framework for implementing forestry policy as set out in the White Paper, i.e. to promote a thriving, equitable and sustainable forestry sector. A review of the NFAP in 2003, led to the development of the National Forestry Programme (NFP), using a globally adopted framework for national forestry policy development, planning, and implementation. It was designed to address forestry issues within the context of sustainable development, to link all government and non-government forestry plans and strategies, and to maximise the contribution of forestry to poverty reduction. The process of developing a long-term strategy for the forestry sector was initiated in 2007. After two years of consultation and deliberation between government and industry, the Forestry 2030 Roadmap was finalised. Among other things, this roadmap seeks to guide the forestry sector to realise its full potential to create jobs and wealth, as well as to promote biological diversity.

The fisheries sector has probably undergone the greatest changes in recent years through the re-organisation of fishing rights. It, however, remains a challenge to balance the high demand for access to marine living resources as a means of household income and subsistence, with the need to ensure the environmental sustainability of resources. Being the meeting place of land and sea, the coast is a distinctive, complex, and interconnected natural system with finite and vulnerable resources that are impacted by perturbations such as pollution, inappropriate development, and environmental degradation. It provides substantial opportunities for economic and social development, but care must be taken such that these can be enjoyed on a sustainable basis. Although detailed policies are addressing the allocation and management of long-term commercial fishing rights, as well as the management, methodologies, and procedures to be applied in specific subsectors, there is no encompassing plan for fisheries. The expectation is therefore that the IGDP will address this gap by providing strategic direction to the fisheries subsector.

The IGDP furthermore speaks to strategic plans within the national government, including the Green Paper on Land Reform, the Comprehensive Rural Development Plan of the Department of Rural Development and Land Reform, the New Growth Path of the Economic Development Department and the National Development Plan (Vision 2030) of the National Planning Commission within the Presidency. At a strategic level, the IGDP for Agriculture, Forestry and Fisheries thus seek to be consistent with emerging policy directions from elsewhere in government, while at a practical level, when devising actual interventions based on the IGDP, the DAFF will continuously strive to align itself with other departments' activities through intergovernmental planning systems. Ultimately, the IGDP seeks to identify what all role players must do to achieve the common vision of "equitable, productive, competitive and sustainable agriculture, forestry and fisheries sectors, growing to the benefit of all South Africans".

4.3.7 Draft Irrigation Strategy for South Africa: 2015

The Irrigation Strategy identifies objectives, priorities, allocates responsibilities and ensures coordinated efforts and estimates realistic funding, as well as sets out the principles for initiatives that are being undertaken to revitalize and expand irrigation schemes in the country.

The Irrigation Strategy is a response to the call for the sector to increase its contribution to agricultural production thus ensuring food security, poverty alleviation, and job creation. This strategy includes directives from recent policy changes and provides directions for institutional reform and guidelines on public investment in irrigation initiatives.

This Strategy aims to coordinate, align, and avail all programmes that target the support and development of irrigation farmers towards achieving optimum utilisation of resources for sustained food security and economic returns. The focus is on subsistence farmers to address the inequities resulting from past policies, but this has several important dimensions, which are explored in this strategy.

Most importantly the Strategy recognises that the Department of Agriculture, Forestry and Fisheries' (DAFFs) policy initiatives have been aimed at achieving the objectives of Outcome 4, Outcome 7 and Outcome 10 of the Medium Term Strategic Framework (MTSF) relating to job creation, food security, and rural development. Furthermore, the Strategy provides a link between policy and practical implementation in a structured way. It ensures coordination by the inclusion of important areas such as Strategic Infrastructure Project (SIP) 3, 4, 5, and 11.

Irrigation has the potential to increase food production thus contributing to the Agricultural Policy Action Plan (APAP) which is guided by the 2030 Vision statement of the National Development Plan (NDP) and the New Growth Path (NGP). The plan is based on the model of the Industrial Policy Action Plan (IPAP) and seeks to translate the high-level responses offered in the Integrated Growth Development Plan (IGDP), into tangible, concrete steps.

4.3.8 Draft Policy Framework on Irrigation for South Africa: Focus on Revitalisation of Irrigation

In South Africa, approximately 1,5 million hectares (ha) are under irrigation (i.e.1,5% of the total agricultural land) of which about 50 000 ha are smallholder irrigation schemes (i.e. 3.3% of the total irrigated area). Unfortunately, a large number of smallholder irrigation schemes have collapsed while the rest are suffering reduced efficiency due to various reasons. However, due to the importance of these schemes, their effective revitalization is extremely important.

Informed by the Election Manifesto, Government has adopted the Medium Term Strategic Framework (MTSF) for the mandate period 2009-2014 in July 2009. The MTSF translated the Election Manifesto into a Government strategic framework and identified the 10 Strategic Priorities that serve as the basis for determining the Government Implementation Plans for the period to 2014. The Department of Agriculture, Forestry, and Fisheries (DAFF) find its role in addressing issues relating to the following outcomes on the MTSF document:

- Outcome 4: "Decent Employment Through Inclusive Economic Growth"
- Outcome 7: "Vibrant, Equitable, Sustainable Rural Communities Contributing Towards Food Security for All"
- Outcome10: "Protect and Enhance our Environmental Assets and Natural Resources"

The revitalisation of smallholder irrigation schemes comprises an integral part of the land and agrarian reform and food security objective of DAFF, thus it must link up with programmes and initiatives such as the Comprehensive Rural Development Strategy, the War on Poverty and other such initiatives. Initially, DAFF set a target to revitalise 2% of small-scale government irrigation schemes that amount 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 between 2009-2014. Recently it was felt that this initiative was not addressing the huge undertaking that was required and in line with the Presidential State of the Nation Address of 2012, it was felt that more effort and resources would be required to bring the smallholder irrigation schemes to full production.

4.3.9 Medium Term Strategic Framework (MTSF): 2014-2019

South Africa has begun a new phase of its democratic transition with the adoption of the National Development Plan (NDP). The electoral mandate of the fifth democratic government is to deepen transformation and implement the NDP. It is to accelerate growth, create decent work, and promote investment in a competitive economy. In giving effect to this mandate, we continue to be guided by our Constitutional commitment to “improve the quality of life of all citizens and free the potential of each person”.

Over the last 20 years, the first phase of the democratic transition, the foundations have been laid for a non-racial, non-sexist, united and prosperous South Africa, and for a society based on fundamental human rights, equality, and unity in diversity. People’s dignity has been restored. Non-racial majority rule based on one-person, one-vote has brought about government based on the will of the people.

At the end of the last administration (2009-2014), the Presidency published a *Twenty Year Review*, outlining progress made since 1994 and identifying the challenges that still need to be overcome. Today, South Africa is a better place in which to live than it was in 1994. Political and social rights are protected, and the lives of millions of South Africans have improved, through new laws, better public services, expansion of economic opportunities and improved living conditions.

However, the challenges still facing South Africa are immense. As the Twenty Year Review and the National Planning Commission’s 2011 Diagnostic Report highlight – poverty, inequality, and unemployment continue to negatively affect the lives of many people. Too few people have work, investment is too slow and education lags set requirements. The weak state of the economy impedes our efforts to reach our development goals.

The second phase of our democratic transition calls for bold and decisive steps to place the economy on a qualitatively different path that eliminates poverty, creates jobs and sustainable livelihoods, and substantially reduces inequality. This requires radical economic transformation and a sustained focus on addressing the uneven quality of service delivery.

4.3.10 Comprehensive Rural Development Strategy

The former Department of Rural Development and Land Reform has been given the mandate by the President of South Africa to develop and implement a Comprehensive Rural Development Programme (CRDP) throughout the country. To achieve this mandate the Department embarked on developing a fresh approach to rural development.

The programme is being focused on enabling rural people to take control of their destiny, with the support from government, and thereby dealing effectively with rural poverty through the optimal use and management of natural resources. This will be achieved through a coordinated and integrated broad-based agrarian transformation as well as the strategic investment in economic and social infrastructure that will benefit the entire rural communities. The programme will be successful when it becomes apparent that “sustainable and vibrant rural communities” are developing throughout South Africa.

A three-pronged strategy to ensure that the Department achieves its objective are:

- ***Agrarian Transformation*** includes increasing all types of agricultural production; optimal and sustainable use of natural resources; the use of appropriate technologies; food security; and improving the quality of life for each rural household.
- ***Rural Development*** includes improving economic and social infrastructure.
- ***Land Reform*** including restitution, redistribution, land tenure reform.

In light of the above, the department has to date initiated the CRDP approach in four provinces namely Limpopo, Northern Cape, Free State, Eastern Cape, and Mpumalanga provinces. The programme is due to be further rolled out in KwaZulu-Natal, North West, and Western Cape.

4.3.11 War on Poverty

Poverty is understood as a deficiency in an individual’s socioeconomic capabilities. Its manifestations include factors such as (i) income, (ii) access to basic services, (iii) access to assets, (iv) information, (v) social networks, or social capital. This broad approach to poverty allows for engagement with the reality of poverty and the combination of things that should be done to deal with it.

The overall objective of the poverty alleviation strategy is to eradicate poverty. At the centre of the fight against poverty is the ***creation of economic opportunities and enabling or empowering communities and individuals to access these opportunities***. Providing a safety net in the form of social assistance and the provision of basic services continues to be critical, but we also seek to empower individuals and communities to support themselves. The strategy builds on the work of the years since the dawn of democracy. It also seeks to change the trajectory of anti-poverty initiatives. As we go forward we need to strengthen our resolve to ***reduce*** the incidence of poverty as well as to ***prevent*** the reproduction of poverty within households and communities.

Central to this resolve is the ending of intergenerational poverty through improving the economic situation of households. Critical elements to this end would include:

- maintaining overall economic growth, including through substantial investment in economic infrastructure as well as appropriate fiscal and monetary policies
- targeting government support at measures that will create economic opportunities on a mass scale for the historically marginalised, including through land reform and agrarian development; support for growth in sustainable, labour-intensive formal activities, and a substantial expansion in public employment schemes, and
- instituting measures to enhance the incomes in cash and kind earned from informal activities, the bulk of which take place in agriculture, retail and services.,

To this effect ***human resource development***, in particular education and skills development, play a significant role in preventing the intergenerational transmission of poverty. An economy that creates jobs including self-employment opportunities and the ability of a country to improve the educational outcomes, skills, and aspirations of children and young people are the most important factors in breaking generational cycle poverty.

A focus on ***rural development and agricultural support for families*** is also at the centre of the anti-poverty strategy. About half of poor people reside in rural areas, where economic opportunities are limited. Reinforced interventions are required to transform the situation of the people in rural areas, in line with the National Spatial Development Perspective.

Furthermore, the strategy aims to ***reinforce partnerships*** at all levels among government departments and agencies, business, organised labour, and other civil society and non-governmental organisations. Within government, over and above the current initiatives, it is about doing some things, differently as well as emphasising implementation and coordination. The current initiatives to combat poverty rely heavily on government-sponsored and administered programmes and projects. Whereas the government has a central role to play, it should also focus on facilitating the involvement of other institutions, providing political leadership, and using its resources and other capacities to mobilise all the role players in the desired direction. Indeed this is the "government's vision for the developmental state, one where public institutions together with other economic actors work in a coordinated way to address poverty and underdevelopment and promote higher and more widely shared, economic growth." (Policy brief, Competition Commission)

Critical interventions that should receive the highest level of attention from the government in addressing poverty (while improving all the others) are:

- economic interventions to expand opportunities for employment and self-employment in particular including improvement of the state's capacity to lead in job-creating industrial development.
- provision of quality education and skills and health care especially to poor communities; and
- promotion of access to assets including social capital to the poor and reduction of vulnerability

- promoting social cohesion

In line with the multidimensional nature of poverty, the anti-poverty framework is anchored on the nine pillars listed below.

- Creation of economic opportunities – aimed at ensuring that the economy generates opportunities for poor households to earn improved incomes through jobs or self-employment.
- Investment in human capital – providing health care, education, and training needed to engage with the economy and in political processes.
- Income security – providing safety nets for the most vulnerable, primarily through social grants. This to ensure that vulnerability associated with disability, age and illness do not plunge poor households into destitution.
- Basic services and other non-financial transfers – what has been termed a social wage, consisting of services such as subsidised housing, and expanded access to water, electricity, refuse removal and sanitation; as well as a raft of minimum free basic services for vulnerable sectors of the population. The inability to pay for basic services should not prevent the poor from accessing these services altogether.
- Improving healthcare – ensuring that poor children grow up healthy, providing quality and efficient preventative and curative care, and ensuring that illness or disability do not plunge poor households into destitution.
- Access to assets – particularly housing, land, and capital, including public infrastructure, both to improve economic and social security and to provide the basis for economic engagement in the longer run.
- Social inclusion and social capital initiatives – combining programmes to ensure a more inclusive and integrated society, based on the development of more integrated structures and engagements across class and race, as well as community solidarity in communities and society as a whole. The focus is also on strengthening social capital, especially for the poor to expand their networks and ensure they have access to information.
- Environmental sustainability – requiring strategies and programmes that help link increasing economic opportunities for the poor to the protection and rehabilitation of ecosystems, reversing environmental degradation, and promoting eco-tourism.
- Good governance – direct intervention in the provision of information, facilitating participatory, pro-poor policies, and sound macroeconomic management. This is to ensure proper use of public funds, encouraging shared economic growth, promoting effective and efficient delivery of public services, and consolidating the rule of law.

4.3.11.1 Targeting the poor

Whereas poverty may affect a wide range of people in different circumstances, the most vulnerable groups are

- ***Older people*** – despite the broad coverage and reach of state old pension, income at old age is still limited. In many households, the state old pension support is eroded by the dependency of unemployed able-bodied members of the households. Inadequate income and declining health status mean they are predisposed to poverty.
- ***The unemployed,*** especially the youth who comprise a significant majority of the unemployed and have low levels of education – the major cause of poverty for the majority is lack of earned income due to unemployment.

- ***Children***, especially those who grow up in poor families. Social assistance efforts have to be reinforced, and we have to ensure that children access education to enable them to escape the poverty trap.
- ***Women*** – especially single parents and particularly black women are vulnerable to poverty because they both face persistent gender discrimination and generally have extensive caregiving responsibilities. Critical support areas include expansion of ECD, provision of basic household infrastructure such as running water and electricity at an affordable cost, and improved access to training and economic opportunities.
- ***People with disability*** – disability is associated with difficulties of physical access, high living costs, low incomes, and problems of social exclusion. It has major effects on employability. Social assistance is essential to provide a safety net for them.
- ***People living in poor areas*** – poverty still reflects apartheid settlement patterns. Most of the poor households are found in the former Bantustan regions, informal settlements, and historically black townships. Therefore improving economic opportunities in these areas is critical.

4.3.11.2 Community empowerment paradigm

Poverty eradication initiatives should have, as a central tenet the empowerment of communities. Processes such as community/ward-based planning linked to municipal IDPs have great potential in giving communities greater control and ensuring a balance in the expectations for change between the government's role as 'deliverer' and communities as the driver. These processes can be unleashed with better support and resourcing focusing on ward-based implementation ideally with growing community control over resource-allocation for anti-poverty efforts.

4.3.11.3 Institutionalising solidarity

The effective implementation of anti-poverty programmes require stronger institutions in the State, the private sector and civil society, and in poor communities themselves.

…in the State

We need to ensure that anti-poverty programmes are a top priority for all departments – social, economic, and otherwise – and for all spheres of government. To that end, The Presidency should be made responsible for championing anti-poverty efforts, including:

- co-ordinating and monitoring efforts by economic, social, and other departments as well as all spheres of government
- working with civil society and the private sector to strengthen, monitor, and supplement anti-poverty programmes.

…in the private sector and civil society

The struggle against poverty requires involvement, not only of the State but also of business, NGOs, students, and others. This support can take several forms, such as mentoring new businesses or community organisations, volunteering in poor communities, assisting organisations representing the poor, or providing funds.

The government will develop an explicit strategy for working with existing structures to prioritise the elimination of poverty, encourage concrete commitments outside of the State, and get feedback on programmes. This strategy should include proposals around the National Economic Development and Labour Council, the Presidential consultative groups, and other structures in business, labour, and civil society. The government will consider establishing a high-level council comprising major stakeholders to advise on and help monitor and implement the Anti-Poverty Strategy.

…community mobilization

Effective community mobilisation requires the emergence of competent and inclusive community groups that can:

- work with the government to identify viable and desirable interventions
- drive implementation in their communities
- ensure that the interventions/programmes benefit the poorest households.

…one-stop delivery

The government is developing a comprehensive data system that will permit the identification of household needs in terms of infrastructure, income support, employment, and basic services. This provides the basis for the establishment of structures that can identify poor households, including ensuring that, where children live without adults, they can access available programmes and monitor the progress of households out of poverty. In addition, the Government will develop easily accessible information material on government services and how to access them.

4.4 Critical Analysis of the Policies and Strategies

Eleven policies and strategies are listed above and it has been observed that there are some similarities between these policies and strategies, especially, between those developed per group. That is, the policies and strategies structured by the Department of Water and Sanitation follow a uniformed thread, likewise, those developed by DAFF also have a unique pattern. There are linkages, as well as, differences, discrepancies, peculiarities, and even irregularities between these different national programmes. A critical analysis of these policies and strategies follows. Most of these programmes have a top-down approach where the government makes policies for the people without knowing what their real issues are. This practice is not acceptable. In addition, much has been talked about on water but not water and agriculture, which requires the bulk of water at 60%.

The National Water Act is considered as the supreme Water law of South Africa. It is well enacted because it mainly targets water distribution and encourages user participation. But it falls short by not identifying the users and their roles. This Act was the result of other policies or strategies being repealed. It was passed in 1998 after repealing the Water Act 54 0f 1956. The latter was considered not to reflect the true needs of the society. Moreover, it adopted several Western approaches, which were not suitable for South Africa due to varying hydrology, weather, and climate conditions (Singh, 1999). As a foremost earner of foreign exchange, agriculture is one of the major, if not the most significant, key drivers of growth in the economy's Gross Domestic Profit (GDP) accounting for backward and forward linkages with other sectors (Agri-SA, 2017). It is interesting, therefore, to see that the allegedly most important industry in the country is not acknowledged in the preamble of the Act. While water is an important commodity for all sectors, there should be a provision in the preamble of this Act recognizing the fact that agricultural management is dependent on water and might require more water than other sectors because it caters for the economy of the country to a large extent.

However, the Act acknowledges that as much as everyone is entitled to water rights and as much as they would like to evenly or equally distribute water to everyone, it might not be possible because, in South Africa, water is a scarce resource. For this reason, the Government holds this authority of water allocation and distribution. Water management is necessary for sustainable development. Therefore, water use regulations should be strict on the users at all times. For instance, using 2 instead of 1 bucket of water to shower in summer, just because it is hot, should incur penalties on the user's bill. This will keep users in check. Furthermore, the Act recognizes and encourages public participation in water management affairs. This participation could be in the form of delegates per area. This will allow the real issues of the people to be heard concerning their farms and agriculture in general. This would curb the top-down approach.

Catchment Management Agencies (CMAs) and Water Users Associations (WUAs) are the key organizations to decentralize water use and ensure water management responsibility to the end-users as both described in the National Water Act. These organizations are the cornerstone of decentralization of water use management. The nine (9) existing CMAs are shown in Figure 4.1.

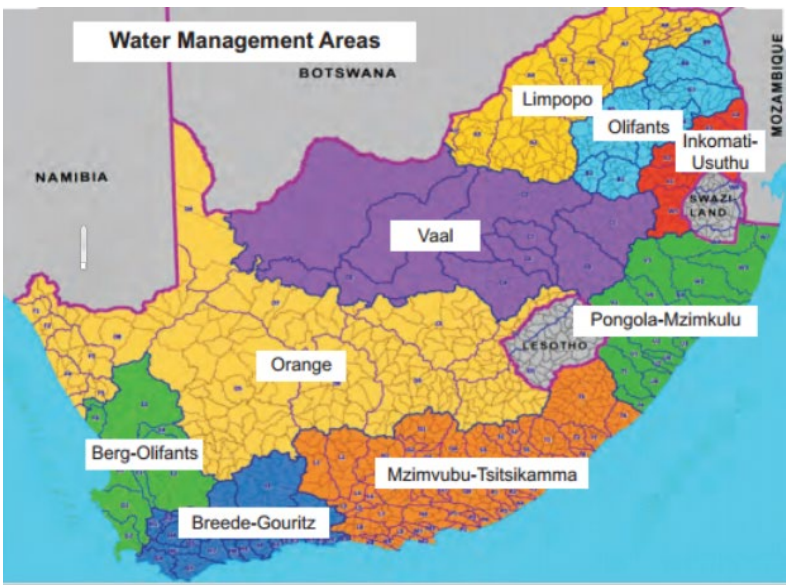

Figure 4.1: CMAs in South Africa
Source: DWA, 2017

However, implementation of these were slow and inadequate with only two (2) CMAs operational namely Breede-Gouritz and Inkomati-Usutu. The number of CMAs were also reduced from nineteen (19) to nine (9) during 2012 as a result of the slow implementation of the CMA structure. The remaining CMAs are Limpopo, Olifants (Mpumalanga Province), Pongola-Umzimkulu, Vaal, Orange, Mzimvubu-Tsitsikamma, and Berg-Olifants (Western Cape). The seven (7) CMAs are called proto-CMAs since they are in the process of establishment.

Currently, there are strong thoughts driven by political agendas within the Department of Water and Sanitation (DWS) to have only one (1) CMA for the whole country meaning that water management will be centralized, which conflicts with the Water Act. This might have serious implications for agricultural water management in South Africa since the DWS simply does not have the capacity to manage water use in the country. Concurrently, Water User Associations (WUAs) remain a problem in, especially, the communal and subsistence regions. Water users in those regions are mostly the poor communal farmers who do not have the capacity and funding for sustenance in their regions.

The second edition of the National Water Resources Strategy (NWRS2) in 2013 again repealed the 2004 pilot NWRS. This strategy was also developed by the Department of Water and Sanitation. However, both the first and second editions are similar, with the exception that the recent edition is more politically inclined with little or no support to the facts of the situation. For instance, the Minister is required to *"maintain a national information system to record and provide data on the development of national policy",* but this is not the case as the subject data is now mostly in the hands of the private sector.

NWRS2 seems to have been put together in a short time just to have the document published. The purpose of this strategy seems unrealistic because it has already been four years into the programme's existence but water resources are still not equitable nationwide as purported by this strategy. This is nobody's fault per se, but when goals are made, they should be attainable and real. There are many factors, which could hinder the reality of equitable water ranging from adverse weather conditions to little or no rainfall in the country. For this reason, this resource cannot be fully controlled because of the unpredictable climate change, which is progressively altering the environment and presenting new challenges. This in turn affects agriculture as a major contributor to the economy.

Similar to the Act, this strategy, too, acknowledges that South Africa is a water-stressed country. However, there is no mention of ways of dealing with this issue identified, rather, it highlights more problems of environmental degradation and resource pollution as well as the inefficient use of water. Just like the Act, NWRS2 also advocates for equitable control of water, which again, does not seem realistic because different sectors do not require the same amounts of water to function. Some sectors require more water than others. In reasoning, within the agricultural industry alone, there are different departments, such as, the production department and others, which require a lot of water in their capacity. Therefore, agriculture cannot be allocated the same water management as other water management programmes. Water must be prioritised within a strategic framework. In this way, farmers may get more water support from the government, and agriculture will be at the forefront of water needs. Among the potential sources of water management suggested for NWRS2 are (i) re-use, (ii) desalination, (iii) groundwater utilization, (iv) water conservation and (v) water demand management measures, (vi) rainwater harvesting, (vii) recovering water from acid mine drainage, and (viii) the import of water-intensive goods.

These water sources need to be expanded into our proposed framework through the mooted “new Paradigm of Abundance” (under recommendation) in hopes of restoring investor confidence thereby promoting poverty eradication. Some of these water management sources, such as desalination, have been applied gradually but only often as a result of an emergency, which almost always ends up in failure. It is therefore paramount to have a strategic framework that promotes the uses of these water management sources. Similarly, groundwater utilization is being elevated at the risk of collapse if there is no aquifer storage and recovery. For this reason, desalination also needs to be linked to Managed Aquifer Recharge (MAR) or Aquifer Storage and Recovery (ASR) which are vital for agriculture or else, eventually lose their water to human consumption in the cities. Seemingly, water from acid mine drainage as a water management source has never been implemented. The water crisis in the Western Cape (2017) and emergency plans for desalination and alternative water sources is an example of poor planning and destined to fail or over-expensive.

The NWRS2 suggests aims to undo the past injustices of the apartheid era where water allocation favoured only the white section of the country. It proposes equity in all water use. This should be more specific regarding specific departments such as agriculture. Even today, most of the commercial farmers are white, which means that there could still be an upper hand of the white farmers to access water resources over the black farmers. However, talks of race and water seem unnecessary because it is not about that anymore but more about building and feeding the nation with adequate food and water supplies. Aside from this, there is a need to protect freshwater ecosystems against pollution from many sources because water pollution only depletes the resource base and increase water scarcity. Therefore, the strategy rightly proposes the need for monitoring and effective detection and adaptation of water protection programmes. However, this should be a specific and subsequent reality.

There is much mention of water conservation and protection but it is not stated in terms of what or in relation to what. Therefore, it is too broad and the talk of water management, though important, is too broad and general. Though the Water Research Commission (WRC) specifically indicated in a research in 2013, that the Non-Revenue Water (NRW) for urban supply systems for a few years was at a low, this needs to be made a priority for positive change. This strategy should be able to pinpoint sectors, such as agriculture, and address water issues there. The need for water in one sector differs from the other, so also the measures and approaches required. It is stated that the irrigation industry uses up to 60% of the country’s water resources and accounts for losses of between 35% and 45%. These are the water management issues that should be addressed with stricter laws and policies because the country is a water-scarce. It is suggested that for water conservation to be effective, there must be appropriate institutional arrangement and effective governance. Successful water management and implementation requires the competence and accountability of handling bodies. However, although the South African environment may differ from other international countries, they should ensure to comply with international water policies, involving agricultural water management, while being compliant to their water management laws as well.

According to this strategy, there is a need to change the approach of implementation of water management priorities. The problem is not making the laws but enforcing it and putting it into practice. The laws are there but nothing is changing. These policies do not need to be too broad. This policy seems abstract of core issues such as water management and agriculture. Based on the water stream reticulation system, the Paradigm of Abundance is specific to resolving water issues as opposed to a Paradigm of Scarcity, which seeks to reduce the use of a dwindling water resource. In similar terms, the South African Agricultural Production Strategy 2011-2025, which was developed by the Department of Agriculture, Forestry, and Fisheries, also isolates agriculture from water. It does not link the two together. The former policy talks of water void of agriculture and the latter seldom mention water but focus on talks of agriculture. According to this strategy, in South Africa, the agricultural production environment is dualistic comprising of (i) commercial agriculture, (ii) smallholder agriculture, and (iii) subsistent agriculture.

Commercial agriculture ensures efficient production from about 40,000 farming units, which covers an estimated production area of 82 million hectares. Commercial farming is responsible for over 99% of South Africa’s formal marketed agricultural input making it more sustainable in the environment. Smallholder agriculture, on the other hand, comprises 1.3 million farming households and farm approximately 14 million hectares of agricultural land. Smallholder agricultural farming is characterized by poor productive land, little or no infrastructural support, and scare remote water sources. These drawbacks lead to the low level of production efficiency exacerbated by insufficient farm management skills such as natural resource management and poor service such as financial and technical support. Subsistent agriculture currently lacks sufficient data but here, farmers practice agriculture mainly for household consumption. Unfortunately, recent studies show that these farmers rely on market purchases for about 90% of their food supplies. This sector is mostly livestock orientated or crop production is inefficient partly due to the fact that there is insufficient water to grow their crops.

If assisted, both smallholder and subsistent farmers can reduce vulnerability to food insecurity of rural and urban households by mitigating high food costs and inflation. The problem faced by many farmers is that agricultural strategies and policies were devised to quash inequalities in the sector through land and labour market reforms but this not the case. Although farmers decide to plant and export without State support, they face even more challenges of domestic and international prices, profitability of production, as well as, harsh and unpredictable climatic conditions. They are poorly supported as adequate information does not get to them. This strategy aims at increasing entry levels into commercial agriculture, which all farmers can eventually qualify for. The objective of this strategy is to improve food security and legislative framework to mitigate against high food prices globally and market manipulation. Strategic interventions will be through Acts and programmes – The Farmers Development Programme/Act and The Food Security Programme/Act. Again, no mention of water and agriculture. Most of these policies remain in the books and not carried out which is where the bigger problem lies.

With regards to rainfall, the world average rainfall is 860 mm but South Africa's mean annual rainfall is less than 500 mm per annum. 35% of the country receives more than 500 mm, which is considered as the minimum rainfall required for crop production. The remaining 65% includes a quarter of the country which receives less than 200 mm rain per annum. Only 3% of the country receives rain throughout the year (DEAT, 2006). It has been acknowledged that one of the key challenges faced by South African agriculture today includes lack of accessibility to natural resources, that is, water and productive land for smallholder and subsistent farmers which leads to low production outputs, asset loss, and land degradation. Some of the challenges of water availability are: (i) uneven spatial distribution and seasonality of rainfall (43% of the rain falls on 13% of the land) (ii) relatively low stream flow in rivers most of the time, which limits the proportion of streamflow that can be relied upon for use, and (iii) location of major urban and industrial developments remote from the country's larger watercourses, which necessitates large-scale transfers of water across catchments.

About 70% of South Africa's gross domestic product is supported by water from the Limpopo, Inkomati, Pongola, and Orange Rivers, which collectively drain two-thirds of the land area. The total natural runoff flowing along our rivers towards the sea amounts to some 50 billion cubic metres per year (on average), of which nearly 10% originates from Lesotho. Of the total runoff, a yield of some 14 billion cubic metres is available for use through dams, basin transfers, and other water resource developments throughout the country. This is currently just adequate to meet the country's total annual water requirements during normal years. The problem is that South Africa faces a water crisis during dry years when demand for water is higher than during normal and wet years. Climate change predictions do not necessarily predict less rain per annum but higher temperatures with higher evapotranspiration levels which have the same influence as dry years. That together with rapid population growth, urbanization and land and water degradation will exacerbate the negative impacts of dry periods.

The main goals of the Water for growth and Development Framework are (i) sufficient water for the country to achieve its economic growth targets, and (ii) every person in South Africa must have access to potable water.

The link between agriculture and water is echoed in the first goal because this sector is known to contribute to the economy. The Reconciliation Strategies of water assessment was also introduced by the Department of Water and Sanitation to ensure adequate water supplies within affordable and appropriate levels of service to users while protecting current and future water resources. However, this does not reflect our present reality as it is stated that most towns could not even implement and achieve the goals set by these strategies. This speaks volumes to the current crisis in the water sector as to why this is allowed to happen. It highlights the deep state of weakened institutions and their lack of control over things. The Reconciliation Strategies also projected depletion in the water supplies and failed generally as evidently seen amongst many localized water cries due to these strategies being neglected by the decision-making elites. The government is still trying to consider how this anomaly can be achieved.

Just like the previous policies, this Framework also advocates for desalination of seawater for domestic use and other uses which could include agricultural use as well as curbing water pollution issues to manage and conserve water systems. In some cases, people live close to water sources but they have no access to these. This translates to the fact that a farmer may be close to a water source but lacks the skills and technological tools to tap this water into his agricultural business. Again, this policy emphasizes the importance of economic growth with the use of water but these activities should not be detrimental to ecological sustainability. Water should be central to both the public and private sector, it does not necessarily have to be equitable. Unfortunately, in the Western Cape, serious water shortages are already impacting adversely on the economy and major capital flight is imminent.

The Draft Position Paper for Water Allocation Reform in South Africa of 2005 talks about the allocation of water in terms of promoting equity, addressing poverty, generating economic growth, and creating jobs. Indeed, water allocation must promote sustainable use of its resources, which are efficient and non-wasteful. However, allocating water does not bring solutions on its own but it is the manner or approach used that makes the difference. For example, a smallholder farmer will need water for his crops but if he lacks the necessary farming tools, he may not succeed. But if the required tools are subsidized and he is provided with an adequate water source, there will be a difference. This is the type of activity that the South African Irrigation Strategy strives to promote. Water allocations, therefore, should be carefully considered. For this reason, the Department of Water and Sanitation began a project, with financial aid from the United Kingdom’s Department of International Development, to review existing and come up with new approaches to water allocation in South Africa. This should be done in such a way that ensures that all users – public and private benefit from it.

The Integrated Growth and Development Plan (IGDP) for Agriculture, Forestry, and Fisheries mainly focus on agricultural development in South Africa. South Africa’s agriculture has grown notably in the past years to ensure national and domestic food security; social and economic growth; job creation; and contribution to rural socio-economic development. This being the case, it must mean that the agricultural sector uses more water now than it did then. Agriculture has grown, therefore, its water use has increased. The IGDP adopted a global framework for the development, planning, and implementation of the National Forestry Programme (NFP). This type of the adoption of external frameworks recommended from time to time where it will assist any issues.

Similar to the previous policy, The Draft Irrigation Strategy for South Africa 2015 focuses on irrigation schemes in the country. Since it is just a “draft”, it can be developed into a standard framework policy such as the Paradigm of Abundance mooted under the recommendation. This Strategy also aims to ensure food security; poverty alleviation; and job creation. It is also a practical policy that targets and supports local farmers towards achieving results. This will include subsidizing what the need like seed and equipment, and perhaps providing them with water sources too. There is an effort to correct past inadequacies and the Strategy provides a link between the policy and practical implementation in a structured way. On a good note, this policy addresses and connects water with agriculture for the benefit of all. Irrigation increases food production, which automatically contributes to the Agricultural Policy

Action Plan (APAP) of the National Development Plan (NDP). Unfortunately, the planned increase in irrigation called for in NWRS2's Reconciliation Strategies is not viable because the fact remains that there is simply no water. This is the danger of a political statement devoid of scientific facts.

The Draft Policy Framework on Irrigation for South Africa – Focus on Revitalization of Irrigation, recognizes the need for water in agriculture and has plans to rebuild the irrigation system as well. The Medium-term Strategic Framework, on the other hand, aims at achieving the NDP by accelerating growth, creating jobs, and promoting competitive investment like most of the other Strategies. This Framework, however, does not focus talk about agricultural water management. Furthermore, the Comprehensive Rural Development Strategy focuses on enabling rural people to take charge of their lives with government support to eliminate poverty through the use of natural resources. This is a viable Strategy encompassing both, water, being a natural resource, and smallholder agricultural farming, which is common in rural areas. To encourage the success of this Strategy, there has been an increase in all types of agricultural production; optimal and sustainable use of natural resources; use of appropriate technologies; food security; and improvement of the quality of life for each household among others.

The War on Poverty Strategy strives to alleviate poverty by providing a safety net through assisting people with basic needs. The approach to poverty is quite broad and leaves room for empowerment through agriculture by providing optimal and sustainable use of natural resources. The objective involves the creation of economic opportunities. There are nine pillars on which this framework is anchored. However, out of those nine pillars, none talks about agriculture or motivation of it in that light. Yes, poverty targets certain groups of poor people but empowering people through sustainable initiatives such as giving them small farmlands could go a long way. This Strategy does not shed light on agriculture as a way out of poverty. It should be more specific in that regard. In addition, there is a lack of investor confidence regarding the nine pillars of which none of these would be possible unless investors feel confident enough to invest in the sector. There is a need to boost investor confidence for better chances.

This Strategy is reconciled with the NWRS2 where they both advocate for the need for stronger institutions to effect the implementation of interventions, which is a good idea. However, there is not enough power handed over to subordinates to handle this. Rather, it feels like there is a deliberate weakening of these institutions by the top elite as an excuse to plunder. Politics are increasingly playing a part in these implementation processes, which should not be. Again, this Strategy strives to ensure that anti-poverty programmes are a top priority for all departments in all spheres of government. One such programme is the Paradigm of Abundance programme, which is a major anti-poverty initiative and will be introduced and expatiated as our recommendation.

4.5 Conclusion and Recommendation

The NWRS2 specifically stresses the need for water resource protection to protect freshwater ecosystems, which are under threat due to pollution from diverse sources but it does not provide methods and solutions of how this should be done. Based on such irregularities of the above policies and strategies, it is only fair to recommend a water management system in agriculture that might work for South Africa. This system is called the Dual Stream Reticulation System which has been articulated over the past years by several water expert researchers such as Botha & Pretorius (1998); Ilemobade *et al.* (2008) and more recent, Turton (2017). The Dual Stream Reticulation system involves constructing separate pipes, which pump different water qualities to users. The pipes will supply potable (consumable) and non-potable (non-consumable) water independently. Briefly, potable water requirements involve cooking and drinking while non-potable water requirements include irrigation and household chores. In this way, clean water is saved for the increasing requirements it can be used for while unclean water can be used to meet other needs.

With this brief introduction, we believe that the implementation of this system will be beneficial to South Africa in response to the increasing water demands and decreasing freshwater availability. A few success stories of this system in other countries worldwide include Australia, Kiribati, Marshall Islands, China, and even Namibia. However, in South Africa, the implementation of this credible water management system is limited. This is due to weak and irrelevant national development plans and guideline documents; inappropriate decision-making tools; sheer ignorance and poor user and decision-maker rapport. Regardless, this system is recommended as an adoptable water management policy for South Africa for the development of a decision-making framework.

The Dual Stream Reticulation system offers new possibilities for maintaining adequate water supply as well as the appropriate use of the dwindling water resources in the country (Botha & Pretorius, 1998). This system is a promising option for arid South African settlements, which are characterized by limited access to freshwater sources (Ilemobade *et al.,* 2008). About 2 decades ago, such recommendations were side-lined due to technological limitations but the world has since evolved and such a project is viable and must be implemented to better the nation. To this end, Turton's (2017) mooted projection, known as the new Paradigm of Abundance vs the Paradigm of Scarcity, will be effective in this management. The former Paradigm is centred on water reuse and recycling for agriculture to survive. It is based on the Dual Stream Reticulation System where the water of different qualities and prices are used for different purposes. The Paradigm of Abundance is strengthened by 3 pillars:

- Recovery of water from waste such as sewage and others;
- Desalination of seawater for coastal cities; and
- Groundwater use sustained by Aquifer Storage and Recovery (ASR) or Managed Aquifer Recharge (MAR) using excess water.

With regards to technological innovations, the city of Cape Town in the Western Cape is in the process of bringing in additional water into their supply system by way of the 2nd pillar – desalination of seawater. It is reported that this assessment will involve a stretch of 2 km of pipeline and will also "evaluate and prepare it for the connection of the desalination plant into the bulk water main. This involves assessing the valves and general conditions of the pipeline" (De Lille, 2017). This procedure is crucial to prepare and ensure that the water coming from the desalination plant can reach the bulk water system safely and securely. To do this, the City must reduce the water pressure to some areas. This effort is not only necessary to better manage water but also to beat the recurrent drought hazard.

In addition, groundwater can become the key driver for agricultural water management, sustained only by ASR and MAR. This is the crux of the Paradigm of Abundance – bringing water management solutions through technology while replacing the prevailing Paradigm of Scarcity, which chases the dwindling water resource into oblivion. The Paradigm of Scarcity suggests that over time, water for agricultural use will lose quality as a result of gradual pollution and subsequently become irregular.

Most of these Strategies talk about the same thing, excluding or isolating water from agriculture and vice versa. This is based on the Paradigm of Scarcity whereby a dwindling resource such as water in South Africa, is never enough for everything. The Paradigm of Abundance can change this if considered seriously. This framework can manage the water issues in the country if implemented especially since it has worked for other countries, including Namibia, which is an African country. The role of agriculture must be integrated into water issues but the challenge is whether the strategy should support current agricultural stakeholders or be redistributive to include the development of the poor. There has been much effort put into water distribution and water management in all sectors, agriculture inclusive, but the water – water access and management, the problem is still a recurring one in South Africa. Why is that? It has been established that the agricultural sector requires more water than some other industries to flourish. It is crucial, however, that the water users as well as, their roles are clarified in the policies.

Most of these strategies are viable water resource management policies but they seem to follow a top-down approach where the government is totally in control. In this case, the people do not own the process and this may hinder the success of the strategies. The government must not act in isolation but involve active public participation in decision-making processes. More joint participation will be required from both sides to ensure achievement. In addition, some of the strategies lack integration of the involvement of different departments, thereby, fragmenting government efforts nationally with regards to water supply and demand. The disadvantage of an externally sponsored strategy is that the sustainability of that strategy may not be guaranteed because what works for the outside may not necessarily work for the inside (South Africa).

We believe that any of the agricultural strategies or policies that leave out water management plans are lacking quality and *vice versa*. There is a thin line between the two because sustainable development depends on them – agriculture cannot thrive without sufficient water. Therefore, provisions need to be made for both in the same stream. Likewise, we cannot talk about successful irrigation without solving the underlying issues or root causes of water access and distribution. We must first integrate the strategies than fragment them. We must learn to address the primary or key issues first, otherwise, all efforts remain in the pipeline as with most of these strategies talking about equitable water allocation. The issue of inequality still lurks its ugly head, more 20 years into a democratic government with white commercial farmers still holding the major water allocation budget. If this is not solved, future water conflict can be expected.

With specific regards to the Comprehensive Rural Development policy and War on Poverty, they seem to be at a level of involving and trying to understand the rural community. The former strategy promotes and supports all types of agricultural production, providing for optimal and sustainable use of natural resources to improve the quality of life for each rural household. The latter strategy can be made to be more sustainable by trying to address gaps and key development enablers. Rather than rely wholly on community initiatives, which limits proper intervention as the community can only suggest what they only know which might be limited, the government may need support from experts in deciding interventions.

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5 DRIVERS FOR WATER MANAGEMENT SCENARIOS

5.1 Introduction

Drivers, driving forces, drivers, capitals, clusters, and dimensions are some of the terms that scenario planners have used in the literature. These terms have been defined as key factors, trends or processes which influence the situation, focal issue, or decisions, and propel the system forward and determine the story's outcome in the micro and macro environments (Van Notten, Rotmans, Marjolein, Van Asselt & Rothman, 2003; Neumann & Overland, 2004; Borjeson, Hojer, Dreborg, Ekvall & Finnveden, 2005; Varum & Melo, 2009). Some of these driving forces, drivers, clusters, or dimensions are invariant over all scenarios; that is, they are to a large extent predetermined (Schwartz, 1991).

The population of the world is estimated to grow by at least 65% within the next five decades. The average per capita income of households is also expected to rise at the same time (Sauer *et al.,* 2008). This implies that there will be a substantial increase in the demand for freshwater for food and various uses because such developments will increase the trends towards more water-intense lifestyles and diets (Sauer *et al.,* 2008). Water resources are essential for agricultural production because they can limit food production, energy generation, and economic activities in other sectors in the economy (Wallace, 2000). It is estimated that four billion people globally live under severe water scarcity conditions for at least one month annually. Furthermore, half a billion people globally are estimated to live under severe water scarcity annually (Mekonnen & Hoekstra, 2016).

Approximately 40% of the global population and many ecosystems are facing water scarcity (Pfister *et al.,* 2011). Agricultural production accounts for an estimated 85% of global freshwater consumption (Shiklomanov & Rodda, 2003) and it is expected to more than double by 2050 (Tilman *et al.,* 2002; Pfister *et al.,* 2011). Climate change is playing a massive part in increasing water stress by altering rainfall patterns and water availability in many parts of the world (Lobell *et al.,* 2008) and as a result, irrigation is expected to increase massively (Lundqvist *et al.,* 2008). Finally, the current challenges faced by agricultural water managers are not the same as they were some years ago (Molden, 2007). Following the business as usual approach, increasing food demand will require more water for agriculture based on current technology and management policies (Molden, 2007). This implies that agricultural productivity depends largely on the supply/availability of freshwater.

The issue of global water scarcity has become a major cause of concern to governments, international and local organisations, policy-makers, water-users, and water managers (Owusu-Sekyere *et al.,* 2017). The complex relationship that exists between water resources and agricultural production has been referred to by scholars as a growing global food crisis (Sauer *et al.,* 2008). Food production is essential for human existence and given the vital role played by water in food production, it is important to design strategies and techniques to use water efficiently by all sectors in the global economy, especially in the agricultural sector which uses a significant proportion of global water (Owusu-Sekyere *et al.,* 2017). To ensure that the food needs of the global population are met by 2050, food production will need to be more than doubled. To improve agricultural yields on the scale required to meet the future food demands of the global population, a strategic rethink of water-management strategies and policies will be required globally (Rockström & Falkenmark, 2015). A significant amount of water is lost in irrigated agriculture in the form of evaporation or leakage during transportation and storage of water to the crops grown (Wallace, 2000). Water use efficiency is therefore very vital in rainfed and irrigated agriculture.

South Africa is a water-scarce country with high temporal and spatial variable rainfall. This has resulted in water being in surplus in some areas and is deficient in others (DWA, 2015). The agricultural sector in South Africa occupied a center stage in the economy, as the sector grew by an estimated 22% and contributed 0.4% to the GDP during the first quarter of 2017. This underscores to a great extent the importance of agriculture to the economy of South Africa. Over the last decade, the agricultural sector in South Africa has contributed approximately 4% to the gross domestic product (DAFF, 2012). Given the economic importance of water to the agricultural sector in South Africa, this contribution does not reflect the allocation and use of freshwater resources in South Africa (DWA, 2015). To develop a sustainable and vibrant agricultural sector in South Africa, capable of meeting the food demands of the growing population in the decades ahead, water in agriculture must be used efficiently and effectively (DWA, 2015). This shows that there is an urgent need for innovative water management systems that incorporate the use of freshwater resources inclusive of rainwater in the rainfed sector in a sustainable, economic, social, and environmentally friendly manner.

The South African population will grow to an estimated 67.3 million people by 2035, most of whom will be youths in working-age group (DAFF, 2012). The manufacturing, energy, and mining sectors, etc. are expected to grow significantly by 2030 (DAFF, 2012). The pressure on water resources will increase. Coping with population growth as well as additional per-capita food demand represents a major challenge in feeding the population in the future. More people are expected to move from lower-income classes to at least middle-income classes and as a result, their demand for agricultural products will increase. Also, their consumption patterns are fast-changing towards more livestock and sugar products that require more water to produce than grains and tuber crops (traditional staple food) (Molden, 2007).

The expected growth in population and growth in almost all the sectors of the economy, the stress on freshwater resources in the 30^{th} driest country in the world (South Africa) will increase tremendously. Therefore, any policies and investment strategies designed to increase agricultural production will affect (i) freshwater use, (ii) the environment, and (iii) level of rural and urban poverty (De Fraiture & Wichelns, 2009). Water resource development and better water management strategies are required to produce enough food to meet the future needs of the growing population and will require promotion and improvements in food security while enhancing the productivity of farmlands and water resources and promoting environmental sustainability (Molden, 2007). Research and policy reviews and analysis will help identify successful strategies regarding proper water management, economics, and human welfare (De Fraiture & Wichelns, 2009).

Most countries in Sub-Saharan Africa are facing increasing water scarcity and a continuous population increase. The demand for freshwater resources for various uses by different sectors in the economy is rapidly increasing globally and especially in South Africa, thereby reducing the quantity of water available for food production. The agricultural sector has grown in importance globally because food is vital for human survival. The sector is competing with other sectors in the economy for scarce freshwater supply (Rosegrant *et al.,* 2002). The industrial, domestic/urban and mining sectors are the agricultural sector-major competitors for freshwater use in South Africa. The major problem facing the economy of South Africa is the proportion of freshwater used by the agricultural sector and the contribution it makes to the GDP. Irrigated agriculture accounts for an estimated 62% of the total water requirements in South Africa, and the sector contributes approximately 30% of the agricultural production and employs an estimated 11% of the labour force nationwide (DWA, 2015). On the other hand, the mining and industrial sectors account for an estimated 8% and 23% respectively to the GDP and employ approximately 7% and 19% of the labour force, and together account to an estimated 15% of the total water requirements in South Africa. Urban and domestic sectors account for an estimated 25% of the total water use in South Africa (DWA, 2015). This means that the agricultural sector uses more water and contributes less to the economy of South Africa. The challenge now and in the future is to produce more food with the same quantity of water or less given the depleting state of water resources in the country. It is therefore empirical to promote the productivity of agricultural water use, to enhance agricultural output and increase the contribution of the sector to the economy.

A large proportion of South African agriculture consists of the cultivation of rain-fed crops or livestock farming. Rain-fed 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 soils, low and variable rainfall as well as limited amounts of arable land. About 85% of the potentially arable land is under freehold tenure (Hardy *et al.,* 2011). This supports a dynamic, commercial agricultural industry of mainly summer and winter grains that accounts for 95% of the marketed output (DAFF, 2014).

Guarantees of future water supply is a problem unique not only to South Africa; it is rather a global crisis. Approximately 3.5 billion people globally will face severe water scarcity by 2025 (Pfister *et al.,* 2011). Based on current usage trends, water demand is expected to exceed the supply of freshwater resources in South Africa by 2025 (DWA, 2015). The continuous increase in the industrial, as well as urban sectors and population growth, will further place enormous pressure on the economy's sources of water supply if appropriate corrective measures are not taken (DWA, 2015). The general objective of water resources management is to promote efficient freshwater use to maximize economic, social, and environmental welfares in an inequitable, efficient, and sustainable manner (Wei, 2008). The objective, principles, and outcomes are summarised in Table 5.1.

Table 5.1: Objectives and principles of water resource management.

Objective	Principle	Outcome
Society	Equity	Ensure effective provision of societal needs: ➢ Provide sufficient freshwater for different users ➢ Provide safe and reasonably priced drinking water ➢ Provide clean water for sanitation ➢ Ensure food security
Economics	Efficiency	Maximize the economic value of water use: ➢ Ensure agricultural growth ➢ Promote the development of the industrial sector ➢ Ensure efficient the generation clean power/energy ➢ Promote regional and local development ➢ Reduce pollutants discharge
Environment	Sustainability	Maintain environmental quality: ➢ Preserve water quality ➢ Maintain the seas and its habitats ➢ Maintain beautiful and natural values ➢ Preserve environmental flow and the hydrological cycle ➢ Reduce the effects of climate change on freshwater resources

Source: UNESCAP (2000); Wang (2005); Wei (2008).

Equity in water resource management is the fair distribution of water resources to different users in the economy. Efficiency on the other hand means the economic use of water resources in ensuring the optimal use of water to produce products with higher economic value. Sustainability in water resource management refers to the use of water to achieve both social and economic development in an environmentally sustainable manner while ensuring water quality.

As stated in the National Water Resource Strategy (NWRS) vision 2030, South Africa's water resources strategy is to efficiently and effectively manage water resources for equitable and sustainable growth and development. The major problem facing South Africa is how to allocate the limited water resources to the different sectors of the economy equitably and sustainably to meet the food demands of the growing population. Given the agricultural sector's high water usage and relatively low contribution to the GDP, many scholars and water managers have argued that water resources should be diverted from the agricultural sector to the industrial and other more productive sectors in the economy to enhance economic development. The importance of the agricultural sector to the South African economy however, cannot be overemphasised. The sector is a source of food to feed the population, employment (both formal and informal) accounting for 15% of employment in rural areas, and foreign exchange through the export of agricultural products. The challenge will be for policymakers to develop policies and invest in strategies that will ensure efficiency and effective water management within the agricultural sector. To ensure a sustainable agricultural sector capable of meeting the food demands of a growing population in the future, policies must be put in place to ensure the effective and efficient use of depleting freshwater resources through efficient irrigation techniques and minimum crop water use.

Research is one of the important tools necessary for identifying policies and strategies that will inform water planning in a face of uncertainties and a constantly changing climate. Scenario planning can be very useful in water planning because it will inform policymakers and all stakeholders in the water sector about the current water situation in the country and provide valuable insights to support future water policies especially regarding the agricultural sector and agricultural development in South Africa.

Scenario development/planning is a very useful tool for analysing/modelling the potential implications of alternative strategies for increasing food production in the future. Developing strategies and formulating policies in the face of uncertainty is often very difficult and sometimes extremely complex (Shadbolt & Apparao, 2016). Many organisations often choose scenario planning as the best method to plan in the face of uncertainty (Konno *et al.,* 2014). Scenario planning has become a very useful planning tool in the agricultural sector and has been gaining visibility in recent years. Scenario planning involves establishing a baseline projection of future food supply and demand, based on current conditions and expected trends, and comparing the baseline projection with alternative projections that reflect changes in key parameters (exogenous changes) or the adoption of new production methods, new investments, or changes in public policies regarding land use, water allocation, environmental protection, or other pertinent issues (endogenous changes) (De Fraiture & Wichelns, 2009). Scenario analysis is very useful when examining alternative futures with regards to long-term goals, such as producing sufficient food in 2050 to feed the world's population, while also eradicating poverty, uplifting livelihoods, enhancing environmental sustainability, and enhancing the productivity of natural resources (De Fraiture & Wichelns, 2009).

Research studies have developed water scenarios in agriculture at global and country levels. De Fraiture & Wichelns (2009) developed scenarios for satisfying water demands for future agriculture while Amarasinghe *et al.* (2007) developed India's water future for 2025-2050 using Business-as-Usual Scenario and Deviations. Wallace (2000), on the other hand, estimated increasing agricultural water use efficiency to meet future food production while Pfister *et al.* (2011) projected water consumption in future global agriculture through scenarios and related impacts. Many other studies have looked at scenario planning in agricultural water use to meet future food production. However, very few empirical studies can be found in future water management scenario planning for South Africa's agriculture sector. Scenario planning will serve as a guide toward proper policy planning and the implementation of sustainable water management practices.

South Africa's success in managing the intensifying water problem which is largely due to increasing population growth, economic growth, and changing food patterns to more water intense crops, will depend largely on the identification and accountability of all the many drivers that determine and influence water use in the country. This involves identifying and classifying the drivers likely to influence future water use and giving special consideration to practices that may be amenable to some degree of change. It is important to recognise the difficulties of projections and the problems associated with identifying specific disparities between future water supply and demand.

The conditioning factors are broadly defined to include: (1) physical and technical factors, including quantity and quality of water supply, rainfall characteristics, soils, terrain, and water application and measuring technology; (2) economic and social factors, including markets, landholding size, population density, and heterogeneity of social background; and (3) policy and institutional factors, including water rights, pricing, regulations, the capacity of government agencies, organizational density and legal frameworks (Dong *et al.,* 2012).

These drivers must present the complex phenomena of the water sector in a meaningful and understandable way to decision-makers as well as to the public. They must establish benchmarks to help analyse changes in the sector in space and time in such a way as to help decision-makers to understand the importance of water issues, and involve them in promoting effective water governance (Gallopín & Rijsberman, 2000). Good drivers help water sector professionals to step *''outside the water box'',* to take account of the broad social, political, and economic issues affecting and affected by water. Furthermore, targets are essential for monitoring progress towards achieving the Millennium Development Goals related to water (WWAP, 2009).

Development and identification of the driving forces (drivers) is a complex and slow process, requiring widespread consultation. New drivers have to be tested and modified in the light of experience. A better understanding has to be gained of the problems related to driver development: data availability, and information scaling drivers (Gallopín & Rijsberman, 2000).

5.2 Scenario Planning and Drivers of Change

In a world where the knowledge base is growing faster than usual, coupled with increasing uncertainties and changing human and natural environments, there is a need for organisations, policymakers, and business leaders faced with increasing uncertainties to respond quickly to these changes. Uncertainty is one of the most important factors policy/decision-makers, planners, and leaders consider when making decisions about the future (Chermack *et al.,* 2001). Konno *et al.* (2014) argue that scenario planning is the method of choice for planners and policymakers for planning in the face of uncertainty. In such a rapidly changing environment, the ability of business leaders, planners, and policymakers to adapt quickly to crucial changes and uncertainties will determine and shape the future. With the continuous growth in population, income, food consumption, global complexities and changes, policymakers will need to be thorough in their ability to determine the forces of change and anticipate possible solutions to potential problems (Roubelat, 2006). In terms of policy organisational planning, strategic planning has been the most commonly used approach to plan and cope with future changes. Though strategic planning has been very useful planning, coping and anticipating future changes, it does very little to inform leaders, policymakers, and planners about crucial economic, environmental, social, and political changes that will occur in future (Chermack *et al.,* 2001; Varum & Melo, 2010). Scenario planning has been used as a great tool for examining future uncertainties in a comprehensible, reliable, and plausible way such that it has been broadly used for strategic planning and policy-making

(Yoe, 2004). Furthermore, scenario planning has been used as a great management technology to examine alternative futures and to help managers make better decisions (Martelli, 2001).

A new strategy for planning under uncertainty was developed some decades ago called scenario planning. Rather than just predicting and forecasting future occurrences, scenario planning examines plausible and possible future occurrences. Scenario planning is crucial for policy planners because it reveals what could happen in the future if certain decisions are made today. The approach focuses on long and short terms changes that can occur and forces planners and policymakers to consider methods and procedures that will challenge their current state of thinking. Scenario planning encourages policy planners to *"think the unthinkable"* (Shadbolt *et al.,* 2017). The definition of scenario planning will follow in the next section. A discussion on the history of scenario planning will follow the definition of scenario planning. Furthermore, scenario theories and methodologies will be discussed in the third section. The fourth section will carry the discussion of water resource planning and management under uncertainty.

5.2.1 Definition of Scenario Planning

Scenario planning has been defined in a variety of ways. A scenario according to Porter (1985) is *"an internally consistent view of what the future might turn out to be not a forecast, but one possible future outcome".* Schwartz (1991) defined scenario planning as "*a tool for ordering one's perception about alternative future environments in which one's decisions might be played out".* The Intergovernmental Panel on Climate Change (IPCC) (2007) interpreted scenarios as a *"coherent, internally consistent, and plausible description of a possible future state of the world. It is not a forecast; rather, each scenario is one alternative image of how the future can unfold".* Van der Heijden (1996) defined scenario planning as a *"strategy focused on the process, which differs from traditional approaches, often characterized as rationalistic, involving the search for the 'optimal' or 'evolutionary' strategy"*. Varum & Melo (2010) reckoned scenario planning is based on the assumption that the global environment is unpredictable, with predetermined events. There is no particular scenario that can provide an accurate description of the future. The main objective of scenario planning is to assist planners, leaders, and policymakers to recognise the effects of the ever-changing environment and uncertainties, reflect on these changes and consider the uncertainties that will arise from the changing environment (Foster, 1993). Leaders, planners, and policymakers can construct scenarios by identifying trends and uncertainties that might occur in the future for better decision making and overcome the mistakes of strategic planning (Schoemaker, 1995). Scenario planning involves the *"participation of people from diverse groups, experts, strategists, managers organized in networks to create alternative representations of the future"* (Ghosh & McLaffert, 1982). Furthermore, scenario planning according to Roubelat (2000) is a process of networking that *"challenges strategic paradigms and forces firms to rethink their internal and external boundaries".* Scenario planning is "*that part of strategic planning which relates to the tools and technologies for managing the uncertainties of the future"* (Ringland, 1998).

Shell (2013) stated that scenario planning *"is not to predict the future but to enable policymakers to make well informed and better decisions involving the future as a result of having a deeper grasp of key* *drivers and uncertainties. Scenarios provide lenses that help us to see prospects more clearly, make richer judgments, and be more sensitive to uncertainties".* Handling complexity is something the human mind struggles with on the daily basis, and scenario planning provides a framework for solving these limitations by breaking down the complexities into smaller, distinct, and easily understandable states (Schoemaker, 1993). Parminter *et al.* (2002) stated that *"scenarios can also provide a tool for overcoming human biases such as overconfidence and unrealistic assumptions".* Shadbolt *et al.* (2017) also stated that *"developing and using alternative scenarios, organizations can prepare themselves for a range of possible futures, so scenario planning can, therefore, serve as a relatively low-cost insurance policy and also, scenarios can be used to stress test a strategy".* Gamas *et al.* (2015) stated that *"scenario planning is a structured process that involves the development of narratives describing alternative future states of the world, designed to differ with respect to the most critical and uncertain drivers. The resulting scenarios are then used to understand the consequences of those futures and to prepare for them with robust management strategies".*

The important point in all the definitions is that scenario planning deals with uncertainty in the future but does not deal with forecasts or predictions. Certainly, scenario planning aims to generate a wide range of possible futures, rather than focusing only on the most likely outcome. The next section will provide a historical background to scenario planning.

5.2.2 History of Scenario Planning

Scenario planning is not a new concept; the long history of scenario planning started centuries ago. Gaston Berger, a French writer in 1960 wrote a book called '*Phénoménologies du Temps et Prospectives'* (translated as *"prospective methodologies")* which contextualised events of the past and present to make decisions in alternative futures (Berger, 1964). Bertrand Jouvenel, a French political philosopher, developed the idea of *'futuribilia'* by combining the word *'future'* and *'possible'* to form a new term which he described as *'futurible'* describing events that will likely occur in future (Jouvenel, 1967). De Jouvenel further explained the term *'futurible'* by stating that the human mind cannot fully gasp future uncertainty but can imagine possible alternatives that can occur (Malaska & Virtanen, 2005).

The concept of scenario planning was made famous by Herman Kahn in the 1940s when he was a researcher at RAND Corporation for the United States Government and the creation of the Hudson Foundation (Fahey & Randall, 1998). Kahn (1940) developed the concept of *'think the unthinkable'* by encouraging people to use their imagination to think well into the future (Bishop *et al.,* 2007). After Kahn (1940) had stated the benefits of using alternative future thinking or scenario planning as a strategic planning tool in the military, the concept went well beyond military planning and moved into the areas of politics, economics, and business and public policy (Chermach *et al.,* 2001). Scenario planning techniques began to gain credibility in the corporate sector in the 1970s when Royal Dutch Shell and the Consulting Firm SRI adopted the scenario planning concept and created a more formalised approach to scenario planning aligned to the concept of strategic planning (Fahey & Randall, 1998).

Kahn (1963) stated that *"the best to prevent nuclear war is to examine the possible and future consequences of the nuclear war".*

The Hudson Institute in an effort to expand their research on scenario planning began seeking corporate sponsorship, which led companies such as Shell, IBM, Corning, and General Motors to become aware and exposed to the concept of scenario planning (Chermack *et al.,* 2001). Shell was one of the early sponsors of the Hudson Institute and scenario planning and was encourage by Ted Newman to adopt the idea of future thinking. Kahn & Weiner published the book titled *"The Year 2000. A Framework for speculation on the next thirty-three years"* in 1967 which *"demonstrated clearly how the future thinking was driving the trend in corporate planning"* (Ringland, 1998).

The SRI group used different approaches to develop scenarios for the US educational system for the year 2000. The SRI developed five scenarios for which one was considered the most important. The important scenario was titled the *"Status Quo Extended".* The scenario suggested that population growth, environmental degradation, and dissent will resolve themselves (Charmack *et al.,* 2001). Similarly, Professor Jay Forrester (1961) of MIT was also using the scenario planning concept to explain the future of demand and supply chain. Scenario planning was adopted in the Shell Company when Pierre Wack and Ted Newman head of planning at Shell in 1967 suggested that thinking and planning six years didn't allow the company enough time to consider future drivers in the oil industry effectively (Wack, 1985). They also found that the *"oil industry was running on two very volatile assumptions; firstly that oil would remain plentiful and secondly that prices would remain low".* They provided Shell with a set of scenarios that would potentially change the perception of the company to see the need to plan for many different possible futures (Van der Heijden, 1997). Shell started planning for the year 2000. One of the scenarios developed looked at *"an accident in Saudi Arabia which led to the severing of an oil pipeline, which in turn, decreased production and supply, creating a market reaction that increased oil prices, allowing Organisation of the Petroleum Exporting Countries (OPEC) nations to pump less oil but make more money"* (Godet & Roubelat, 1996). When the *"Yom Kippur"* war began, oil prices fell and Shell was prepared for it because they had planned for such a scenario (Willmore, 2001). Shell made huge progress by moving from the eighth biggest oil company to the second-biggest oil company within two years of implementing scenario planning.

By the late 1970s, Shell had experienced so much success that most Fortune 1000 corporations started adopting scenario planning and using them in different forms (Ringland, 1998). By the late 1980s, the use of scenario planning started declining in most corporations. Most of the planners started confusing the use of scenario planning with forecasting and over-simplified the process of scenario planning (Kleiner, 1996). Most consulting companies were still using scenario development and started developing methodologies for proper scenario development to assist planners in the scenario development process. Wack developed the intuitive logic of scenario planning, the Future Group developed the Trend-Impact Analysis and Battelle implemented the Cross-Impact Analysis method (Charmack *et al.,* 2001).

Shell was the most successful company using scenario planning and their success was evident as they went through two major oil incidents in the late 1980s without feeling the effects like most companies because they were prepared for them. As a result, most corporations slowly began re-integrating scenario planning in their planning activities and applied the concept to a wide variety of situations, at local, national, and regional levels and it also brought diverse groups of people together (Rui *et al.,* 2011). Scenario planning techniques have been a successful way of thinking in a business context and recent years, scenario planning techniques have been emerging in every sphere from industry to academia (Van der Merwe, 1994).

5.2.3 Theories and Methodologies of Scenario Planning

Scenario planning is a concept that has been applied widely and in different areas of research for future planning under uncertainty. There are many different methods of conducting scenario planning; however, in answering all relevant questions, the various analyses may not produce identical results. According to Tucker (1999), *"scenario methodology"* is a broad term that covers a wide variety of possible theories, approaches, techniques, and research designs with varying degrees of complexity. In the process of conducting scenario planning, scenario theories/methods can be seen to be a complex set of methods which regularly consists of a variety of Methodological steps or phases (Kosow & Gaßner, 2008). In developing a practical scenario framework, various appropriate scenario techniques may be applied in the scenario process. According to Miller *et al.* (1997), *"the sequence of steps or phases comprising the concrete, relevant characteristics of a scenario method is determined by the selection of a specific scenario technique".*

Huss & Honton (1987) and Martelli (2001) identified three methodological approaches to scenario planning and they are:

- **Intuitive Logics:** First described by Pierre Wack (1985) and developed by SRI, Global Business Network, and Shell, it is the best-suited way to use every available information about the future; it generates new ideas and it can help in identifying the underlying patterns. On the other hand, intuitive logic is strictly connected with the experts who work on the scenario, the techniques are assembled in the most varied way and consequently, it is difficult to check the validity of the particular approach adopted from a scientific point of view.
- **Trend Impact Analysis:** First introduced by the Future Group, is a combination of statistical extrapolations with probabilities. This scenario planning method has the advantage that it correctly stated and formalised. At the same time, it does not rule out creative thinking at all, as the choice of the factors influencing the development of a given trend is in its essence a creative procedure. But trend analysis has its shortcomings: it can be used only if a long, detailed, and reliable time series of data is available and if the researchers using it have a background in statistical and probability theory. For this reason, it is used by a minority of experts.
- **Cross-Impact Analysis:** Employed by Battelle with BASIC (Batelle Scenario Inputs to Corporate Strategies) and owing much to Godet (1987), it is probably the methodology most directly connected with the use of scenarios. The great advantage of cross-impact analysis is that it is a highly formalised method, which allows to control the process.

The disadvantage is that if it is not contained within certain limits, it is the formalisation itself that can cause it to go out of control and to gain an excessive edge on the usefulness and reliability of the content. Several scenario researchers are quite positive on the method, pointing out that it is often a good point of entry to begin with scenarios, that it arouses the interest of people of various backgrounds and that it is very good for stimulating new ideas, even if one does not bother to go as far as to extracting projections out of it. As the complexity of strategic problems increases, there is the need to resolve the problems collectively by means of using methods/approaches that are rigorous and participatory to recognise the problems and find satisfactory solutions (Godet, 2000).

According to Schoemaker (1991), scenario planning methodology is very useful when (i) the system under consideration is highly uncertain and complex, (ii) surprises would be highly costly or foregone opportunities would have been highly beneficial, (iii) insufficient new opportunities are emerging, (iv) planning is not sufficiently strategic with respect to changing conditions, and (v) strong differences of opinion may exist where each opinion has merit. In an attempt to answer the question of why there are many techniques to scenario planning, Kosow & Gaßner (2008) gave the five reasons for the multiplicity of approaches in scenario development. They stated that;

- Firstly, many different scenario techniques have been developed due to the growing spread of scenario use in different application contexts. Among the fields of application are business enterprises, city and land-use planning, and research and advisory services (e.g. global scenarios affecting the environment or energy uses) with their correspondingly different assumptions and standards. Many areas of science and practical application today use scenario techniques. The individual forms of these techniques, however, may vary widely depending on those who commission or instigate the respective scenario and on the respective developmental roots of these techniques.
- Secondly, and this is presumably the primary reason for the multiplicity of methods, the spectrum of goals and functions has grown constantly since the first emergence of the scenario concept.
- Thirdly, different schools of thought and paradigms have influenced work with scenarios and have infused different perspectives into the field of scenario methods by bringing in patterns of thought and creative techniques from the natural sciences.
- Fourthly, scenarios may have widely varying positions of importance in projects and research processes depending on the concrete, salient characteristics involved. Scenarios may not only be the end product of a project (scenario generation) but equally also its point of departure (scenario evaluation) or even its interim product (scenarios as an intermediate step toward further processing and transfer.
- Fifthly, the concept of a “scenario technique” subsumes on the one hand fully different approaches, while on the other hand, different labels may also exist for intrinsically similar approaches since different “scenario service suppliers” use them merely to give prominence to their approach and set it off from the others.

Schwartz (1991) developed a methodology called the "*The Art of the Long View"* where a conceptual overview of the scenario building process was described. This technique of scenario planning has been adopted and used by the Global Business Network. According to "*The Art of the Long View”* methodology, step one identifies the focal decision or issue to be analysed. The second step identifies key forces in the local environment that influences the general environment. This step examines the factors that may influence the success or failure of the issues identified in step one (Chermack *et al.,* 2001). The third step involves identifying the driving forces in the macro-environment. These drivers include social, economic, technological, ecological, political, and natural forces. The fourth step involves allocating ranks (weights) to the drivers based on two (2) criteria: (i) "*the degree of importance for success and (ii) the degree of uncertainty around the forces themselves"* (Schwartz, 1991). Furthermore, the development and selection of main and sub-scenario logics based on the "*matrix from the ranking exercise"* is done in step five (5). Finally, step six (6) involves stating the scenario plans based on step two and four and checking for plausibility at every stage. Amara (1991) classifies futures research methodology into three categories. The study placed a lot of emphasis on validation and quality criteria for futures studies, and a set of initial criteria is outlined – plausibility, reproducibility, and explicitness of values and impacts.

This study will use the cross-impact analysis method where both qualitative and quantitative drivers will be used for scenario planning. The qualitative drivers and drivers will be used to develop five drivers and also to formulate and develop and model for future water use. The quantitative drivers and drivers will be used to simulate the policy scenarios using game theory and dynamic systems.

5.2.4 Water Resource Planning and Management under Uncertainty

The main objective of water resource planning and management is to ensure that the demand for water resources by the socio-economic system is at least equal or more to the supply (quantity and quality) of the water resources by ensuring administrative control and management (water regulations/laws and infrastructure) are put in place, without damaging ecosystem sustainability (Dong *et al.,* 2012). In essence, changes in water resource systems (W) are driven by changes in three related subsystems, i.e. the climate system (C), the socio-economic system (SE), and the management system (M). Important socioeconomic variables include population growth, economic development, technological change, and water and land-use practices. For example, demographic change, economic development, technological innovation, and geographical conditions directly impact future water consumption patterns, and water demand by different users (McCarthy *et al.,* 2001). The climate system has a direct impact on water availability and water demand via changes in temperature, precipitation, and evaporation. Finally, management intervention such as water allocation strategies, legislative standards, political intervention, and technology inefficient water use stimulates changes in the socio-economic system and hence plays an important role in influencing future pathways of water systems.

The underlying idea is that scenarios that display alternative future states of the water system facilitate water managers to make robust decisions and management strategies (Lempert *et al.,* 2003). Scenario development for water resource planning and management helps decision-makers to understand the implications of the uncertainty (Groves, 2006). It explored the future water availability (surface water, groundwater storage, water quality) (and water demand conditions (Zhu & Ringler, 2012; Mimikou *et al.,* 2000). Scenario development is important for designing and making robust management strategies or policies to achieve planning objectives (alleviating water stress, improving water quality, maintaining the ecosystem service) (Groves, 2006).

5.3 Drivers for Scenario Development

The analysis of the water issue in the context of sustainable development requires the adoption of a long-term view to be able to account for the slow unfolding of some of the hydrological and social processes and the necessary time for waterworks investments to yield their fruits. Projections of trends in human affairs may be legitimate over the short-term, but they become unreliable as time horizons expand from months and years to decades and generations (Gallopín, 2012).

Fundamental uncertainty is introduced both by the limited understanding of human and ecological processes and by the intrinsic indeterminism of complex dynamic systems. Moreover, social futures depend on human choices which are yet to be made (Gallopín *et al.,* 1997). Water must be viewed holistically, in its natural state as rainwater, streamflow, groundwater or potable water, and in balancing competing demands upon it for domestic, agricultural, industrial, and environmental use, in a way that ensures the sustainability of the resource (Gallopín & Rijsberman, 2000).

The approach followed will focus on the development of qualitative scenarios initially, to allow incorporation of the clusters[1] with corresponding drivers such as social, economic, environmental, cultural factors, environmental, technological, etc. The drivers that play a major role in shaping the water future, will also be modelled quantitatively. These drivers will be used to develop a framework for future agriculture water resource management. The development and discussion of qualitative scenarios will serve as a platform for consultation among many stakeholders from different disciplinary backgrounds and different stakeholder perspectives. Mathematical simulation models will be used subsequently to analyse the consistency and coherence of the qualitative scenarios, explore some of the consequences, and help fill in some of the gaps. The scenario planning process will occur in rounds of development, discussion, feedback, and subsequent improvement, in the interaction between the scenario developers, modellers, reviewers, and the groups working on visions for sectors and regions.

Scenarios are not predictions, forecasts, or projections. Rather, they are stories about the future with a logical plot and narrative governing how events unfold (Miles, 1981). A scenario is a possible course of events leading to a resulting state of the world (or image of the future it should be noted that some define the image as a situational scenario as opposed to the development scenarios, which represent the trajectories (Godet, 1987). Originally it was defined as a hypothetical sequence of events constructed to focus attention on causal processes and decision points (Kahn & Wiener, 1967). The importance of considering scenarios as courses of events is that this directs attention to the unfolding of alternatives and to branching points at which human actions can significantly affect the future. The scenario approach can also provide a common framework for diverse stakeholders to map and address the critical concerns and identify alternatives and a forum for discussion and debate.

[1] Similar drivers are grouped as clusters

The development of scenarios generally begins with the characterization of the current situation. An important step is represented by the definition of the critical dimensions describing the scenario. Collectively, they define the multidimensional space within which scenarios can be mapped or constructed. Dimensions do not necessarily imply causal assumptions; rather, they are defined in terms of their relevance, as descriptors of the most important attributes of the images of the future (Gallopín & Rijsberman, 2000). The major drivers propelling the agricultural water scenarios have been identified and categorised in the following clusters as shown in Table 5.2.

Table 5.2: Drivers and clusters for scenario planning

#	CLUSTERS	DRIVERS	
1.	Natural/Ecological	• Climate change & variability • Water availability • Rainfall • Groundwater • Streamflow • Dams/reservoirs • Climate extremes (droughts / floods)	• Land degradation • Water quality • Water pollution • Soil Salination • Ecosystem health • Land use
2.	Cultural	• Innovative thinking and doing • Dependency syndrome • Entitlements • Productivity	• Cultural values • Values of care for the water • Attitude of the group
3.	Technological	• Rainwater harvesting techniques • Irrigation technology • Desalination technology • Water recovery technology • Groundwater recharge • Engineered wetlands	• New Alternative technology (Super oxidants technology • Water sanitation investment • Adoption of new crops • Precision agriculture
4.	Economic	• Capital availability • Shift in production systems (SADC) • Bankability - South African economy - Water sector - Agriculture • Energy price (input costs)	• Subsidies • Economic output • Waterworks investment • Economic prosperity • Globalisation • International markets
5.	Human	• Education • Capacity within the water sector • Attitude of individuals	• Cadre deployment • Leadership capacity
6.	Social	• Population growth/HDI • Agricultural organisations • Community groups • Civil society involvement • Lifestyles • Poverty	• Inequality • Migration pressures • Urbanization • Civil action • Rural safety and security
7.	Political	• Land reform policy • Racial disparities • Internal political conflict • Level of conflict	• Understanding • SADC collaboration (Lesotho) • Power structure • Policy and political employment
8.	Organizational	• DWS, DAFF, COGTA, DEA functionality • The capacity of government organizations to fulfil mandate	• Local governance capacity • Farmers Organizations – AFASA, NAFU, AgriSA • Commodity organizations
9.	Infrastructure	• Siltation of dams • Inter-basin transfers	• New water infrastructure • Maintenance of current infrastructure
10	Institutional	• Coordination and collaboration between governance structures • Rules and regulations of water management	• Monitoring • Water management policies

Examples of possible dimensions are economic growth, social progress, environmental quality, conflict level, etc. Next, the major driving forces must be identified; they represent the key factors, trends, or processes which influence the situation, focal issue, or decisions, and propel the system forward and determine the story's outcome. Some of these forces are invariant over all scenarios; that is, they are to a large extent predetermined (Schwartz, 1991).

The drivers listed in Table 5.2 were not the final list of drivers and changed after consultations with expert groups, workshops, and national symposia. The purpose of the list of potential drivers was to use it as a basis for future discussion where some drivers might be eliminated or grouped. The final process for scenario building was to identify the main drivers and allocate weightings to different drivers and or clusters of drivers.

These drivers influence, but do not completely determine, the future of agricultural water utilization and management. Thus, while the initial drivers are the same in all scenarios, the trajectory of the global system follows a different course in each of them. Some of the driving forces may represent critical uncertainties, the resolution of which fundamentally alters the course of events (Gallopín & Rijsberman, 2000). A detailed discussion of the drivers and clusters will be done in the next section.

5.4 Agricultural Water Use Drivers in South Africa

The four Dublin Principles of 1992, which are still relevant till today states the following:

- Principle 1: "Freshwater is a finite and a vulnerable resource, essential to sustain life, development and the environment";
- Principle 2: "Water development and management should be based on a participatory approach, involving users, planners, and policymakers at all levels";
- Principle 3: "Women play a central part in the provision, management, and safeguarding of water",
- Principle 4: "Water has an economic value in all its competing uses and should be recognized as an economic good".

Furthermore, the Hague Ministerial Declaration of March 2000 adopted seven challenges as the basis for future water action and included in the World Water Development Report (WWDR) as the basis for monitoring the progress of all water management plans and strategies. These are:

- Meeting basic needs for safe and sufficient water and sanitation
- Securing the food supply especially for the poor and vulnerable through more effective use of freshwater resources
- Protecting ecosystems by ensuring their integrity via sustainable water resource management
- Sharing water resources promoting peaceful cooperation between different uses of water and between concerned states, through approaches such as sustainable river basin management

- Managing risks to provide security from a range of water-related hazards
- Valuing water by managing water in the light of its different values (economic, social, environmental, cultural) and to move towards water pricing to recover the costs of service provision, taking account of equity and the needs of the poor and vulnerable
- Governing water wisely by involving the public and the interests of all stakeholders.

A key component of water scenario building is the development of a set of drivers for the water sector. Drivers must present the complex phenomena of the water sector in a meaningful and understandable way to decision-makers as well as to the public (WWAP, 2009). They must establish benchmarks to help analyse changes in the sector in space and time in such a way as to help decision-makers to understand the importance of water issues, and involve them in promoting effective water governance (WWAP, 2009).

5.4.1 Natural/Ecological Drivers

These drivers express the articulation of territory based on the category of use (rainfall, water bodies, forests, agricultural, urban areas, and grazing land). Water stocks, including geographic and temporal distribution, renewability, quality, and availability (as affected by climate change, by ecosystem processes, by agricultural, industrial and drinking consumption, and by the technology employed). There is evidence that the global climate is changing. The main impacts of climate change on humans and the environment occur through the water. Climate change is a fundamental driver of changes in water resources and an additional stressor through its effects on other external drivers. Policies and practices for mitigating climate change or adapting to it can have impacts on water resources, and the way we manage water can affect the climate (WWAP, 2009). Managing water has always been about managing naturally occurring variability. Climate change threatens to make this variability greater, shifting and intensifying the extremes and introduces greater uncertainty in the quantity and quality of supply over the long term (Connor *et al.,* 2009).

The ecological status, as an indicator for monitoring sustainable water management, is a very important driver for measuring water use efficiency. An increasing number of river basins lack sufficient water to meet all the demands placed on them, and competition among users can be intense (WWAP, 2009). The Millennium Ecosystem Assessment has demonstrated how modifying landscapes to increase food production and allow development has resulted in adverse ecological changes to many ecosystems, with accompanying loss and degradation of ecosystem services.

Synergistic and cumulative effects can make it difficult to attribute changes to a single cause. Losses have adverse effects on livelihoods and economic production, and some ecosystems have passed thresholds into regime shifts, with a collapse in ecosystem services, making the cost of restoration (if possible) very high (Muir, 2007). The biggest threat today, and for the foreseeable future, however, is the deteriorating quality of water resources due to poor management of water by all governance institutions. The DWS is primarily responsible for the monitoring of water resources while local and regional governance structures disregard their responsibility for water management. Raw sewerage water is discharged in major rivers with DWS not doing anything or very little about the problem. Water infrastructure management and management of water resources are probably one of the main drivers for future water scenarios in the agricultural sector.

South Africa is a semi-arid country with high climate variability. Dry periods and droughts will have a decisive influence on the rainfed agricultural sector. Future dry periods will have a strong influence on production patterns and adaptation measures. One of the main push or pull factors for agriculture is climate. South Africa is a water-scarce country with climate extremes and farmers will either change production systems to adapt or they will shift production to areas with a better climate for production, which provides a comparative advantage. An example is where rainfed crop farmers in South Africa moved to the northern parts of Zambia, Mozambique and the northern parts of Botswana with higher rainfall and excellent climatic conditions for rainfed crop production.

The monitoring and management of groundwater resources and smaller farm dams will become more important. Siltation of dams is also an important driver that needs to be monitored and controlled. Increased land degradation might increase dam siltation.

5.4.2 Cultural Drivers

Culture describes the patterns of human activities and the symbolic structures that impart significance and importance to these activities such as art, institutions, science, beliefs, and moral systems (Gallopín, 2012). Because such structures are passed from generation to generation, culture can be defined as the way of life for an entire society. In several regions, the empowerment of women has emerged as an important driver, particularly at the household and community levels. The perceived values of natural resources reflect cultural perspectives as well as economic perspectives. Lakes and reservoirs, for example, provide many valuable services, including water for drinking and sanitation, agriculture, industry, and livestock uses and, in the case of reservoirs, for electricity generation (Lutz *et al.,* 2008). They serve as buffers against water shortages and excesses and as contaminant sinks for their drainage basins. They provide food and economic livelihoods through fisheries, aquaculture, and environmental tourism. They are important aquatic ecosystems and provide habitat for rare and threatened species (Morton *et al.,* 2008). Also, they can possess important cultural and religious values that emphasize humanity's connections to the natural world. Which of these uses are pursued or emphasized depends largely on the cultural perspectives and economic values assigned to them by society (Gallopín, 2012).

The cultural cluster refers to drivers such as an attitude toward innovation and innovation capacity (*"boer maak n plan – umfama wenza icebo – umlimi wenza uhlelo"* attitude), dependency syndrome, entitlement, productivity, attitude, and cultural values. These values create some of the greatest pressures on how water is perceived, utilised, and managed. The cultural processes can directly affect water management challenges through increased water demands and consumption and pollution resulting from water use often for cultural purposes and rituals or the lack of conscience for the value of proper water management. Cultural behaviour and cultural beliefs have a direct impact on how people perceive and manage climate extremes such as dry periods and droughts. Evidence exists on the impact of cultural beliefs on the resilience of livestock farmers for example (Jordaan *et al.,* 2017). These cultural beliefs will impact on future dryland agricultural systems and water management in rainfed systems. They affect water use patterns directly and indirectly through changes in land use and adaptation strategies (some cultures for example have restrictions as to who can use land and water resources), with significant implications at local, regional, and global levels. Also, the availability and quality of water as well as trends in water use can influence cultural processes as well (Lutz *et al.,* 2008).

Probably the most important cultural indicator as a driver for future water management scenarios is the attitude of leadership to water as a strategic resource for the future economic development of South Africa. The attitude of civil society is important but strong direction and leadership can ensure the required attitude amongst water users and civil society in general.

5.4.3 Technological Drivers

Water supplies are being enhanced in many countries through innovative wastewater treatment and reuse techniques. Technological innovation is driven largely by both human wants and needs (WWAP, 2009). Technological innovation can create both positive and negative pressures, sometimes simultaneously, resulting in increased or decreased water demand, supply, and quality. Technological innovation is one of the most unpredictable drivers. It can create rapid, dramatic, and unexpected changes, both in pressures and solutions (Gallopín, 2012).

Technological innovation and dissemination are amongst the most important drivers for future water management scenarios. These include amongst others (i) rainwater harvesting, (ii) precision agriculture, (iii) irrigation technology, (iv) desalination, (v) water recovery technology, (vi) groundwater recharge, (vii) engineered wetlands, (viii) super oxidants technology, (ix) water sanitation investment, (x) adoption of new crops. Technological innovation should focus on (i) increases in water use efficiency in all systems, (ii) cost-effective desalination technologies, (iii) technologies to reduce water pollution, (iv) water decontamination techniques, (v) development of new crops (for example salt-tolerant varieties),(vi) desalination plants, (vii) traditional and science-based Eco-technologies, (viii) new water storage and transportation technologies (Gallopín, 2012).

Four types of technology might have the biggest impact on future water use management in the agricultural sector.

- First is the application of new irrigation technology that increases water use efficiency with increased production output per volume unit of water.

- Second is the technology in especially urban environments as well as in agriculture to implement the re-utilization of the same water for different purposes. This includes the design of new urban water infrastructure with a different water supply and reticulation systems; the separation of blue, grey, and black water.
- The third important technology is the application of smart agriculture in both rainfed and irrigated agriculture
- The fourth most influential technology is rainwater harvesting. Smart agriculture combines precision agriculture with minimum tillage, which is a very important water harvesting or water-saving technology in that it limits levels of water evaporation. These technologies are extremely important in rainfed crop production systems. Rainwater harvesting and conservation is essentially a technique to collect, channel, and store surface water run-off for household consumption, livestock watering, and food production. Water-harvesting methods can be classified as macro-catchment methods such as small farm dams; and micro-catchment, on-farm methods such as contour ridges, and run-off strips (Backeberg, 2009). Rainwater harvesting techniques are probably one of the major drivers for rainfed agriculture.

5.4.4 Economic Drivers

Growth and changes in the economy have far-reaching impacts on water resources and their use. Water is needed for the production of energy of all types, so expansion of energy supply will affect water resources. Water is affected by economic forces, while the state of water resources has strong feedback on the economy (WWAP, 2009). Lack of water storage infrastructure may cause heavy economic losses from flooding and drought. Polluted water has high costs for human health. In short, adequate investments in water management, infrastructure, and services can yield a high economic return by avoiding such related costs. Growing international trade in goods and services within the SADC region can aggravate water stress in some SADC countries while relieving it in others through flows of ‘’*virtual water’’*, particularly in the form of imported agricultural commodities. According to the Commission on Growth and Development, there are many potential causes for the continuous increase in global food prices. Contributing factors include rising demand, shifting diets, droughts, increased costs of agricultural inputs (such as fertilizers), and policies that encourage the use of agricultural land and output for bio-energy production (Gallopín, 2012). It is very important to note that these factors greatly influence water availability and it is believed that policies favouring bio-energy over food need to be reviewed (WWAP, 2009).

Global markets, competition in agricultural production, cost of production, production prices, availability and affordability of insurance products are amongst the main drivers that will influence future production patterns in both the rainfed and irrigation agricultural systems. Rainfed crop production is regarded as a higher risk than irrigated crop production, yet livestock production in rainfed areas seems to be a low-risk system. The market and profitability of agricultural systems are in most cases decisive factors influencing production decisions. Most business managers will naturally follow production systems with the highest return on investment and it might be the case with some farmers but the vast majority of farmers follow systems familiar to themselves. The choice of agricultural systems is normally influenced by a combination of scenario drivers and it includes drivers grouped under ecological, human, social, cultural financial, and other clusters.

Future market mechanisms are important drivers in that it will impact of agricultural systems. The traditional auction system for livestock is already replaced with computer-based auctions. Small scale farmers are currently disadvantaged because of the computer-based auction system due to lack of access to the internet and economies of scale. The internet will play a more important role in marketing strategies not only for livestock but also for other agricultural commodities.

Economic drivers are directly linked to the willingness of the Government to invest in water infrastructure and to appoint qualified people to manage our water resources.

5.4.5 Social Drivers

Social drivers influence the resilience of people and communities against external shocks and also play an important role in the adoption of new technology. Human perceptions and attitudes about the environment, including water resources, in turn, influencing the pressures people exert on water through water demands and uses. Changes in lifestyles are one of the principal drivers of change. They reflect human needs, desires and attitudes (as illustrated in consumption and production patterns), which are influenced by social drivers as well as cultural, educational, economic drivers and technological innovation; the rapid global rise in living standards combined with population growth presents the major threat to the sustainability of water resources and the environment (Björklund *et al.,* 2012). Social drivers are about both individual and collective actions and also about the way people think and act on a day-to-day basis. The social drivers that will be considered here include population growth/HDI, poverty, education, cultures and value systems, and lifestyles, migration pressures, urbanization, consumption patterns, and social support structures.

According to the UN, whatever actions are taken to reduce poverty, it must also be recognized that increasing the economic wellbeing of the very poor will ultimately translate into higher demand for natural resources, especially water. An educated populace typically has a better understanding of the need for sustainable use of aquatic ecosystems and the important environmental goods and services they provide (Gallopín, 2012).

Lifestyles and associated consumption choices are increasingly considered the most important drivers affecting water resources, along with population growth (Gallopín, 2012). And the pressures these drivers generate can be transmitted through trade and investment activities. As standards of living continue to rise in South Africa, the demand for larger homes and 'luxury' items such as kitchen appliances, cars, and other vehicles and the energy to run, heat and or cool them is increasing the demand for the resources required to produce, generate and operate them. The desire for a better lifestyle is arguably one of the most powerful human motivations, and the production of goods to satisfy this growing human wants is often not possible without the overuse of natural resources (Gallopín & Rijsberman, 2000).

The way civil society organise themselves in advocating for proper water management in SA could become an important social driver towards responsible water management. Equally important is how water users and specifically the irrigation sector approach water use management.

5.4.6 Human Drivers

Human drivers point to the capacity of individuals and leadership for water management. An important driver here is the education and training of qualified people to manage water in all its elements in SA. The training and education of hydrologists, engineers, and other experts is a major challenge in SA. The willingness and capacity of local governments to appoint experts to manage water systems will determine water management at the local level while expertise on national is required for proper management at the national level. It is currently a well-known fact the water sector lacks the required expertise to properly manage water in SA. Leadership is also an important human driver that will have a decisive impact on future water management scenarios. Important here is political leadership as well as leadership within the state that directs an important department such as DWS.

Education is one of the most important human drivers. Education can lead to greater water use efficiency. For example, knowledge of water systems, new materials, and emerging technologies (such as package treatment plants) can help extend water services to informal areas. Knowledge of water conservation practices also facilitates improved water use efficiency in these areas (Hoekstra & Chapagain, 2008). More education (human indicator) enables people to improve their economic circumstances, leading to empowerment, better health, and longer life expectancy. At the community level, the education of broad segments of society can accelerate the demographic transition, through declines in fertility and infant mortality rates (Institute for Statistics, 2006).

Human drivers also have an impact on the behaviour of individuals in terms of the adaption and application of new technologies and adaptation strategies. Farmers with higher education levels for example might be better informed on technologies and the application of *"smart"* agricultural strategies than lower educated farmers. Age is also an important driver in that younger farmers tend to be more open to new technology. Few young farmers are interested in traditional/communal farming systems because of the perception of poverty and low-income levels. The youth tend to move to urban areas where they can find jobs and entertainment. This might be an important driver for future traditional farming systems.

5.4.7 Political Drivers

Policy-makers need to make political decisions on socially and environmentally acceptable trade-offs among different objectives and on who bears the costs of such compromise (Comprehensive Assessment of Water Management in Agriculture, 2007). The UN stated that 'political negotiations involved in global and regional and local water arrangement or water-sharing agreements are meant to avoid conflicts between different uses or users of water because they serve as major drivers for water resource management". Governance of the water sector is complex and involves actors beyond the water sector. The actors can be national legislatures and governments, other sector agencies, local governments, river basin authorities, representatives of indigenous peoples, consumer bodies, private companies, and others (Gallopín & Rijsberman, 2000). Who is involved may differ with the issues concerned, for example, surface waters, groundwater, coastal waters, or wetlands. Effective action on such a complex group of interests requires open communication and strong coordination facilitated by an appropriate legislative and regulatory framework (Rosegrant & Ringler, 1999). Although water allocation systems can be difficult to establish, managing competing water uses requires clear, widely accepted allocation rules, especially where water is scarce. Water allocation systems should balance equity and economic efficiency (Kariuki & Schwartz, 2005).

Some of the major political drivers of water use in South Africa are (i) land reform, (ii) internal political conflict, (iii) level of conflict in society, (iv) political perceptions of agriculture, (v) corruption, (vi) SADC collaboration, (vii) future border control mechanisms, which is linked to SAC collaboration, and (viii) power struggles. The allocation and utilization of water for BEE might also impact future water management scenarios.

5.4.8 Organisational drivers

Organisations refer to government departments and private sector companies. The management and leadership in government departments are decisive in the performance of departments to efficiently execute their mandates. The future state of departments such as DWS, DEA, DAFF, Rural Development, and COGTA will play an important role in future water management scenarios. Organizations such as AFASA, NAFU, and AgriSA as representing farmers as well as commodity organizations are grouped under social drivers since these are socially driven and managed. Other organizations that might be important are the water management authorities, agricultural cooperatives and businesses, and agro-processing business.

5.4.9 Institutional Drivers

Various institutional drivers are very important in water resource management. These drivers ensure according to Gallopín (2012), proactive decision-making (anticipating policy consequences and negative impacts), global, national and local water policies, regulations and laws enforcement, functioning water resource and use of monitoring and reporting systems in place, integration of water resource management with national development planning, effective and efficient water management at national and river basin levels involving government and nongovernmental organizations.

Effective policy and legal frameworks are necessary to develop, carry out, and enforce the rules and regulations that govern water use and protect the resource. Water policy operates within a context of local, national, regional, and global policy and legal frameworks that must all support sound water management goals (Gallopín, 2012). Legitimate, transparent, and participatory processes can effectively mobilize input for designing and implementing water resources policy and create a strong deterrent to corruption (Muir, 2007). Although water is often described as a *''gift of nature''*, harnessing and managing it for a wide variety of human and ecological needs entail financial costs (IWMI, 2003). While there may appear to be many financing options for water resources development, governments still have only three basic means of financing them: tariffs, taxes, and transfers through external aid and philanthropy (Gallopín & Rijsberman, 2000).

The World Water Vision report concluded that both public and private management of water will improve through greater accountability, transparency, and the rule of law. Incentives must improve for all stakeholders. More community participation will provide a sense of ownership and empowerment to local stakeholders. The role of education in making this process possible cannot be overestimated. Public access to information will provide an incentive to elected officials and private operators, who will be held responsible for results, including maximizing social welfare. It will also reduce opportunities for corruption and capture of the system by powerful elites (WWDR, 2009).

The most important institutional driver is how DWS, DAFF, DEA, Rural Development, and local government will correct the current deficiencies to provide sound institutional support and efficient collaboration between departments.

5.4.10 Infrastructural Drivers

The main diving forces in the infrastructure cluster are linked to infrastructure requirements for multiple water users. The competition for irrigation water will increase with economic growth and population growth. Irrigation currently uses approximately 60% of potable water and streamflow; the same water sources utilised by industry, tourism, drinking water, and sanitation. Drivers that will influence available water for the irrigation sector also are (i) changes in water infrastructure design (from massive to small-scale and flexible; integration of ecosystems into infrastructure), (ii) ratio of water stored to the potential for storage, (iii) trans basin and transboundary water transfer, (iv) obsolescence of existing waterworks (e.g. due to climate change as well as aging), (v) changes in groundwater reserves and withdrawals. The level of over-pumping of groundwater might also have an impact on future water management (Gallopín, 2012).

The aging infrastructure and the lack of maintenance of current infrastructure will have a decisive impact on future water management scenarios. Also important here is the building of new water infrastructure to meet future water demands in SA. Infrastructure, technology, and financing of infrastructure together will influence future water management scenarios on the one hand but also economic development scenarios since the SA economy depends on the availability of good quality water. Infrastructure drivers for rainfed agriculture are linked mainly at the micro or farm level where water reticulation systems for livestock production need to be maintained and upgraded. Infrastructure for water reticulation in communal land is non-existent or poorly developed and maintained and it might become an important driving force depending on future government policy and support to communal farming systems.

5.5 The Need for a Long-Term View

A long-term view of the water for sustainable development requires taking into account the slow unfolding of some hydrologic, environmental, and social processes and allowing time for waterworks investments and water mitigation schemes to yield results. The need to make decisions in a context of high uncertainty. Decision-makers in the water sector must often address water management issues against a background of rapidly changing environmental conditions and increasing uncertainty. The uncertainty results from both a limited understanding of human and ecological processes and the intrinsic indeterminism of complex dynamic systems. Further, water resources futures depend on future human choices, which are unknown.

The need to include non-quantifiable factors is already illustrated in the discussion of the different drivers. The world’s water system includes and is influenced by many factors that are difficult to quantify (such as cultural and political variables and processes), as well as factors that can be quantified and modelled mathematically (such as hydrologic and climatological dynamics and economic factors). Qualitative scenario analyses can provide insight into these factors that simulation models cannot.

5.6 The Need for Integration and Breadth

Water resources must be viewed holistically, considering both their natural state and the need to balance competing demands – domestic, agricultural, industrial, and environmental to ensure sustainability. Decisions on land use can affect the availability and condition of water resources, while decisions about water resources can also affect the environment and land.

This study deals with agricultural water management – both rainfed, irrigation, and water required for agro-processing – therefore policies and institutions that develop and implement water policies have a great role to place in driving future water management. Political drivers are very important for deciding on socio-economic development objectives and formulating policy and operational decisions to achieve them. Their decisions, which respond to life and livelihood requirements, are implemented in a context of externalities often beyond their direct control that interacts with and modifies drivers of change, creating pressures on land and water resources (among others) (WWAP, 2009).

Water institutions (water resources managers) deal with addressing the demands of water uses to meet the life-sustaining requirements of people and other species and to create and support livelihoods. In doing so, they may add to or reduce the pressures caused by these drivers. However, their actions may fall short of their objectives because of constraints related to inadequate water, financial or human resources or because the external forces are behaving in unforeseen ways. Making progress thus requires a return to the original political actors in the decision-making process for responses that take these constraints into account.

Figure 5.1 is an illustration of a draft decision-making system in the water sector.

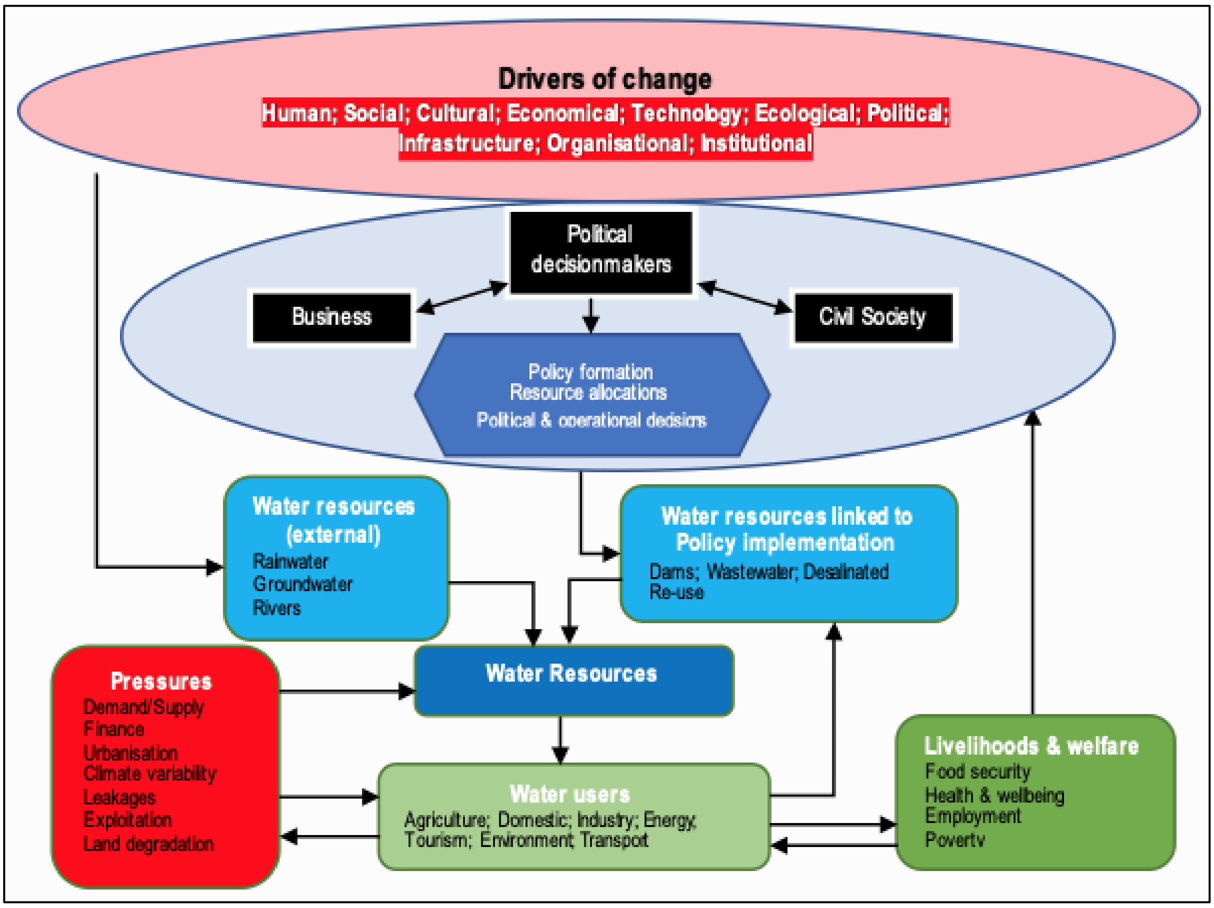

Figure 5.1: Draft decision-making activities affecting water use
(Adapted from: World Water Assessment Program (WWAP), 2009)

5.7 Conclusion

The future of agricultural systems in South Africa depends on multiple numbers of factors that interact with each other. Many farmers already diversify and invest in other SADC countries. If SADC becomes an open border region we might see the free flow of people and more farmers investing in higher rainfall regions. That will change the face of especially rainfed agriculture where we will see more extensive livestock production in the semi-arid areas of South Africa and increased rainfed crop production in higher rainfall areas of Zambia, northern Botswana, Mozambique, and Zimbabwe – if the political environment improves.

Figure 5.2 illustrates the push and pull factors currently influencing the movement of commercial farmers in SADC. As entrepreneurs, individual commercial farmers, and large-scale food production companies need to make profits. Profits in agriculture depend on sustainable production and reliable markets and good management principles just as in any profitable business. Farmers or farming businesses have to be competitive and they shift to products, markets, or geographical regions where they have a competitive advantage.

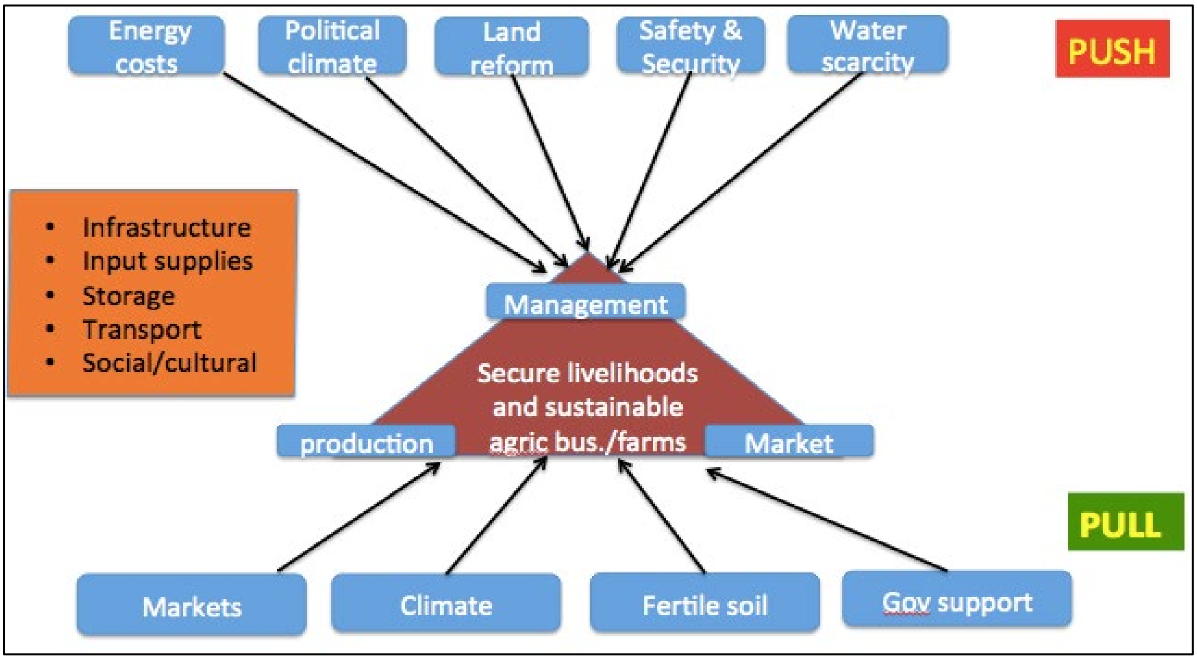

Figure 5.2. Push and pull factors for geographical food production shifts in southern Africa
(Source: Jordaan, 2017)

Water, energy, and governance are core motivations for companies that invest in agriculture in certain areas. Food production naturally moves away from water-scarce areas with high energy costs with regards to agricultural production; called a push factor. Push factors noted by farmers who already shifted production to Zambia and Botswana are (i) energy costs, (ii) rural safety and security, (iii) negative political climate towards agriculture, (iv) land reform and threats of land expropriation without compensation, (v) water scarcity and extreme droughts coupled with low rainfall for rainfed agriculture. Some of the push factors might be subjective and based on personal perceptions of individual farmers but it is already the cause of the movement of many farmers to other SADC countries. The pull factors noted by farmers are (i) the market, (ii) fertile soils, (iii) favourable climatic conditions, and (iv) a political climate favouring food production. Barriers to this movement include poor (i) infrastructure such as roads and storage facilities, (ii) shortage of input supplies, (iii) social and cultural changes, and (iv) border controls. For the entrepreneur, these factors provide additional opportunities.

The geographical shift in agricultural production systems depends on several driving forces and the geographical movement in itself is a strong driving force that will impact future water management scenarios. Each of the water drivers is dynamic and continues to evolve, as do the direct and indirect pressures they exert on water resources. Thus, it is difficult to draw a comprehensive picture of the future by examining each driver independently. The drivers interact and can have even more of an impact on future water resources collectively than they can individually. Future scenarios that consider these interactions offer a more holistic picture (WWAP, 2009).

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6 RESULTS FROM CONSULTATIVE WORKSHOPS AND DISCUSSIONS

6.1 Introduction

The competition for freshwater use in South Africa is growing and sometimes leads to conflicts in the use of freshwater resources. Conflicts over quality and quantity of water are usually caused by water scarcity caused by uneven precipitation, multiple water users competing for the same scarce freshwater resources, and/or water pollution caused by discharging waste into water (Wei et al., 2010). Decision-making in water resource management in South Africa involves conflicting objectives, such as allocating the scarce freshwater resources to the different sectors of the economy to maximise economic growth and minimise the effect of poverty (improve economic prosperity). In such cases, the decision-makers will be tasked with policies that balance the conflicting objectives in a socially acceptable manner (Raquel et al., 2006).

When objectives are conflicting, improvements in one objective can only be achieved at the expense of another objective (Raquel et al., 2006). For example, allocating more water to the industrial sector at the expense of agriculture or food sector. Policy/decision-makers will have to choose from different alternatives and seek the best possible outcome. Given the fact that different stakeholders are involved in the process, it becomes even more complicated with each stakeholder having a different set of priorities concerning freshwater resources (Raquel et al., 2006). The allocation of water resources to the different users is further complicated by the fact that there are multi-stakeholders involved in the water sector, both internally and externally. It is therefore very important to adopt a bottom-up approach to policies regarding water management and distribution.

Given the recurring drought in South Africa (which has resulted in certain parts of the country running out of freshwater resources), the declining contribution of the agricultural sector to the GDP of South Africa (despite it being the highest water consuming sector in the country), the conflict by various water users on the use of freshwater resources, and the need to manage available freshwater resources to ensure sustainable food production to feed the growing population, it is crucial to develop future water scenarios that will provide guidelines for proper policy implementation regarding water use. It is also very important to resolve the conflict over freshwater use to ensure equitable, efficient, and sustainable use of water resources. However, there is very little information available on scenario building in agricultural water management that will guide policymakers in developing appropriate policies to ensure the sustainability of freshwater use in South Africa. Given the importance of the agricultural sector to the South African economy and the uncertainty that surrounds the future of demand and supply of water in South Africa, an empirical study needs to be done to develop possible scenarios in agricultural water use that will aid governments and other stakeholders in the industry to develop policies towards enhancing water use efficiency and productivity, and reducing poverty and food insecurity in the country.

This study will develop scenarios and system dynamic models to simulate future water use, resolve the current conflicts in freshwater use in South Africa. Causal loop diagrams (CLDs) based on the principle of system dynamics technique has been the most used modelling technique in resource management modelling in environmental economics over the years to simulate policies and develop relevant scenarios (Schreider et al., 2007). Although the general understanding of water resource problems in Africa in general, and South Africa in particular, has grown in recent years, the ability of policymakers to improve their decision-making is still limited. Participatory modelling and stakeholder engagement is an important tool that can facilitate strategic decision-making in environmental/natural resource management systems. To this end, this study focused on developing an integrated qualitative, conceptual model using causal loops diagrams (CLDs) – after identifying all the relevant clusters and drivers of change in agricultural water management in South Africa from the different workshops – with the focus to assist integrated water resources management and sustainable agricultural development in South Africa.

6.2 Methodological Approach to Scenario Building

A mixed methodological approach based on qualitative and quantitative modelling techniques was adopted for this project. The qualitative tools applied a participatory approach whereby relevant stakeholders in the water and agricultural sectors across South Africa were consulted and included in the study in a series of interactive workshops. These workshops were important to identify drivers of change, trends, and processes influencing the sustainable management of water resources and agricultural development in South Africa. The qualitative tool used was participatory conceptual modelling. Conceptual modelling – based on the principle of system dynamics – provides a suitable methodology for capturing the opinions of all relevant stakeholders, and representing those opinions visually to help understand a complex system, especially when there is uncertainty about the system, or quantitative data is limited. (Argent et al., 2016; Zare et al., 2019).

System dynamics methodology was developed almost half a century ago as a framework to model the interactions of drivers and their influence on the functioning of a complex system, with the main aim of improving the understanding of the causal relationships that interact, so as to determine the dynamic behaviour of a complex system (Forrester, 1961). System dynamics modelling (SDM) uses systemic feedbacks to simulate and gain insights into the complex behaviour of the system (Mirchi et al., 2012; Kotir, 2020). SDM equally examines the causal-relationships that exist between key drivers of change (such as biophysical, economic, and social drivers) influencing the behaviour of the system (Walters et al., 2016). SDM is a useful tool for simulating complex system problems through the structural identification of feedback structures that determine the behaviour of the system (Sterman, 2000; Khan et al., 2009). SDM is a powerful modelling technique for *"framing, understanding and discussing complex issues and problems"* (Azar, 2012 pp 45). SDM combines qualitative and quantitative models to understand how information feedback governs SDM behaviour, and assist in designing robust information feedback structures and control policies through simulation and optimisation (Coyle, 1997; Galanakis, 2006; Azar, 2012).

Efforts to enhance the sustainable management of water resources and agricultural productivity in a catchment are very complex because they involve several actors, some of whom go beyond the water and agricultural sectors. (Videira et al., 2010; Voinov et al., 2016). Participatory modelling (PM) allows for such diverse stakeholders – with a comprehensive understanding of the systems – to be included in the modelling process through stakeholder feedback, and allows transparency in the model, and acceptance by stakeholders, due to their engagement in the modelling process (Carr, 2015; Voinov et al., 2018; Crevier & Parrot, 2019).

Conceptual modelling is one of the methods used in the PM process and is preferable because it increases the understanding of complex dynamic systems where there are several drivers of change (variables) interacting with each other to develop multiple feedbacks and processes. According to Horlitz (2007:1098), *"PM is very relevant because stakeholders are directly involved in the design of the models, which ensures that the models are aiming at the problems and stakeholders can use it".*

Several studies have stressed the importance of stakeholder participation in water management modelling (see Videira et al., 2010; Davies & Simonovic, 2011; Carmona et al., 2013a,b; Lopes & Videira, 2017; Kotir et al. 2017; Basco-Carrera et al., 2017; Pluchinotta et al., 2018). One of the benefits of the PM approach is that it facilitates the engagement of all relevant stakeholders (technical, non-technical, and local experts) during the modelling process, and facilitates their mind maps, thereby creating an environment for social learning, and increasing the credibility of the model outputs and legitimacy of management decisions (Kotir et al., 2017). Some studies have reviewed in detail the use of system dynamics in water resource management (Winz et al., 2009), and PM as a modelling approach with stakeholders using a variety of techniques (Voinov et al., 2016; Voinov & Bousquet, 2010).

System dynamics based on causal loop diagramming (CLD) was chosen for this study because the stakeholders included local experts, some of whom had little or no knowledge of modelling. According to Sterman (2000), causal loop diagrams (CLDs) based on the systems thinking approach can show, through a simple graphical structure, the cause-effect relationships between a set of variables that characterise a dynamic system.

Causal loop diagrams (CLDs) are useful tools for mapping the feedback structure of systems in any domain. They provide simple maps showing the causal links among variables with arrows from a cause to an effect (Sterman, 2000). CLDs provide a useful tool for the visualisation and communication of environmental problems, especially when dealing with a complex system that has multiple drivers influencing the system. Unlike Bayesian networks, fuzzy cognitive mapping, and other visualisation tools that have been used in PM, CLDs can model system feedbacks and delay processes in a dynamic and complex system.

Comparatively, a Bayesian network is inherently acyclic, and cannot represent feedbacks and delays within the structure of dynamic and complex systems (Kotir et al., 2017). See a detailed discussion of CLDs in chapters 7 and 8.

Quantitative systems dynamics modelling was applied to simulate different policy scenarios using historical data. The quantitative model was used to model the important feedback inherent in the Breede river catchment. Data for this model was obtained from secondary sources such as previous studies in the catchment, Western Cape Department of Agriculture, Western Cape Department of Environmental Affairs, and the Breede river management agency. The Breede river catchment was selected for this study because it is one of the strategic catchments in South Africa, with an effective management system in place, and available data. A detailed explanation of the modelling process, the data used and the different sub-systems are presented in chapter 9. This thesis adopts a publication route and thus has provided the details of each method used in the manuscripts drafted. To avoid repetition, this section provided only a synopsis of the methods used in the study.

The next section provides the framework that guided the categorisation, identification, and analysis of drivers of change presented in this chapter. The first section presents the framework for categorising the drivers; the next section presents a brief discussion on the selection of relevant stakeholders included in the study; the third section presents a detailed discussion on the different stakeholder workshops organised as part of this study and; the final section presents the concluding remarks.

6.2.1 Community Capitals Framework (CCF7)

Managing water and food systems in South Africa is complex because these systems have several drivers, trends, and processes interacting to influence their functioning. A lack of understanding of these drivers, their characteristics, and dynamic interactions by decision-makers and relevant stakeholders increases the vulnerability of a system to external shocks and/or stresses. The lack of foresight in managing the water and food systems reduces the capacity of decision-makers and stakeholders and exposes the systems to external shocks and stresses (Frankenberger et al., 2013). Despite the importance of these drivers of change in policy development and implementation (Booth & Golooba-Mutebi, 2014), their impacts, especially in agricultural development and water management, is not well known in South Africa, where the impacts are often severe. Knowledge of the different drivers of change, and their impacts on agricultural development and water management, can enhance the capacity of policymakers, decision-makers in the private sector, and stakeholders in the agricultural and water sectors to design strategies to manage water sustainably for human well-being and sustainable food production both now and in the future (Clark, 2005; Amoako, 2019).

It is therefore important to understand in detail the drivers of change to ensure effective planning and management of the systems. The methodology proposed for the study has a strong participatory element to obtain inputs and participation from all stakeholders. To effectively identify, categorise, and analyse drivers of change in a complex system like the Breede river, the community capital framework developed by Flora & Flora (2004) and modified by Jordaan et al. (2017) was adapted and applied to this study. This framework provides a platform for the categorisation of drivers under different clusters for easy identification and analysis.

Flora et al. (2004) developed a more detailed community capital framework (CCF7) based on the analysis of entrepreneurial communities. In the context of this study, the adapted CCF7 framework was employed for its ability to handle complex systems with multiple sub-systems and stakeholders. Though the framework is primarily concerned with community sustainable livelihoods, it has been adapted to capture the drivers of change and their dynamic interactions for sustainable water management and agricultural development. According to Gutierrez-Montes et al. (2009, pp 109), *"the framework highlights interdependence, interaction, and synergy among the capitals, as the use of the assets in one capital can have a positive or negative effect over the quantity and the possibilities of other capitals"*. It should be noted that assets refer to drivers of change, and capitals refer to clusters in this study. The CCF7 framework goes beyond the identification of seven clusters; it also explores the dynamic interaction amongst the seven clusters and the influence that they have on the overall functioning of the system (Jordaan et al., 2017).

The CCF7 framework can be used as a tool for analysis, and as a way to assist project managers to identify key boundary partners (Fey et al., 2006; Flora et al., 2007). The CCF7 framework allows for the inclusion of stakeholders in the identification and analysis of relevant drivers of change under each cluster. The CCF7 framework provides a platform for decision-makers to identify the drivers with the highest impact, priority areas, and intervention strategies to ensure sustainable management of natural resources (Lemieux et al., 2011; Jordaan et al., 2018).

The CCF7 framework includes the following capitals (Flora & Flora, 2004; Flora et al., 2004):

- **Natural Capital**: the environment, soil, land, water, natural beauty, lakes, rivers and streams, forests, wildlife, soil, and the local landscape.
- **Financial Capital**: money, charitable giving, grants, access to funding, insurance, and wealth.
- **Built Capital** (Infrastructure): buildings and infrastructure in a community, schools, roads, water and sewer systems, water articulation systems, camps, and access roads.
- **Human Capital:** all the skills and abilities of people, leadership, knowledge and the ability to access resources, experience, and education.
- **Social Capital**: groups, organisations, networks in the community, the sense of belonging, bonds between people, and national and international linkages.
- **Political Capital:** connections to people in power, access to political resources, leverage, and influence to achieve goals.

- **Cultural Capital**: ethnicity, generations, stories and traditions, spirituality, habits, heritage, and cultural beliefs.

Jordaan et al. (2017) modified and added three additional key capitals to the CCF7 framework namely:

- **Organisational Capital:** organisations that play a role in drought risk reduction and drought response, namely government organisations such as departments; and civil and private organisations such as businesses, organised agriculture, NGOs, etc.
- **Technological Capital:** technology such as IT infrastructure, remote sensing products, communication systems, early warning systems, drones, etc.
- **Institutional Capital:** rules, regulations, acts, policies, and agreements that regulate how organisations work together and how things should be managed.

The ten capitals (CCF10) proposed by Jordaan et al. (2017) provided a valuable platform for identifying, categorising, and analysing an extensive list of drivers in this study. The drivers identified, categorised, and analysed in this study can form the basis of a new conversation regarding water management, and, more so, the implementation of water policies. The significance of the influential clusters and drivers of change can form the basis for decision-making around sustainable water resources management and agricultural production in South Africa and other water-stressed economies within Southern Africa and beyond.

6.2.2 Scenario Planning

Scenario planning is a framework that has been used quite extensively across different fields. This study made use of the intuitive logic approach, first developed by Pierre Wack in 1985, and later improved by SRI, Global Business Network, and Shell (Ratcliffe, 2000; Shadbolt et al., 2017). This approach has been used widely and has become a very important tool for policy planning in different areas (Goodwin & Wright, 2010). The approach generally starts with the identification of predetermined (known) drivers and critical uncertainties (Shadbolt et al., 2017). The drivers are then categorised under clusters such as social, technological, human, ecological, economic, natural, global factors, and political (Ratcliffe, 2000). Comprehensive scenarios are then developed from the most important drivers based on their impact and degree of uncertainty (Goodwin & Wright, 2010, Shadbolt et al., 2017).

Proper scenario planning usually takes time, and several sessions (workshops) are required (Konno et al*.,* 2014). In this study, interactive workshops, semi-structured interviews and two national symposia were conducted targeting academia, Department of Human Settlement, Water and Sanitation (DHSWS), Department of Agriculture, Land Reform and Rural Development (DALRRD), Department of Environment, Forestry and Fisheries (DEFF), South African Weather Service (SAWS), Agribusiness Chamber (Agbiz), AgriSA, AFASA, NAFU, water management authorities, agricultural industry leaders, and other stakeholders (such as farmers and commodity organisations) in the water sector in South Africa.

For the first set of workshops targeted at organised agriculture, the study used the approach outlined in Table 6.1:

Table 6.1: Scenario planning Approach

Steps	Approaches/Strategies
Step 1: Issues Identification	This session challenges stakeholders to strategically think, analyse, and identify key issues/uncertainties that would shape the water sector in South Africa by 2030.
Stage 1:	Key stakeholders will be tasked with identifying key issues facing the water sector in South Africa within a broader context of important capitals (social dynamics, economic, cultural, human, technological, institutional, ecological, infrastructural, and global factors).
Stage 2:	Several small groups will be created from the larger group and each assigned a capital for deliberation in great detail – to list all the issues associated with that capital, and to identify and prioritise key issues related to the capital.
Stage 3:	All issues generated by each group will be collected, and key issues identified that will shape the future of the water sector in South Africa by 2030.
Step 2: Scenario Identification	This session will have stakeholders working in groups to determine possible uncertainties that can influence the water sector in South Africa.
Stage 1:	Small groups will be created, and each group provided with a set of uncertainties regarding the water sector. Each group will discuss, debate, and deliberate these uncertainties around how they will occur and influence the water sector, and their effects on the agricultural sector in South Africa.
Stage 2:	At this stage, the uncertainties will be ranked based on their expected influence and potential impact on the agricultural sector. The uncertainties are further grouped, and plausible scenario themes are developed.
Step 3: Scenario Validation	This step involves presenting the selected scenarios and validating them against the general objectives.
Stage 1:	A general discussion will take place around the possibility and plausibility of the scenarios, and the validation of assumptions. After the various discussions and debates, at least three – and up to four – scenarios will be selected.

Source: Shadbolt et al. (2017).

6.3 Participatory Stakeholder Workshops

The project team organised three consultative workshops with farmer leaders at national level from AFASA, AgriSA and NAFU plus five stakeholder meetings with farmers and experts in Mpumalanga, Western Cape, Northern Cape, and the Free State. The first stakeholder workshop was held on 24 July 2019 at Nelspruit, Mpumalanga province in South Africa, with commercial farmers and government officials in the province. Eleven members attended the workshop in a very interactive session. The second workshop was held on 29 July 2019 in Stellenbosch, Western Cape Province with irrigation farmers. Twelve participants attended the workshop. The third workshop was held in Malmesbury, Western Cape Province on 31 July 2019, with dryland farmers. Six participants attended this workshop. The fourth workshop was held in QwaQwa, Free State Province, with smallholder and emerging farms on 13th September 2019. Sixteen participants attended this workshop. The fifth workshop was held in Upington, Northern Cape, with farmers and government officials. Eight members attended this workshop. These workshops were important because the current and future agricultural trends in South Africa were highlighted; gaps in current water policies were identified; the future of water management and agricultural development were discussed; and various drivers of change, and clusters, were discussed and selected from the viewpoint of commercial and smallholder farmers. The profile of the participants ranged from agricultural economists, disaster managers, water modellers, farmers, senior researchers, and bankers from all over South Africa.

Sustainable water resource management requires that conservation must be included in the implementation of public policy, which will require a contribution from scientific experts and non-experts (Turner, 2016). This study followed the approach noted by Turner (2016) in selecting the participants for the workshops and symposia, making the participants for the exercises as diverse as possible. Participatory planning is so important for policy development and implementation because it takes into account the views of stakeholders who are most likely to be affected by the policies.

6.4 Feedback from Stakeholder Workshops

The methodology proposed for the project has a strong participatory element in order to obtain inputs and participation from all stakeholders. The research team organised eight consultative workshops with stakeholders, and two national symposia to obtain information from water users and water managers. The summary of the workshops conducted is shown in Table 6.2.

The profile of the participants ranged from agricultural economists, disaster managers, water modellers, government officials, agri-business managers, commercial farmers, and smallholder communal farmers.

The structure of the workshops promoted interaction and discussion between experts and attendees. Experts provided informative presentations, which were followed by small group discussions and a final feedback session. This method stimulated and informed active debate, which provided important insight for scenario building. The structure of the workshops changed slightly when it was realised that time limitations sometimes didn't allow for a detailed discussion of all the drivers. It was also learned that participants did not understand how weighting should be done when the rating system ranged from zero to one. The method was changed and participants allowed to do weightings ranging from one to a hundred. That was better understood by the participants.

Table 6.2: Summary of consultative workshops

#	Organisation	Place	Date	# people participated	Profile of attendees
1	AgriSA	Stellenbosch plus virtual	12 Sept 2018	7	Executive plus provincial representatives for WC, NC, EC.
2	NAFU	Pretoria	14 Nov 2018	7	Senior Executive.
3	AFASA	Pretoria	20 Nov 2018	6	Senior Executive.
4	National Symposium	Pretoria	29 Nov 2018	44	Representatives from various stakeholder organisations.
5	Western Cape	Elsenburg	3 April 2019	23	Experts and officials in the agricultural sector, water management sector, and environmental management sector.
6	Mpumalanga	Mbombela	24 July 2019	11	Water management officials, commercial farmers (irrigation, dryland, extensive).
7	Agri WC	Stellenbosch	29 July 2019	12	Water management officials, commercial farmers (irrigation, dryland, extensive)
8	Communal & small-scale farmers	QwaQwa	31 July 2019	16	AFASA provincial farmer leader, subsistence farmers, small scale farmers, and new land reform beneficiaries
9	Northern Cape Agri	Upington	2 Oct 2019	8	Commercial farmer leaders (irrigation, extensive livestock)
10	National Symposium 2	Virtual / Pretoria	Nov 2020	39	Framers, bankers, scientists, agric-business managers, opinion leaders, government officials, media

The first national symposium provided a national platform where results from workshops were presented and discussed. The main aim of the national symposium was to bring all the relevant stakeholders together in a working and interactive environment where they could share, discuss and debate the future of agriculture and water management in South Africa. The national symposium served as a platform for all stakeholders to compare notes and contribute to the development of scenarios for future agricultural water management in South Africa.

Phase 1 workshops were conducted with AgriSA, AFASA and NAFU

6.4.1 Phase 1 Consultations

A discussion of the phase 1 consultative workshops follows.

6.4.1.1 AgriSA

A WRC Project Workshop was held on the 12th of September in Stellenbosch with heads and officers of AgriSA and representatives from AgriWC, AgriEC, and AgriNC. In attendance were Janse Rabie, Head of Natural Resources, AgriSA; Cornie Swart, President of AgriWC; Willem Symington, Vice-President of AgriNC; Wayman Kritzinger, Chairperson of Natural Resources, AgriEC; Greg Smith and Nel Coetzee, Water and Trade officers at AgriSA, respectively; Andries Jordaan, Project leader; and Aniebo Hagan, DiMTEC Research Assistant and student on the WRC project.

At this meeting, Prof. Andries Jordaan presented the identified clusters – namely, human, social, cultural, economic, political, technological, natural, infrastructure, and institutional. These clusters were then used as a framework for specific drivers. Weights were then assigned individually by each attendee and discussed in the larger group. Due to time limitations, not all drivers could be discussed.

The discussions were fruitful in that the group recognised the importance of rainfed agriculture and potential production shifts to other SADC countries with better climate conditions for rainfed agriculture. The expected pressure on irrigation water for agriculture, due to population growth and economic development, was also recognised as the main drivers for future water scenarios. Important drivers identified by the participants under each of the clusters are presented in Table 7.3.

6.4.1.2 National African Farmers Union (NAFU)

The second preparatory workshop took place in Pretoria on 14 November with NAFU senior executives; the following members attended: Dr Faith F. Radivha, J. Bosch-Wessels, Moshe Molefe, Vusumzi Stok, Percy Raduba, Jack Nkopo and Otto Mbambula (pictured).

Details of the project were explained to all members, and information shared through a participatory process. All members present were most concerned about the future of agriculture and water management in agriculture. The NAFU members highlighted the problems of emerging and small scale farmers in accessing water rights. They also mentioned that land reform farms are transferred to new black farmers without water rights. The process to obtain inputs was similar to the first workshop, with individuals allocating the relative importance of each driver and cluster, followed by a group discussion. Education, technology, and climate extremes were identified as important drivers that will influence future water scenarios. Important drivers identified by the participants under each of the clusters are presented in Table 7.3.

6.4.1.3 African Farmers Association of South Africa (AFASA)

The third workshop took place in Pretoria on 20 November, and the following AFASA executive members attended the workshop: Malesshane Masebe, Abel Nephtaly, M. Lufuno, Tshanes Mathidi, Dr Job Mthonoseni and T. Monile,

Details of the project were explained to all members and information shared through a participatory process similar to the previous workshops. All members present were most concerned about the future of agriculture and water management in agriculture. Policy and political influence were not high on the agenda, but all members felt strongly that the case of communal farmers and emerging farmers should be addressed through equitable access to all resources. Issues such as mentorship and assistance to new farmers were thoroughly discussed. Red flag issues identified were education, natural capital or climate extremes, the gap between the haves and have nots in agriculture and the lack of access to resources. Important drivers identified by the participants under each of the clusters are presented in Table 7.3.

6.4.1.4 1st National Symposium

On 29 November 2018, the project team organised and hosted a full-day national symposium titled, *"Agricultural Water Management Scenarios"* at the Grain Building, 1st Floor, 477 Witherite Road, The Willows, Pretoria. Agbiz offered the venue to the project team. The symposium was part of the nationwide consultations where the inputs of relevant stakeholders in the agricultural and water sectors were considered regarding the future of agriculture and water. The main aim of the national symposium was to bring all the relevant stakeholders together in a working and interactive environment, where they could all share, discuss and debate the future of agriculture and water in South Africa. The national symposium served as a platform for all stakeholders to compare notes and contribute to the development of scenarios for future agricultural water management in South Africa.

The 44 symposium participants represented more than 10 organisations, including DAFF, Agbiz, NAFU, AgriSA, AFASA, DAFF, DWS, NDMC, FNB, and ABSA.

The agenda of the symposium began at 9:00 am with an overview of the project by Prof. Andries Jordaan (Project leader), whereby he gave some background and context as to why the country needs to develop agricultural water scenarios.

Chantell Ilbury (project team member) from Mindofafox delivered a presentation on the art of scenario building and its value for policy development. Her presentation looked at the process of scenario building, and how it can contribute to the development of better policies in the future.

The keynote speech was delivered by Dr Frans Cronje, CEO South African Institute for Race Relations (IRR). Dr Cronje presented the future scenarios for South Africa and how it will impact on agriculture. He presented the future of the South African economy, and highlight key aspects and areas that will be affected should certain key decisions/policies be made. His presentation also looked at the political climate in South Africa, how it might change during the 2019 elections, and how it will affect the country. His presentation also examined the socio-economic situation of the country, how things might change in the future, and the people who might be affected the most.

Prof. Tony Turton (project team member) also delivered a presentation on the future challenges for agricultural water management in South Africa. His presentation examined the paradigms of scarcity and abundance, and he argued the fact that we should manage water as a flux and not as a stock. He further argued that South Africa must invest in technologies that will enhance efficient water desalination and water recycling.

Dr John Purchase of Agbiz SA gave his contribution by thanking the project team members for the brilliant initiative and pledged his support in ensuring that the project is successful. Prof. Sue Walker (project team member) from ARC also delivered a presentation on climate extremes and climate change impact on future agricultural scenarios. Her presentation examined the effects of climate change and climate variation on water availability in the future and how it will affect agriculture.

Presentations were also delivered by members of AFASA Free State. They gave a situation report on the state of small and emerging farmers in the Free State, and water distribution and use in the Province. Each participant was handed a questionnaire in the morning, which contained the identified clusters (10) and drivers within each cluster. Participants were asked to allocate a score to the drivers and clusters using the following scale:

(1) 0-25% = Not Important; (2) 26-50% = Somewhat Important; (3) 51-75% = Important; (4) Above 75% = Very Important

The questionnaire aimed to identify the most important drivers in each cluster according to allocated weights, as well as the most important clusters. An interactive session took place where each participant identified the drivers they thought were important. Lively debates ensued among participants regarding the different drivers, following which the most important drivers were identified. These are presented in Table 3.

6.4.1.5 Results from phase 1 workshops

Table 6.3 is a summary of the important drivers of change as identified by each of the first three workshops and the 1st national symposium.

Table 6.3: Drivers identified by phase 1 workshops

Clusters	Workshops			
	AFASA	**NAFU**	**AgriSA**	**National Symposium**
Human	• Education • Age • Gender • Health	• Education • Gender • Coaching and mentorship	• Education	• Education • Leadership capacity within the water sector
Social	• Racial relations • Population growth • Poverty • Urbanisation	• Civil society involvement • Urbanisation	• Migration pressure • Lifestyles	• Population growth • Inequality • Poverty
Cultural	• Dependency • Entitlement • Traditional water access	• Religious beliefs • Traditional leadership • Racial relations • Perception and attitude	• Dependency • Entitlement	• Innovative thinking and doing
Economic	• Access to market • Access to capital • Energy costs • Sectorial competition	• Profitability of farmers • Government support	• Energy prices • Government subsidies • Economic prosperity	• Subsidies and government support • Energy price and input costs
Political	• Land reform • Political understanding of agriculture • Racial disparities in agriculture	• Land reform • Political understanding of agriculture • Government policies	• Land reform • Water policies	• Political understanding of agriculture • Land reform policies
Technological	• Irrigation technology • Precision agriculture • Adoption of new crops	• Water purification • Precision agriculture • New technologies	• Rainwater harvesting • Irrigation technologies • Precision farming	
Natural	• Climate extremes • Water availability • Ecosystem health	• Climate extremes • Water availability	• Climate extremes • Ecosystem health	• Water available for agriculture
Infrastructural	• On-farm infrastructure • New water infrastructure • Dam siltation	• On-farm infrastructure • Dam siltation	• Maintenance of current infrastructure • On-farm infrastructure	• New water infrastructure • Maintenance of current infrastructure
Institutional	• Implementation of laws		• Monitoring • Coordination and collaboration	
Organisational	• Local governance capacity • Capacity of government organisations	• Farmers' organisations • Local governance capacity • Capacity of government organisations	• Farmers' organisations (AFASA, NAFU, AgriSA, etc.)	• DWS, DAFF, COGTA, DEA functionality • Farmers' organisations (AFASA, NAFU, AgriSA, etc.)

Table 6.4 is a summary of the relative importance or weighting and ranking of the different clusters.

Table 6.4: Ranking of clusters in order of importance

Clusters	AFASA	NAFU	AgriSA	National Symposium	Average ranking
Human	1	2	2	4	2,25
Social	9	7	8	9	8,25
Cultural	10	9	4	10	8,25
Economic	8	3	10	5	6,5
Political	4	6	6	6	5,5
Technological	7	1	1	3	3
Natural	2	5	5	8	5
Infrastructural	3	4	9	2	4,5
Institutional	6	8	7	7	7
Organisational	5	10	3	1	4,75

According to the average ranking of the smaller workshops and the national symposium, the most important clusters are social and cultural, with an average ranking of 8,25. According to the results, the least important is human capacity with an average ranking of 2,25. The drivers contributing to the high ranking in the social cluster are (i) racial relations, (ii) population growth, (iii) poverty, (iv) urbanisation, (v) migration, (vi) inequality, and (vii) civil society involvement. The drivers contributing to the high ranking of the cultural cluster are (i) dependency of society on government, (ii) entitlement, (iii) belief systems, (iv) perceptions and attitude of society, (v) innovative thinking and doing – or the lack thereof. The economy and the political environment followed social and cultural clusters in terms of ranking.

Key ideas from the symposium included:

- Water reform policies are now more important than land reform policies in South Africa.
- The paradigm of abundance and scarcity are very important when dealing with water management in South Africa.
- Politicians must be kept out of water management discussions.
- The vulnerable smallholder sector needs to be supported.
- Social cohesion and a social pact amongst stakeholders is key to future success

6.4.2 Phase 2 Consultative Workshops

The methodology applied for the phase 2 workshops was adjusted slightly in that the focus was to find results through consensus from the onset of the workshop instead of having individual weightings that were then grouped at a later stage. The adjustments were because the time available for discussion was found to be limited during the first group of discussions. The consensus-seeking method supports a better discussion of each of the drivers and clusters. The consensus-seeking approach stimulates lively discussions and also provides the opportunity for participants to understand water management challenges in a more holistic way. Participants reacted positively to the proposed cluster framework. The second group of workshops had a larger focus on water users such as commercial and communal farmers. Provincial officials also attended some of the workshops. A discussion of the second group of workshops follows.

6.4.2.1 Mpumalanga Consultative Workshop

A WRC Project Workshop was held on 24 July 2019 in Nelspruit, Mpumalanga province, with farmers and officials of the Department of Agriculture. The workshop was planned to be small so that all the participants could fully participate in the conversations, debates, and opinion sharing. As a result, 11 participants attended the meeting, which started at 09h00 and ended at 16h00.

The workshop started with Prof. Andries Jordaan (project leader and the facilitator of the workshop) giving some background related to water management and agricultural development, and the objectives of the project. The ten clusters were presented and explained. Stakeholders – those present at the meeting – were then tasked to identify drivers of change under each cluster through a process of consensus-seeking, and then assign weights to them. A discussion of each weight ensued. All stakeholders debated amongst each other and unanimously agreed on the weights of the drivers and clusters.

The workshop was very insightful because stakeholders expressed their honest opinions regarding water management and agricultural development in South Africa. Participants expressed concerns regarding uncertainty around land reform, especially expropriation without compensation, and water reform policies. The important drivers identified by the participants under each of the clusters are presented in Table 6.5.

Table 6.5: Weighting of Drivers of Change by Nelspruit Farmers

Cluster	Weight	Drivers of Change	Index / Relative impact
Human	1	Education / awareness / knowledge	25
		Experience – background	5
		Work ethics / ethics / character	30
		Will / commitment	15
		Emotional decision-making	10
		Expectations / Perception	15
		Total	**100**
Social	8	Civil participation	15
		Livelihood conditions / poverty / superiority	10
		Support base informal	10
		Support base formal	10
		Understanding of social dynamics & conditions	12
		Civil strife / conflict	8
		Leadership	35
		Total	**100**
Cultural	4	Ignorance / respect for others / value system / perseverance	20
		Entitlement	15
		Dependency	10
		Traditions & cultural belief systems	10
		Conservatism (“*pull-down syndrome*”)	15
		Intimidation / group pressure	10
		Ubuntu	10
		Blaming / not taking responsibility	10
		Total	**100**
		National Water budget – distribution	10
Economic	9	Fund mismanagement / corruption	15
		Economic disparity	15

Cluster	Weight	Drivers of Change	Index / Relative impact
		Water cost – basic	10
		Value of water – trade-off between drinking, production, industry	15
		Cost of delivery / electricity / infrastructure	10
		Hydropower	5
		Sabotage – economic	5
		Water efficiency utilisation	15
		Total	**100**
		Water storage capacity	15
Infrastructure	8	Poor maintenance	25
		Technology upgrades	15
		Water infrastructure as key points	10
		Purification & sewerage works	25
		Design smart cities with dual water systems	5
		Inter-basin transfer schemes	5
		Total	**100**
		Groundwater exploitation	25
Natural	8	Water availability	25
		Pollution	20
		Land degradation	10
		Wetlands	15
		Evapotranspiration / climate change / hotter	5
		Total	**100**
		Precision agriculture / farming, advanced production methods / inputs	40
Technology	2	GIS & spatial analysis & remote sensing / water demand assessment technology / statistics and data	15
		GMO & new cultivars	10
		Land rehabilitation	15
		Yield vs sustainability / conservation agriculture	20
		Total	**100**
		Departmental efficiency	20
Organisational	9	Organised agriculture	20
		Water management agencies	25
		Municipalities	15
		Agri businesses / secondary agriculture	15
		Organised pressure groups	5
		Unions	
		Total	**100**
		Departmental coordination	10
Institutional	8	Private sector / Gov collaboration	10
		Catchment management & water monitoring	20
		International agreements	10
		Regulatory enforcement	50
		Total	**100**
		Land reform	20
Political / Governance	9	Expropriation without compensation	35
		Land use system (title deeds)	20
		Policy uncertainty	10
		Political leadership	10
		Brain drain	5
		Total	**100**

6.4.2.2 Stellenbosch Workshop

The Project team organised another stakeholder workshop on 29 July 2019 in Stellenbosch, Western Cape province with irrigation farmers and officials of the Department of Agriculture. The workshop proceedings took place at the Stellenbosch Agricultural Society head office. The workshop was planned to be small so that all the participants could fully participate in the conversations, debates, and opinion sharing. As a result, 12 participants attended the workshop, which started at 09h00 and ended at 16h30.

The workshop started with Prof. Andries Jordaan (project leader and the facilitator of the workshop) giving some background related to water management and agricultural development, and the objectives of the project. The ten clusters were then explained to workshop participants. Mr. Yong Sebastian (PhD student and project team member) explained the modelling process to the participants and demonstrated, with examples, how the conceptual and mathematical models will be developed and the purpose for such models. This was to allow participants to see how the drivers identified will be modelled. A similar process was followed as in the Mpumalanga workshop with individuals allocating weights to drivers of change and then finalising results through consensus by all participants.

The important drivers identified by the participants under each of the clusters are presented in Table 6.6.

Table 6.6: Weighting of Drivers of Change by Stellenbosch Farmers

Cluster	Weight	Driver of change	Index / relative importance
Human	7	Education levels	25
		Individual responsibility / ownership	10
		Innovation thinking & doing	5
		Leadership	20
		Training / extension	15
		Mentorship / extension	10
		Incompetency / cadre deployment / favouritism	15
		Total	**100**
Social	7	Informal support structures	5
		Social responsibility	10
		Brotherhood	10
		Co-ownership of natural resources/stewardship	10
		Poverty	10
		Population growth	15
		Urbanisation	30
		Crime / vandalism	10
		Total	**100**

Cluster	Weight	Driver of change	Index / relative importance
Cultural	4	Attitude to natural resources	10
		Life skills	7
		History / cultural background / past experiences	25
		Adapting to change	25
		Productivity of water utilisation	15
		Dependency syndrome	8
		Destitute	10
		Total	**100**
Economic	6	Market trends / niche markets / diversification	30
		Income levels & employment levels	15
		Profitability	25
		Economies of scale	25
		Energy & water costs	5
		Total	**100**
Infrastructure	7.5	Maintenance & ownership	40
		Water recycling re-use infrastructure	25
		New infrastructure for storage and distribution	5
		Inter-basin transfer – long term	5
		Upgrades of current structures	25
		Small-scale storage	
		Total	**100**
Natural	6	Climate change / extremes (floods / droughts)	50
		Alien vegetation	15
		Wetlands management	10
		Catchment managements / areas	10
		Crop suitability	15
		Total	**100**
Technology	6	Drought resistant crops	10
		Drones & remote sensing, precision farming	30
		Innovative production systems (mulching, drips, netting)	40
		Conservation agriculture – same as above	
		More affordable technology / adoption	20
		Total	**100**
Organisational	2	DHSWS	40
		Provincial department of agriculture	10
		Water boards	25
		Agri WC Organised Agric	10
		Local Government	15
		Total	**100**
Institutional	2	Enforcement	15
		Monitoring & data & record keeping	40
		Bureaucracy	15
		Implementation	20
		Municipal by-laws	10
		Government coordination	
		Total	**100**
Political / Governance	9.5	Accountability	20
		Political stability	40
		Unions	10
		Land reform (EWC)	20
		Regional integration	10
		Total	**100**

The workshop was very insightful because stakeholders expressed their honest opinions regarding water management and agricultural development in South Africa. Participants also expressed concerns regarding uncertainty around land reform – especially expropriation without compensation – and water reform policies. Participants also mentioned bureaucracy ("bottlenecks") in the water sector as one of the factors influencing the effective implementation of water policies.

6.4.2.3 Malmesbury, Western Cape Consultative Workshop

The Project team organised a stakeholder workshop on the 31st July 2019 in Malmesbury with the assistance of the farmers' associations in the Swartland. This workshop was with dryland farmers and officials of the Department of Agriculture. Turnout was poor and the project team decided to facilitate an open discussion on water management issues. The attendees were concerned about the lack of support, and the Department of Water and Sanitation officials' understanding of water management. They cited examples of applications to build dams for irrigation that have been dragging on for more than 10 years due to unnecessary red tape and poor governance.

6.4.2.4 QwaQwa Consultative Workshop

Another stakeholder workshop was held on the 13th September 2019 in QwaQwa, Free State province with smallholder and emerging farmers. The workshop proceedings took place at the QwaQwa campus, of the University of the Free State. The workshop was planned to be small so that all the participants could fully participate in the conversations, debates, and opinion sharing. As a result, 16 participants attended the workshop, which started at 09h00 and ended at 16h30.

A similar procedure as previous workshops was followed with a background to the study, the scenario building process, and an explanation of the cluster framework. Again, stakeholders were tasked with identifying drivers of change under each cluster and then assigning weights to them based on their individual opinions. A discussion of each weight ensued. Stakeholders debated with each other and unanimously agreed on the weights of the drivers and clusters. Prof. Jordaan explained the modelling process to the participants and demonstrated with examples of how the conceptual and

mathematical models will be developed, and the purpose for such models. This was to allow participants to visualise drivers identified in a model.

The workshop was very insightful with lively debates regarding water issues as experienced by small scale and communal farmers. Participants explicitly raised their concerns regarding the influence of politics in the water sector, and how it influences the effective implementation of water policies. The majority of the participants farm on municipal land, and the poor management and service delivery from the Maluti A Phofung municipality over-shadow their concerns for future water management. For many years now, water infrastructure in the QwaQwa area was not maintained, and workshop participants cited numerous examples of politicians using water as a tool for political gain. Also of great concern is the conflict in the water sector in QwaQwa between water for gardening and animal use, and drinking water. The important drivers identified by the participants under each of the clusters are presented in Table 6.7.

Table 6.7: Weighting of Drivers of Change by QwaQwa Farmers

Cluster	Weight	Drivers of change	Index / relative importance
Human	2	Leadership	30
		Dependency syndrome	20
		Education levels / skills development	35
		Gender	5
		Expertise	10
		Total	**100**
Social	5	Population growth	30
		Informal groups	10
		Societal involvement	15
		Migration between provinces / countries	20
		Urbanisation	25
		Total	**100**
Cultural	2	Attitude to water management	25
		Traditional beliefs	20
		Acceptance / understanding of other cultures	15
		Value & respect for water	15
		Water is politicised	25
		Total	**100**
Economic	1	Water-heavy business systems (car wash)	15
		Income distribution	25
		Economic opportunities	10
		Water costs / price	10
		Strategic value of food security	20
		Capital for new water infrastructure	20
		Total	**100**
Infrastructure	7	Development of new dams & canals	20
		Water recycling	10
		Maintenance of water infrastructure at municipal level	30
		Bulk infrastructure maintenance	20
		Underground water storage	20
		Total	**100**
Natural	5	Water quality	20

Cluster	Weight	Drivers of change	Index / relative importance
		Alien & invasive species	10
		Land degradation / erosion	10
		Groundwater exploitation	20
		Climate change / extremes	10
		Water availability	30
		Total	**100**
Technology	5	Recycling	25
		Desalination	5
		Water harvesting	30
		Hydro power generation	5
		Irrigation technology	35
		Total	**100**
Organisational	2	Municipal water management	30
		Research organisations	15
		Government departments	40
		Organised agriculture	15
		Total	**100**
institutional	2	Water use rights	10
		Failure of government to implement Water Act	30
		Billing & revenue collection	15
		Master water & sanitation plan	15
		Government coordination	30
		Total	**100**
Politics/Governance	6.5	Water as a political tool / commodity	35
		Corruption with water allocation and licenses	20
		Allocation of mining rights to detriment of agriculture	15
		Political interference in water management	30
		Total	**100**

6.4.2.5 Northern Cape Consultative Workshop

The Project team organised another stakeholder Workshop on 2 October 2019 in Upington, Northern Cape province with farmers and water managers. The workshop proceedings took place in the department of agriculture. The workshop was planned to be small so all the participants could fully participate in the conversations, debates, and opinion sharing. As a result, 8 participants attended the workshop, which started at 09h00 and ended at 16h30.

The workshop started with Prof. Andries Jordaan (project leader and the facilitator of the workshop) giving some background related to water management and agricultural development, and the objectives of the project. Prof. Jordaan then presented the identified clusters – human, social, cultural, economic, political, technological, natural, infrastructure, and institutional. Stakeholders were tasked with identifying drivers of change under each cluster and then assigning weights to them based on their individual opinions. A discussion of each weight ensued. Stakeholders debated with each other, and unanimously agreed on the weights of the drivers and clusters. Mr. Yong Sebastian (PhD student and project team member) explained the modelling process to the participants, and demonstrated, with examples, how the conceptual and mathematical models will be developed, and the purpose for such models. This was to allow participants to visualise how the drivers identified will be modelled.

The workshop was very insightful as stakeholders expressed their honest opinions regarding water management and agricultural development in South Africa. Participants expressed concerns regarding the influence of politics, corruption, and mismanagement in the water sector and how it influences the effective implementation of water policies. The important drivers identified by the participants under each of the clusters are presented in Table 6.8.

Table 6.8: Weighting of Drivers of Change; Northern Cape workshop

Cluster	Weight	Driver of change	Index / relative importance
Human	2	Lack of acknowledgment for expertise	10
		Leadership	25
		Individual level of practical skills	9
		Education levels / skills development	9
		Early childhood development	15
		Disability management	2
		Self-motivation	15
		Integrity	15
		Total	**100**
Social	7	Population growth	30
		Foetal alcohol syndrome	5
		Medical care	5
		Migration between provinces / countries	20
		Urbanisation	20
		Civil society involvement	20
		Total	**100**
Cultural	2.5	Attitude to water management	25
		Water-wise society	10
		Acceptance / understanding of other cultures	15
		Attitude to pollution	15
		Value & respect for water	15
		Sanitation systems – water is politicised	20
		Total	**100**
Economic	1	Water heavy business systems (car wash)	5
		Income distribution	5
		Economic opportunities	10
		Water costs / price	11
		Strategic value of food security	13
		Profitability per unit water	13
		Conflict between sectors (mining, agriculture)	10
		Capital for new water infrastructure	13
		Product prices	10
		Socio-economic impact/responsibility	5
		Access to capital	5
		Total	**100**
Infrastructure	6	Development of new dams & canals	15
		Water recycling	10
		Mine water recycling	10
		Maintenance of water infrastructure at municipal level	20
		Bulk infrastructure maintenance	20
		Underground water storage	20
		Private dams – unplanned	5
		Total	**100**
Natural	4	Water quality	20
		Alien & invasive species	10
		Land degradation / erosion	10
		Groundwater exploitation	10
		Aridity – permanent dryness	15
		Climate change / extremes	10
		Water availability	25
		Total	**100**

Cluster	Weight	Driver of change	Index / relative importance
Technology	6	Recycling	20
		Desalination	17
		Water harvesting	17
		New water storage solutions	16
		Hydro power generation	10
		Irrigation technology	20
		Total	**100**
Organisational	3.5	Municipal water management	10
		Failure of government to implement agriculture projects	5
		CMAs, WUAs & Water Boards	25
		Research organisations	10
		Government departments	35
		Organised agriculture	10
		Training and education organisations	5
		Total	**100**
Institutional	4	Right to access to water (human rights)	10
		Water use rights	10
		Failure of government to implement Water Act	30
		Pricing strategy	15
		Billing & revenue collection	15
		Master water & sanitation plan	20
		Total	**100**
Political / Governance	6	BEE limitations	15
		Water as a political tool / commodity	10
		Corruption with water allocation and licenses	20
		Allocation of mining rights to detriment of agriculture	15
		Allocation of mining/development rights in sensitive ecosystems	15
		Political interference in water management	25
		Total	**100**

6.4.3 Cluster weightings

The results for the weightings and importance of the different clusters are presented in Table 6.9 and Figures 6.10a-i. The social cluster had the highest average score (7.3 out of 10), and included drivers of change such as (i) population growth, (ii) urbanisation, (iii) poverty, (iv) civil strife, and (v) civil society as an agent of positive change, conscience and public monitoring. The political cluster scored the second-highest at 6.7; and the most important drivers of change mentioned here are (i) corruption, (ii) land-use systems and policies, including land reform and dispensation of land, and (iii) political interference. The economy and infrastructure clusters followed closely, with 6.1 each. The most important drivers of change in the economic cluster are (i) price of water and electricity, (ii) disparity in income distribution (Gini-coefficient), and (iii) profitability of agriculture. The most important drivers of change in the infrastructure cluster are (i) new water infrastructures such as inter-basin transfers, desalination, and water re-use, (ii) maintenance of water infrastructure, and (iii) new bulk storage capacity such as groundwater storage and recharge and dams.

Table 6.9: Weightings and importance of clusters

Clusters	AFASA	NAFU	AgriSA	1st National Symposium	W Cape	Mpumalanga	Stellenbosch	QwaQwa	N Cape	Average per cluster	Standard Deviation
Human	1	2	2	4	5	1	7	2	2	**2.89**	**1.81**
Social	9	7	8	9	6	8	7	5	7	**7.33**	**1.18**
Cultural	10	9	4	10	3	4	4	2	2.5	**5.75**	**2.93**
Economic	8	3	10	5	6	9	6	7	1	**6.11**	**2.55**
Political	4	6	6	6	7	9	9.5	6.5	6	**6.67**	**1.50**
Technological	7	1	1	3	5.5	2	6	5	6	**4.06**	**2.08**
Natural	2	5	5	8	9	8	6	5	4	**5.78**	**1.99**
Infrastructural	3	4	9	2	8	8	7.5	7	6	**6.06**	**2.22**
Institutional	6	8	7	7	7.5	8	2	2	4	**5.72**	**2.18**
Organisational	5	10	3	1	5	9	2	2	3.5	**4.50**	**2.81**

The standard deviation for the cultural cluster is the highest (2.93) with the AFASA leadership group allocating a weighted score of 10 compared to only 2 from the QwaQwa group, which consisted mainly of AFASA members, and 2,5 from the Northern Cape group. The large variance between the national leaders of AFASA and its members in QwaQwa is interesting; maybe an indication that the leadership is not really in touch with the grassroots members. Standard variation for the organisation cluster is also large (2.81) but then the average weighted score is the third lowest.

Standard deviation for the social cluster is the lowest (1.18) and it also received the highest weighted average (7.33); an indication that all agree the social dynamics to be the most important. The cluster with the second-lowest standard deviation (1.5) is the political cluster and it also received the second-highest weighted average (6.67). Both of these results are significant in that the political climate and the social environment are closely linked.

Also an interesting result is the high standard deviation for the economic cluster (2.55) with the third-highest weighted average (6.11). Similar to the case with AFASA and its members in QwaQwa, the highest variance in the weighted score is between AgriSA (10) and its members in the Northern Cape (1).

What is surprising is the relatively low score for the human cluster across all workshops except for the Stellenbosch workshop. Standard deviation for the human cluster is also low at 1.81. The human cluster contains drivers of change such as (i) education levels, (ii) leadership, (iii) skills, (iv) age, and (v) gender.

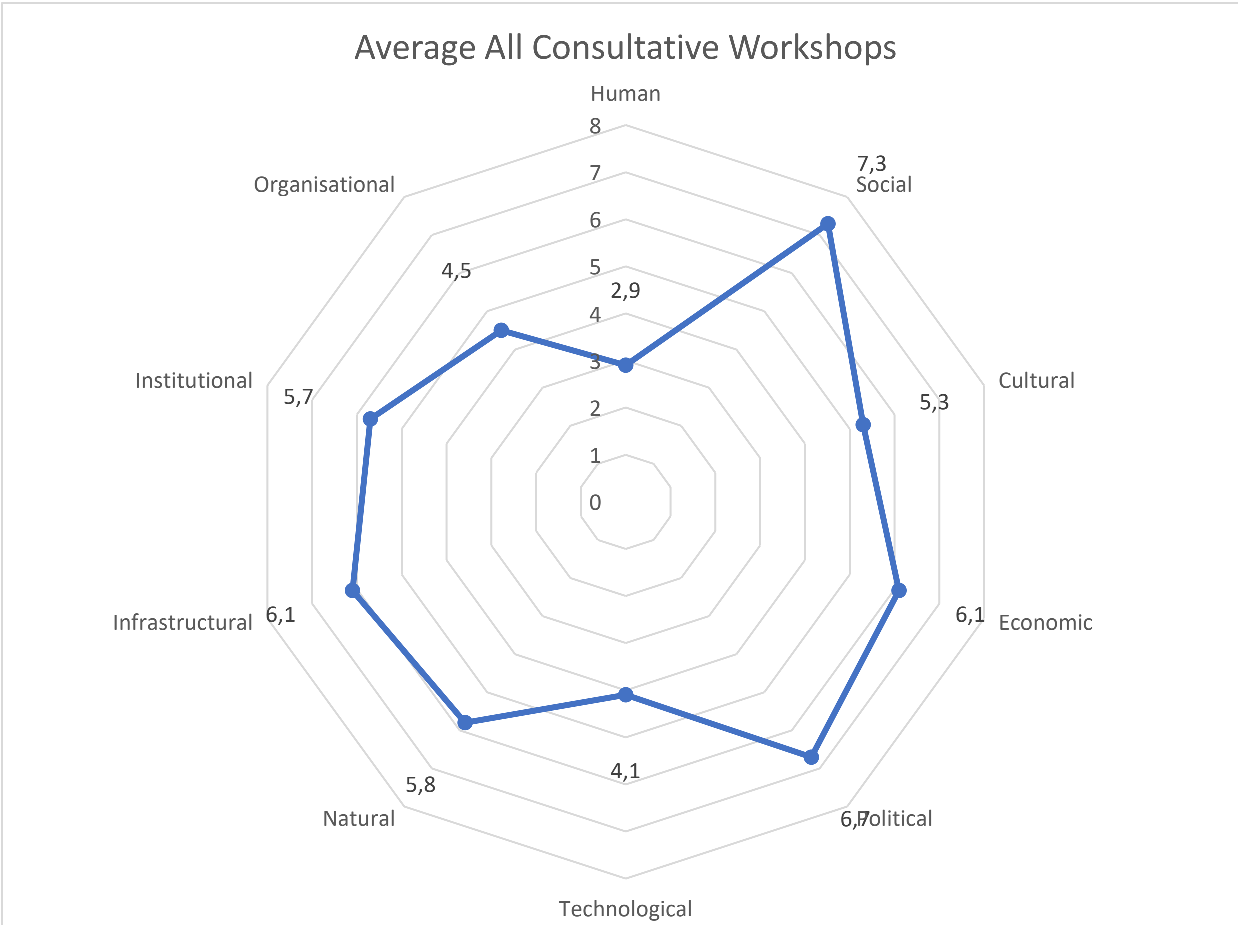

Figure 6.1: Mean cluster weighting

The cluster weightings obtained from each consultative workshop is illustrated in Figures 6.2a-i.

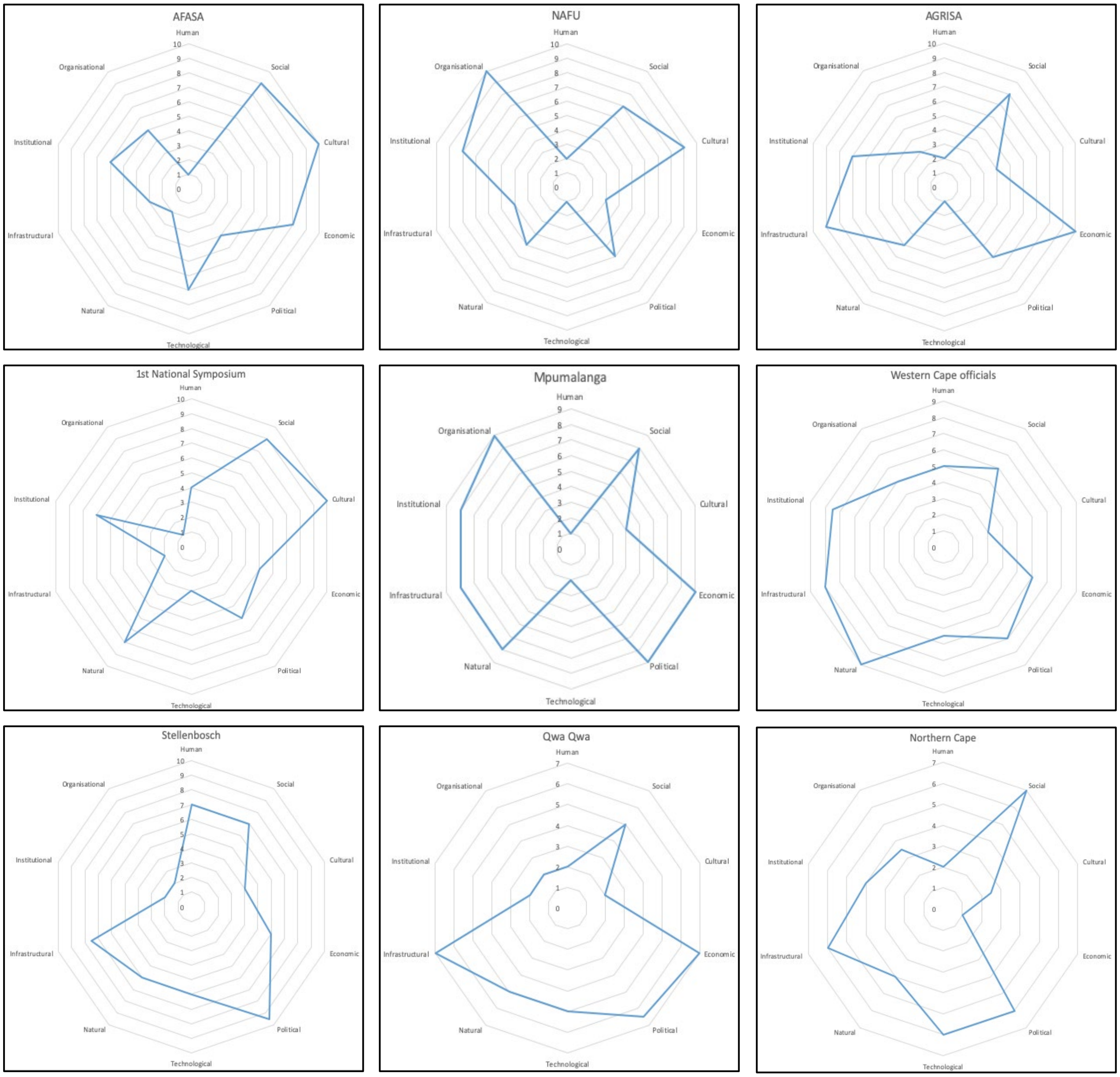

Fig 6.2 a-i: Cluster weightings per consultative workshop.

6.5 Conclusion

The results from the different workshops provided insightful information that was used in the development of the final scenarios and the mathematical model.

The high score for the social cluster is an indication of the importance of a "*social pact"* amongst the different stakeholders. Participant in all the workshops were well aware of political and racial tensions in South Africa and the potential devastating effect on the future management of a strategic resource such as water. It became clear that agreement exists that the combination of politics and the social environment are the two clusters that will have the strongest impact on future water management in South Africa.

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7 CONCEPTUAL MODELLING. SYSTEM DYNAMICS APPROACH

7.1 Introduction

The issue of global water scarcity and food insecurity has become a major cause of concern to governments, international and local organisations, policy-makers, water-users, and water managers (Owusu-Sekyere *et al.,* 2017). The general objective of water resources management is to promote efficient freshwater use to maximise economic, social, and environmental welfares in an equitable, efficient, and sustainable manner (Zeng *et al.,* 2012). Water management and agricultural development have received significant attention and transformation over recent decades (Basco-Carrera *et al.,* 2017). Water resources are essential for agricultural production because, if badly managed, they can limit food production, energy generation, and economic activities in other sectors in the economy (Schneider *et al.,* 2011; Ringler *et al.,* 2013; Chartres & Noble, 2015).

Participation by all involved stakeholders in policy development and decision-making is very important, and forms a crucial part of Integrated Water Resource Management (IWRM). IWRM is an approach used in water resource management, which allows water management issues to be solved holistically with active stakeholder involvement. IWRM ensures that the management of water, land, and related resources are properly coordinated in order to maximise the sustainability of economic and social welfare equitably, without compromising vital ecosystems (Giupponi & Sgobbi, 2008). The participatory approach is a common methodology within the IWRM as it allows *"stakeholders at all levels of the social structure to have an impact on decisions at different levels of water management*" (Global Water Partnership GWP, 2000).

Environmental issues are quite dynamic and complex, and therefore require flexible and strategic bottom-up policies that will pave the way for multi-stakeholder participation in planning and decision-making processes (Reed, 2008). Water management and agricultural sustainability are some of the environmental challenges confronting natural resource managers and planners. Water and food systems are challenging to manage because of the complexities arising from the functioning of hydrological cycles and biological systems (Antunes *et al*., 2009; Kotir, 2020). The system is made complex by the dynamic interaction of drivers such as rapid population growth, urbanisation, land use change, climate change, land degradation, and unsustainable water policies (Nyam *et al.,* 2020). This complexity is further exacerbated when there are multiple stakeholders with different perspectives, interests, values, and concerns regarding the use of water and land for human-related purposes (Kotir *et al.,* 2017). Natural resource managers, researchers and practitioners have often adopted a reductionist, linear cause-effect analytical approach to address problems related to water and food systems (Musavengane, 2019; Moldavska & Welo, 2019). However, linear reductionist thinking analyses and explains parts of a complex system thereby making it an unsuitable framework for analysing complex systems with several interdependent and interconnected systems and drivers

(Nayak & Waterson, 2019; Turner & Baker, 2019). A non-linear thinking approach that offers a holistic framework to promote the sustainability of water and food systems is needed.

Participatory modelling (PM) and stakeholder engagement based on the principle of systems thinking and system dynamics have become very important tools for facilitating strategic decision-making in complex natural systems (Reed *et al*., 2008; Voinov & Bousquet, 2010; Voinov *et al*., 2014; Voinov and Gaddis, 2017). Qualitative system dynamics based on PM is a useful technique for identifying and capturing feedback loops inherent in a complex system. Therefore, PM provides a suitable platform for planning and managing water and food systems (Mirchi *et al.,* 2012).

Several studies have used PM to model water resource management around the world (e.g. Videira et al., 2009; Beall *et al.,* 2011; Davies & Simonovic, 2011; Carmona *et al.,* 2013a, b; Butler & Adamowski, 2015; Lopes & Videira, 2015; Basco-Carrera *et al*., 2017; Kotir *et al*., 2017; Pluchinotta *et al.,* 2018). Carmona *et al.* (2013a, b) combined the Bayesian network with economic and crop models to develop an integrated modelling framework to support decision-making in water management under uncertainty in Spain. Pluchinotta *et al*. (2018) developed a model using system dynamics modelling to support decision-making in irrigation water management in agricultural systems in Southern Italy. Davies & Simonovic (2011) developed a system dynamics-based model to assess the nature and structure of connections between water resources and socio-economic and environmental change globally.

Furthermore, PM has been applied to water and food systems in Africa (e.g. Kotir *et al.,* 2017; Simonovic *et al*., 1997; Daré *et al.,* 2018). Kotir *et al.* (2017) developed an integrated conceptual model using causal loops diagrams to assist integrated water management and agricultural sustainability in Ghana. Simonovic *et al.* (1997) developed a system dynamics approach for long-term water planning and policy analysis in Egypt. Daré et al. (2018) used a Companion Modelling approach (ComMod) to develop role-playing games and a computerised agent-based model to support the identification of problem shed areas in Ghana.

In South Africa, PM has been applied to water management, and as part of the IWRM (e.g. Sherwill et al., 2007; Farolfi *et al.,* 2010; De Lange *et al.,* 2010; Brown, 2011; Du Toit *et al.,* 2011; Claassen, 2013). Farolfi *et al.* (2010) used companion modelling to develop multi-agent models to represent water supply and demand dynamics for the Kat River. However, the model developed did not consider the feedback processes operating between the system components. Studies by Brown (2011), Claassen (2013), Sherwill *et al.* (2007), and Du Toit *et al.* (2011) proposed frameworks for IWRM through the involvement of all relevant stakeholders in the decision-making process regarding water. Furthermore, Stone-Jovicich *et al.* (2011) used a consensus analysis process to assess the mental models of water users and management in South Africa.

However, these studies did not examine the feedback processes operating within a dynamic system. Here, we describe the development of a qualitative conceptual model for studying complex water problems in South Africa to identify areas of convergence and divergence in understandings key issues.

Specifically, we used causal loops diagrams (CLDs), to show the causal relationships that exist between drivers influencing sustainable water management and agricultural development in South Africa. This process involves the use of participatory modelling methods, thereby allowing the inclusion of relevant stakeholders in the model development process. Building on this approach, this research further develops the process to explore how ecological scientists and farmers think about agro-ecology, and to map areas of convergence and divergence in these understandings. Despite the importance of conceptual modelling, very few studies have attempted to use this modelling approach to understand the feedback processes that exist among the drivers influencing water management and agricultural development in South Africa. A knowledge gap exists, and needs to be filled to makes sense of the relationships and feedback processes between the multiple drivers influencing water and food systems in South Africa, in order to understand the systemic behaviour of the complex system in South Africa.

7.2 Methodological Approach – Participatory Modelling (PM) with System Dynamics

The PM used in this study is based on the system dynamics approach (Forrester, 1961; Sterman, 2000; Ford, 2010). System dynamics (SD) is a methodology based on feedback systems borrowed from control theory, and is mainly used to study the non-linear behaviour, time-delay, and multiloop structures of the complex and dynamic systems (Forrester, 1961; Bala *et al.,* 2017). Models based on SD are generally designed as tools to improve system understanding of the decision-making process, and to foster system thinking skills and knowledge integration for modellers and end-users (Kelly *et al.,* 2013). The involvement of diverse stakeholders is an important part of the system dynamics approach (Forrester, 1961; Richardson & Anderson, 1995; Vennix, 1999). This has led to the upsurge in participatory system dynamics modelling (see Stave, 2010; Beall & Ford, 2010), which is the main approach implemented in this paper. Thus, participatory system dynamics modelling uses a system dynamics perspective in which stakeholders or clients participate to some degree in different stages of the model-building process (Stave, 2010; Bala *et al.,* 2017). It provides a mechanism for integrating scientific knowledge with local knowledge, and building a shared representation of the problem (Stave, 2010). It involves building shared ownership of the analysis, problem, system description, and solutions, or a shared understanding of the trade-offs among different decisions (Bala *et al.,* 2017).

System dynamics models can be represented in an object-oriented form of casual loop diagrams or stock and flow diagrams (Sterman, 2000; Amadei, 2019). Stock and flow diagrams represent integral finite difference equations involving the variables of the feedback loop structure of the system, and simulates the dynamic behaviour of the system (Bala *et al.,* 2017). On the other hand, CLDs – comprised of words and arrows with appropriate polarity – depict combinations of positive and/or negative causal relationships among key components or variables of a complex system, including cause and effect (Sterman, 2000; Mirchi *et al.,* 2012). They help in laying out the different structural components of a system in a conceptual manner, and show how those interact dynamically in a qualitative manner (Amadei, 2019). This allows the identification of both reinforcing (R) feedback loops – which can cause runaway behaviour in the system – and balancing (B) loops – which create selfcorrecting processes that lead to stability, equilibrium, and reaching the desired outcome. Here, we used CLDs to explain the complex challenges in collaboration with key stakeholders in South Africa to represent how different sectors interact. An example of a CLD and its constituent's elements is depicted in Figure 7.1.

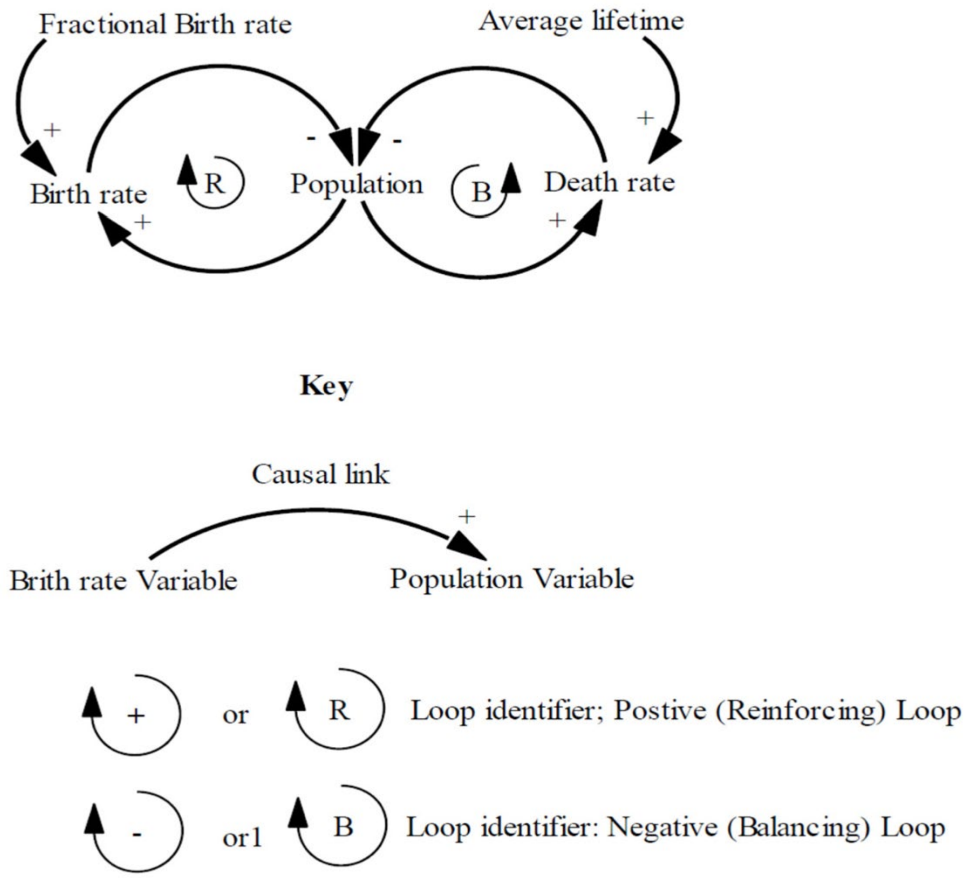

Figure 7.1: Causal loop diagram notation
(Adapted from Sterman, 2000:138).

A positive (+) causal relationship indicates that an increase in one variable in the model would lead to an increase in another, connected, variable (or a decrease in one will lead to a decrease in the other). On the other hand, a negative (-) causal relationship indicates that an increase in one variable in the model will lead to a decrease in another, connected, variable in the model (or a decrease in one will lead to an increase in the other).

7.2.1 The Modelling Approach

We approached participatory modelling from the perspective of the six broad steps of conceptual model building adapted from Inam *et al*. (2015) and Kotir *et al.* (2017) (see Figure 7.2). Each step involved several key activities that guided the implementation of the overall process. A brief description of each step is described in the following sections. Note that the evaluation of the modelling process is self-explanatory, and so is not described (see Figure 7.2).

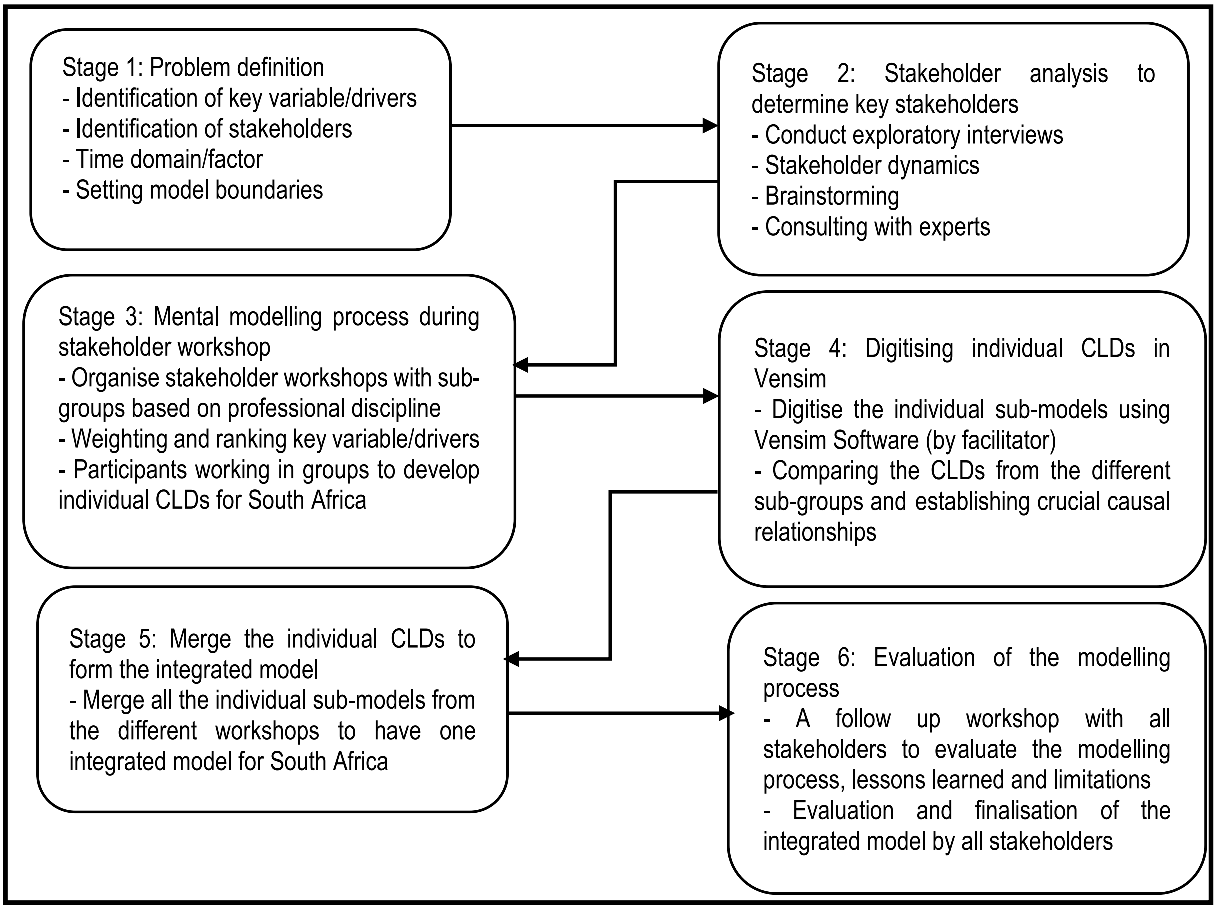

Figure 7.2: Main stages of the proposed modelling approach in South Africa

7.2.2 Problem Definition

The first step in model building is to identify the problem, set its boundaries, and state the specific objectives of the modelling exercise. While a clear articulation of the problem is particularly helpful in defining the purpose of the model, its boundaries and the time domain, it also affects the selection of stakeholders in the modelling process (Inam *et al.,* 2015). As part of the problem definition, drivers influencing water and food systems in South Africa have been identified and analysed (see Nyam *et al.,* 2020).

7.2.3 Stakeholder Analysis to Determine Key Stakeholders

Stakeholder analysis is the process of identifying, categorising, and selecting participants in the modelling process based on their role, interest, power, legitimacy, and urgency (Reed *et al.,* 2009; Carr, 2015). The aim is to evaluate and understand the stakeholders' relevance to a project or policy (Lienert *et al.,* 2013). Generally, there are no standards or guidelines for identifying and selecting stakeholders for a PM process. However, it has been widely suggested that the process be all-inclusive – capturing a diverse group of stakeholders (Reed, 2008; Voinov & Bousquet, 2010; Voinov *et al*., 2016; Voinov *et al.,* 2018). Since the problem to be addressed in this paper involved water management and its influence on agricultural development in South Africa, it was important to ensure that stakeholders from both sectors were represented. Thus, to begin the process of stakeholder identification, invitations were sent to the leaders of the main institutions involved in the water and agricultural sectors in South Africa. These included farmers' organisations, the Department of Agriculture (DoA), and other private organisations such as Greencape and the Council for Scientific and Industrial Research (CSIR). Following Videira *et al.* (2009) and Kotir *et al*. (2017), a preliminary meeting was organised with the leaders of the farmers' organisations to explain the purpose of the project, system dynamics, the modelling process, and Vensim® software (the primary software used in this analysis, see http://www.ventanasystems.com/). Subsequently, these institutions were requested to nominate stakeholders within their organisations with multiple years of experience in research or practice and knowledge of water and agricultural related issues in South Africa, and their likely availability to discuss problems. Independent farmers (i.e. commercial and smallholder farmers) were also consulted through referrals to check their competencies and availability to be included in the modelling process.

7.2.4 Mental Modelling Process during Stakeholder Workshop

According to Jones *et al.* (2011), a mental model is the internal representations of the external reality individuals have about how a system works, and which forms a cognitive basis for their reasoning, decision-making, and behaviour. Mental models are updated and maintained through direct observation, learning, and experience, and are continuously relied upon to reason, explain, design, communicate, act, predict, and explore (Anjum *et al.,* 2019). As such, mental models are often of interest to those in the fields of natural resource management (Van Hulst *et al.,* 2020). To capture the mental models of diverse stakeholders from different sectors, five workshops were organised with the identified stakeholders described above. To manage group dynamics, each workshop was limited to a maximum of 22 participants. The first modelling workshop was organised at the Western Cape Department of Agriculture in Cape Town on the 2nd April 2019 with 22 specialists and experts from the Western Cape Department of Agriculture (DoA), Department of Human Settlement, Water and Sanitation (DHSWS), Department of Agriculture, Land Reform and Rural Development (DALRRD), Department of Environment Forestry and Fisheries (DEFF) and Green Cape. The second workshop was organised with nine commercial (irrigation) farmers in Mpumalanga on 24 July 2019, and the third meeting was organised at the Stellenbosch agricultural society head office on 29 July 2019 with 11 experienced farmers and heads of the Stellenbosch agricultural society. The fourth workshop was organised with seven stakeholders in the Upington department of agriculture on 2 October 2019, and the fifth workshop took place with 13 smallholder farmers in QwaQwa on 13th November 2019.

At each workshop, participants were introduced to the objectives of the project, the system dynamics modelling approach, and the Vensim® modelling software and its functionalities. This was to allow participants with little or no modelling experience to gasp the objectives and procedures for conducting the modelling. Participants were then asked to brainstorm and identify the drivers that would influence water and food systems in South Africa, initially categorised under 10 clusters and later clustered to 3 for initial programming and later to 7 for more detailed analysis – social, biophysical/environmental, economic, infrastructural/technological, political, institutional, and management clusters. After identifying and clustering the drivers under each category, participants were asked to rank the drivers within each category from the most influential to the least influential driver (see Nyam *et al.,* 2020). This allowed the participants to understand the drivers of change influencing water resource management and agricultural development.

A3 type sheets and sticky notes were provided to each participant in the small workshops, and to each sub-group in the large workshop, to develop their individual or sub-group CLDs using the identified drivers, focusing on the causal relationships between the drivers of change. The drivers were written on the sticky notes and placed on the A3 type paper, and arrows were used to show the cause-effect relationship between the drivers. In the end, individuals and group leaders were required to present and explain their mental models. Participants were allowed to comment, criticise, and suggest areas of improvement after each presentation. This made the process transparent, and ensured that all the contributions of the participants were duly tracked and taken into consideration. According to Kotir *et al.* (2017), this method is highly effective because it allows stakeholders to continue amending their CLDs during the workshops until all participants are satisfied that they had built a simple model representing their mental model, and had captured the most important causal-relationships. All workshops were facilitated by the project leader, specifically providing further explanation on the modelling process, and tracking participants' responses.

7.2.5 Digitising Individual (Sub-models) CLDs in Vensim®

After all the individual workshops, all data were translated and digitised using Vensim® modelling software. The 10 clusters were re-clustered for initial model development into 3 main sub-models that focused on socio-political, economic, and ecological issues. The sub-models were digitised and vital causal-relationships identified within each cluster. After this process, preliminary CLDs for all the sub-models were finalised. After receiving comments and suggestions from stakeholders, sub-models were evaluated for simplicity and comprehensiveness to ensure all-important causal-relationships were captured, before finalising the sub-models.

7.2.6 Merge the Individual CLDs to an Integrated Model

These sub-models were merged to produce an integrated model, which aim was to capture the different perspectives and mental maps of all stakeholders that participated in the workshops while taking into consideration the problems faced, the causes, consequences, feedback loops, policies, and strategies (Mourhir *et al.,* 2016; Elsawah *et al.,* 2017), in order to address the problems related to the sustainability of water and food systems in South Africa. The integrated model allowed for all the views and opinions of all stakeholders to be represented in a simple yet comprehensive model. The integrated model captures all the important causal-relationships, feedback loops, and delays in the systems, and allows robust qualitative scenarios to be developed regarding the future of water management and agricultural development (Zare et al., 2019).

7.3 Results

7.3.1 Thematic Sub-Models (Individual CLDs)

Individual CLDs were developed based on the clusters and drivers identified, and ranked by the stakeholders as most important for water management and agricultural development in South Africa. Dividing the integrated model into thematic sub-models allows for the detailed evaluation of each sub-model and how the variables under the sub-models interact to influence water management and agricultural development in South Africa. The sub-models allowed stakeholders to visualise the interaction between the drivers identified and the causal relationships that exist between the drivers.

7.3.1.1 Socio-political sub-model

Figure 7.3 represents the socio-political sub-model denoting 22 variables is illustrated in figure 7.3.

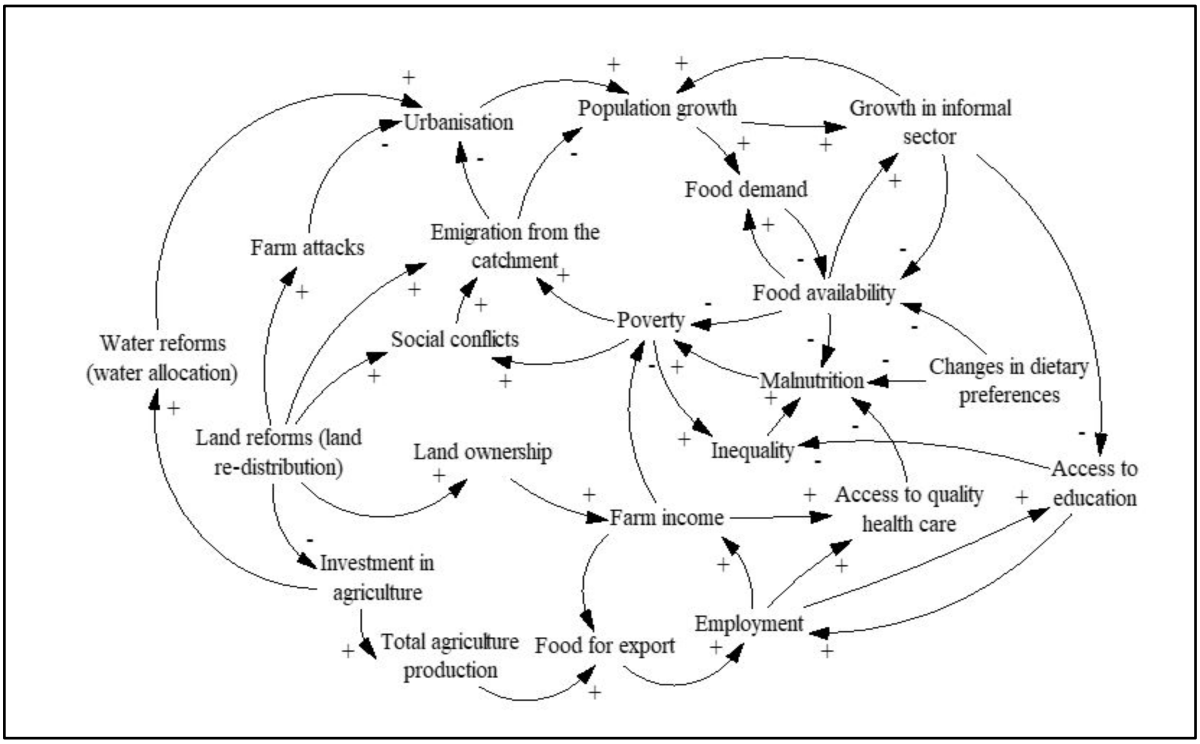

Figure 7.3: Socio-political sub-model

The model is dominated by issues of land reform and land ownership (driver in the political cluster), social conflicts, population growth, growth of informal settlements, food demand, food availability, and poverty. The model hypothesised that land reform, if done efficiently, can produce positive results. The model shows that land reform can increase land ownership among the previously disadvantaged group in the economy. This will positively influence agricultural productivity, food exports, and farm income, as well as reduce poverty and inequality. On the other hand, if land reform is not implemented effectively, the outcome could be an increase in the number of farm attacks, reduced agricultural investment (due to uncertainty), social conflicts, and emigration from South Africa.

7.3.1.2 Economic sub-model

The economic sub-model is shown in Figure 7.4.

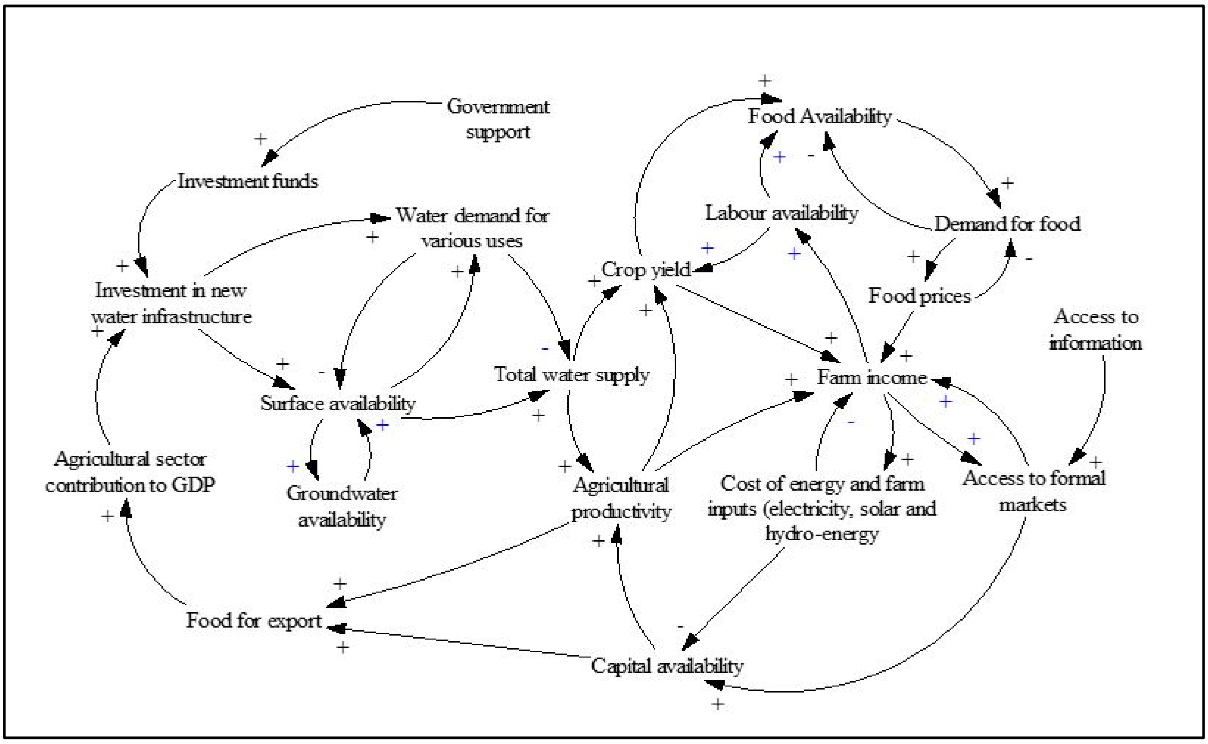

Figure 7.4: Economic sub-model

The model has 20 variables showing the causal relationships between economic variables such government support, investments in water infrastructures, food exports, agricultural contribution to GDP, and how they interact with other related variables such as surface and groundwater availability, water demand, agricultural productivity, crop yield, labour availability, and food availability to influence water management and agricultural development in South Africa. The model hypothesised that government support, especially to smallholder farmers, will increase investment funds, investment in water infrastructures, surface water availability, total water supply, and agricultural production. This model places investment in the water and agricultural sectors as a top priority.

7.3.1.3 Biophysical sub-model

The biophysical sub-model is illustrated in Figure 7.5, denoting 23 variables. This model is dominated by issues such as climate change, surface and groundwater availability, water demand and supply, agricultural production, crop yield, land availability, and food demand. Stakeholders identified this model as one whose interactions can severely influence water management and agricultural development in South Africa in the future.

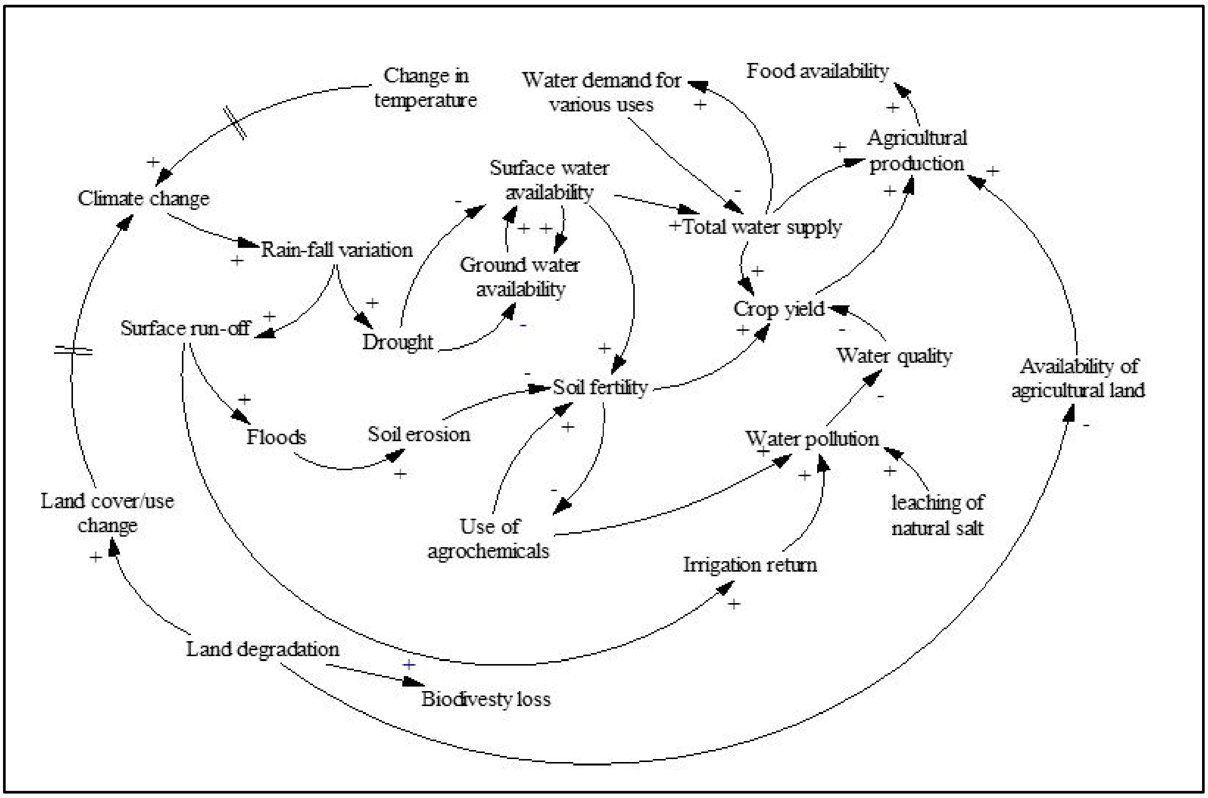

Figure 7.5: Ecological sub-model

7.4 The Integrated Conceptual Model

The integrated conceptual model presented in Figure 7.6 captures the major relationships in the different sub-models, taking into account variables that can be quantified in the next phase. The integrated model has 36 variables representing several causal relationships. The model shows 21 major loops consisting of 13 reinforcing (positive) loops and 8 balancing (negative) loops. Loops R1 and R2 show the relationship between agricultural production, crop yield, food availability, food demand, crop prices, and farm income. As agricultural production increases, it leads to crop yield, food availability, food demand, crop price, and farm income being reinforced. This shows that agricultural productivity will increase crop yield and food availability, which will increase food demand, food prices, farm income, and eventually agricultural productivity. The recurring drought in the Western Cape Province has resulted in a significant decline in agricultural productivity, crop yield, and food availability in South Africa. The decline in agricultural productivity has resulted in rising food prices in South Africa. If water is not sustainably managed in the province, agricultural productivity will continue to decline resulting in low food availability and rising food prices (see loops R1 and R2). The drought conditions in the Western Cape significantly reduced agricultural production due to water scarcity and drove consumer prices for agricultural products higher (Ogundeji & Jordaan, 2017). These loops are balanced by loops B5 and B7 that show that an increase in food availability will increase food demand and an increase in food demand will reduce food availability.

Furthermore, all things being equal, an increase in food demand will increase food prices and increases in food prices will reduce food demand. Loop R3 shows the population dynamics. This loop shows the causal-relationships between population growth, food demand, and food availability. Population growth will increase food demand, food demand will decrease food availability, and food availability will reinforce population growth. Loop R3 is balanced by loop B4 which shows that population growth will eventually feedback to reduce the amount of food available to feed the population. Loop R4 shows a causal-relationship between population growth, labour availability, agricultural production, crop yield, and food availability. According to the model, population growth will lead to an increase in the labour force over time (after a delay), agricultural production, and, consequently, crop yield. An increase in crop yield will lead to an increase in food availability and population growth.

Other studies have found that population growth contributes to the reduction in agricultural land in most developing countries, and poses a threat to food security and livelihoods (Premanandh, 2011; Pham, 2014). Population growth can also contribute to land and water-use conflicts with agriculture in urban areas (Chen, 2007). Urban agriculture can benefit significantly from urbanisation through cheap and available labour, which will allow farmers to sustainably manage resources, and increase agricultural yield (Prokopy *et al.,* 2008; Mkwambisi *et al*., 2011; Wästfelt & Zhang, 2016). Loop R5 is very important because it demonstrates the profit dynamics of the farmers. Farmers placed a lot of emphasis on this loop because it shows the causal-relationship between agricultural productivity, food export, and farm income. The loop indicates that an increase in food production will increase food for export, farm income, and reinforce agricultural production. According to stakeholders, policies should be geared towards enhancing agricultural production, which will increase agricultural export and farm income. As farm income increase, it reduces the poverty level of the farmers (especially smallholder farmers), which will increase access to education and education levels. Access to education, and increases in educational levels, will increase access to information and formal market channels, and access to markets will reinforce farm income (loop R6). Similar studies have found a positive correlation between farmer education and sustainable management of natural resources. An educated farmer has access to information, market, knowledge on water, and farm management, which positively influences agricultural productivity and income levels of farmers (Chen, 2007; Food and Agricultural Organization FAO, 2012; Danso-Abbeam *et al.,* 2018). Educated farmers have the knowledge and skills to efficiently manage resources and adopt better production techniques to enhance productivity (Fan & Hazell, 2001; Khapayi & Celliers, 2016). Less educated farmers are often slow to adopt efficient production techniques and adapt their farm activities to changing social and environmental conditions (Reimers &

Klasen, 2013; Li *et al*., 2016). According to the stakeholders, education and training have the potential to equip farmers with efficient production and water conservation techniques.

Loop B6 shows a balancing effect that indicates that food available will reduce poverty levels, and an increase in poverty levels will reduce access to formal education, educational levels, access to information, and formal markets, and eventually reduce farm income. Poverty reduces the capacity of farmers to manage and sustain resources (Hazell & Wood, 2008; Van Noordwijk, 2019). According to Molden *et al.* (2010), poverty is a major driver of resource degradation and tools to manage water resources, agricultural lands, and agricultural sustainability, which support a majority of the population. Furthermore, poverty reduces the ability of farmers to access formal education, access to formal markets, and standards of living (Kanianska, 2016). An increase in farm income will lead to agricultural expansion and with it an increase in economies of scale. Economies of scale for individual farmers will decrease input costs and marketing costs with corresponding larger profits. Higher profit margins and capital availability will increase agricultural production and crop yield and eventually reinforce investment in agriculture (Loop R7). Farmers expressed concerns over the increasing cost of production (due to increases in farm inputs and supplements) which is affecting capital availability and agricultural production. These concerns are expressed in Loop B8, which shows that farm income will increase the cost of farm inputs and supplements and an increase in the cost of farm inputs will reduce farm income.

Loop R8 shows a very important causal-relationship in water resource management. The loop shows that the availability of surface water will increase the availability of groundwater, and an increase in groundwater availability will increase surface water availability. This relationship is very important for the effective management of freshwater resources in South Africa. Loop R9 shows the dynamics between population growth, water demand, agricultural production, and food availability. According to the stakeholders, this loop is very important, and will play a vital role in the management of water and agriculture in South Africa. An increase in population growth will increase water demand for various purposes (especially for agricultural purposes), agricultural production, crop yield, and food availability, and eventually reinforce population growth. Population growth will increase pressure on scarce water resources and food production.

Loop 10 is equally an important loop in this model. It shows the water investment dynamics, and establishes a very important causal-relationship between investment and water management. Stakeholders were very concerned about loop 10 because, according to them, the water problems faced in South Africa are due to the lack of, or insufficient investment in, the water sector. The model shows that an increase in investment in irrigation schemes and water infrastructures (such as dams, wastewater plants, salination plants, etc.) will increase surface water availability, total water supply, and water demand for various purposes, and eventually reinforce investment in the water sector. Farmers (mostly commercial farmers) complained of being unable to invest in building dams on their farms to ease water issues due to too much bureaucracy in the water sector. Some farmers also complained that due to policies (such as non-compliance to AgriBBEE), they are not allowed to dig boreholes on their farms These frustrations were echoed by commercial farmers who felt their productivity is declining due to policies preventing them from investing in water infrastructure on their farms. Investment in appropriate technologies is the driving force behind improved water-use efficiency, soil health and fertility, as well as pest, weed, and disease management in most developed countries (Pham, 2014).

The use of appropriate technologies is the driver of water-use efficiency, improved agricultural productivity, and agricultural sustainability in most developed countries worldwide (World Bank, 2008). Technologies such as rainwater harvesting, efficient irrigation systems, conservation tillage to reduce soil evaporation, and water-efficient crops, have enhanced sustainable water management and agricultural sustainability in developing countries (Pretty, 2008).

Loop R10 is counteracted by the balancing loop B2, which shows that increases in water demand for various purposes will reduce surface water availability, total water supply and eventually reduce water demand for various purposes. In South Africa, investing in efficient and productive infrastructural services and technologies could be an important input to improve water-use efficiency, a vital component for economic growth and efficiency, productivity, and competitiveness (Ruiters, 2013). Infrastructure productivity is crucial for managing rapid population growth in South Africa.

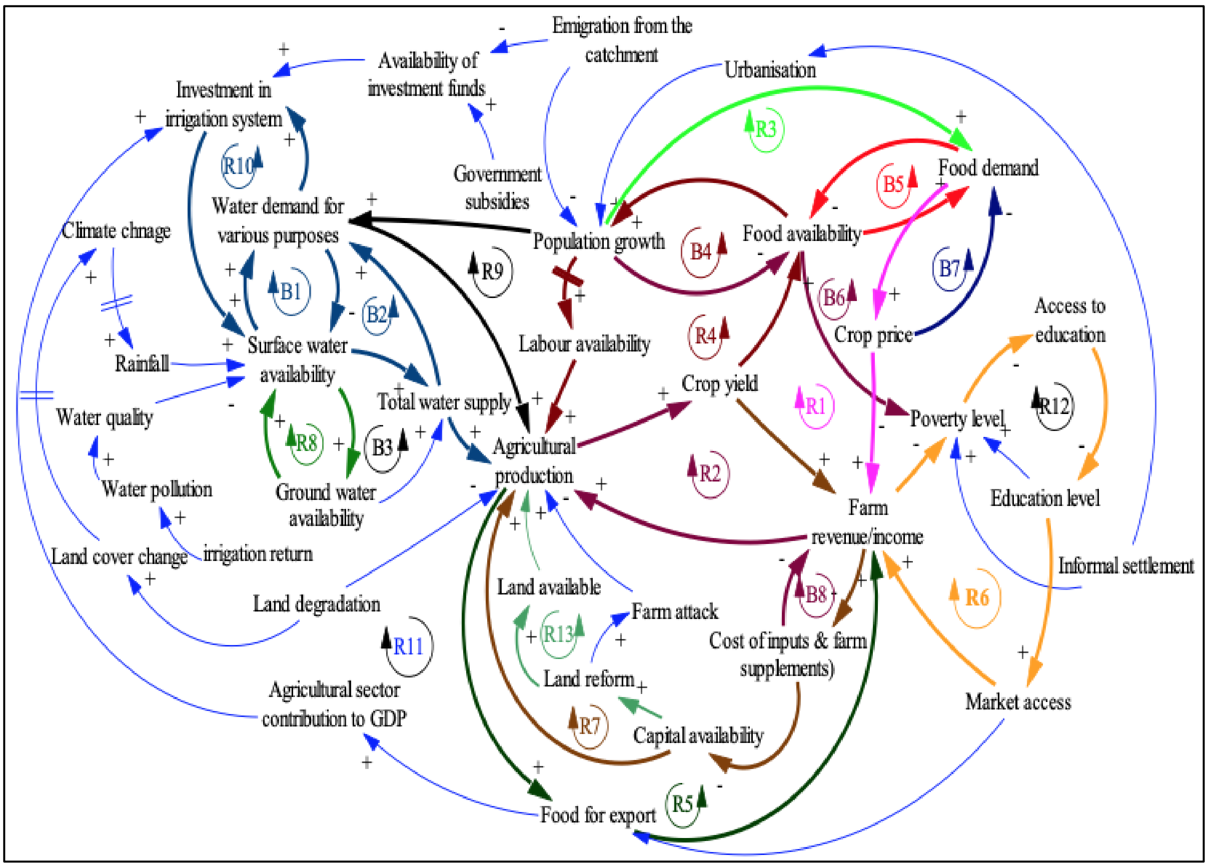

Figure 7.6: Integrated model for water management and agricultural development in South Africa

7.5 Discussion

The results of this study show how stakeholders perceive the social, economic, and biophysical dimensions of water resources management and agricultural development in South Africa. The stakeholder workshops were important in promoting an important dialogue between diverse participants from various backgrounds and helped in building a mutual understanding of water and food systems in South Africa. The participatory approach adopted in these workshops assisted in creating a collaborative partnership, and helped participants understand the importance of collaboration in solving the issues of water management and fostering agricultural growth in South Africa. Similar to previous studies, the methodology proposed and tools used in this study can help bridge the communication gap between policymakers and local stakeholders. This situation highlights the importance of participatory modelling to incorporate the knowledge of key stakeholders for a holistic view of a complex system. The integrated model shows an important causal-relationship between social, economic, and biophysical drivers influencing water and food systems in South Africa. The workshops conducted in this study have provided a framework for conducting future research on water management and agricultural systems in South Africa. The integrated model captured major relationships that exist in water and food systems consistent with related studies in the literature (e.g., see Inam *et al*., 2015; Kotir *et al*., 2017). The model also shows leverage points that need policy intervention to ensure efficient water management and agricultural sustainability.

7.5.1 Leverage Points for Sustainable Water Management and Agricultural Development

The results presented in this study place decision-makers at public and private levels as the core agents tasked with the formulation and implementation of policies geared towards ensuring efficient water management and agricultural sustainability in South Africa. The study in general, has contributed to enhancing our understanding of the dynamics of stakeholder analysis and stakeholder theories. Several empirical studies were also conducted to validate the theoretical claims relating to the stakeholder concepts. The sub-models and the integrated model have revealed not only some areas of major concern but also leverage points for enhancing water and food systems. A leverage point in system thinking is any point in the system where an input of force generates a greater output force; i.e. where a small shift in one thing can produce big changes in everything (Kotir *et al*., 2017). There were a few leverage points in the integrated model built by the stakeholders. For example, the stakeholders mentioned that population growth reduces the resilience of water and food systems by increasing demand for water (loop R9) and reducing land for agricultural production, thereby increasing food demand (loop B4 and B5), and increasing food insecurity. Similar studies have already noted that a complete transformation in approach would be needed in South Africa to build resilient food systems that would require efficient water-use, thereby reinforcing environmental, social, and economic pillars of sustainable development, and ensuring food security (World Wide Fund (WWF), 2018).

Increasing water scarcity and water demand due to population growth, economic growth, climate change, mismanagement of water resources, and deteriorating water quality are some of the challenges facing the water sector in South Africa. Water resources in South Africa are threatened by the invasion of alien species, and wastewater discharge and return flow from agriculture and the household sector. According to Seeliger *et al*. (2018a; b, pp 23), *"The invasion of alien species is severely impacting the ecological sustainability of the Breede river catchment, with about 70% of riparian areas in the catchment in a transformed state"*. The collaborative approach proposed in this study is very important for solving the water problems in South Africa – stakeholder investment is needed at the public and private levels to solve the problems of both water quality and quantity in South Africa. Furthermore, these challenges can be overcome by improving land and water productivity, and reducing the non-beneficial use of land and water resources (Pereira *et al*., 2012). According to FAO (2012), increasing climate change events, rising input costs, ecosystem and resource degradation, shifting dietary preferences due to population and income growth, increasing social gap, and conflicts over resource use will continue to influence ecosystem management, water management, and agricultural sustainability in South Africa. Policymakers cannot fully understand food security in isolation because it has multiple economic, social, and environmental drivers influencing the system, and must, therefore, be viewed within the framework of the intersecting resources of land, biodiversity, water, and energy (Godfray & Garnett, 2014; Biggs *et al.,* 2015; WWF, 2018).

The issue of land reform demands urgent and serious debate in South Africa (loop 13). The future of the agricultural sector in South Africa depends on policymakers ensuring secure land rights for all. The uncertainty regarding the land reform policy has reduced investment in the sector, especially by private sector investors. This has a serious impact on agricultural productivity (Chamberlain & Anseeuw, 2018). Land tenure is a driver that can affect the efficiency of land use (Pham, 2014). Farmers will have less incentive to invest and use land sustainably if land rights are not properly secure (Toulmin, 2009). According to Besley & Ghatak (2010), secure land tenure enables farmers to sustainably manage land, enhance productivity-enhancing investment, operate land markets that transfer land to its best and most productive use, and eventually secure access to capital by using land as collateral.

Loop R8 is very important according to the stakeholders who consider investment in the water sector imperative to ensuring sustainable water management. Investment in water systems and water infrastructures will increase surface water availability. An increase in surface water availability will increase water supply and water demand for various purposes (B2). Decision-makers in South Africa should develop investment models to close the water infrastructure-funding gap, and extend access to water and efficiency in water-use, especially by funding innovative techniques for managing water resources and ensuring sufficient surface and groundwater availability (Ruiters, 2013). Investments in agricultural water management, infrastructural development in rural areas, and related policies are the pathways to breaking the poverty trap in smallholder African agriculture (Hanjra *et al.,* 2009; Valipour, 2015).

The method used to develop the model for this study is different from most other studies that have used system dynamics to model water and food systems in South Africa. The conceptual model developed in this study provides the basis for a quantitative model that enables the development of practical policy-based scenarios regarding water management and agricultural development in South Africa using real data.

There are a plethora of biophysical, social, and economic drivers influencing water management and agricultural development in all the catchments in South Africa. Some of these drivers are unique to certain catchments, and the stakeholders differ with respects to needs and expectations. Developing a model like the one in this study for all the catchments could be beneficial for future research, because developing policies targeted at the specific needs of different stakeholders could assist in securing efficient water management and sustainable agricultural development. The model developed in this study can easily be extended and adapted to other major catchments in South Africa, as well as transboundary river basins in other parts of Africa and beyond. The lessons from this study, described in the next section can help guide this future endeavour.

7.5.2 Participatory Framework for the Sustainability of Natural Resources and Important Lessons

This study has identified important feedback loops and leverage points for sustainable management of water and food systems in South Africa using participatory modelling based on the principle of systems dynamics. This study has demonstrated that participatory frameworks are useful for including relevant stakeholders to constructively identify and capture important feedback loops inherent in complex systems, and the dynamic interactions between important drivers, thereby serving as an important framework for planning and management of water resources and agricultural sustainability. The approach equally shows policymakers how to frame problems and design intervention strategies for solving them. Qualitative system dynamics tools offer a valuable platform for identifying and explaining system behaviour over time (Mirchi *et al*., 2012). For instance, Kotir (2020), Kotir *et al*. (2017), and Inam *et al*. (2015) have applied qualitative tools based on system dynamics to explore and identify the key system drivers influencing the mode of behaviour and sustainability of coupled water-food systems. We have shown that qualitative system dynamics, such as the ones identified here, are capable of capturing the underlying feedbacks structures inherent in natural systems, thereby making it valuable for sustainability planning, policy formulation, and research (Elsawah *et al.,* 2017; Perrone *et al*., 2020).

Socioecological systems are complex and unpredictable due to the multiplicity of drivers and stakeholders with diverse opinions, values, and interests regarding water management and agricultural development (Reed *et al.,* 2013). Participatory approaches are increasingly being used at different temporal and spatial scale to assist policymakers and stakeholders to prepare for change (Pahl-Wostl, 2002; Voinov *et al*., 2016). According to Gray *et al*. (2012) pp 94) "*integrating stakeholder knowledge into natural resource governance is considered to add flexibility to socioecological systems, because knowledge diversity reduces rigidity, represents multiple perspectives, and promotes adaptability in* *decision-making".* This study has demonstrated the value of including stakeholders in problem-framing, policy formulation, and decision-making processes because they are core agents with supporting knowledge of the system. According to Davila *et al.* (2018), the application of participatory approaches to natural resource management and policy formulation has increased considerably because such approaches allow important findings to be made, and increase the knowledge of the stakeholders about the systems. Integrated water resource management is not a new concept in South Africa, but this study has provided a framework for involving stakeholders directly in the design of the models, which not only ensures that the models are directed at the problems, but that stakeholders can use them. Conceptual modelling – based on the principle of system dynamics – provides a suitable methodology for capturing the opinions of all relevant stakeholders, and representing those opinions visually to help understand a complex system, especially when there is uncertainty about the system, or quantitative data is limited. Worthy of note is the fact that the participatory approach takes a great deal of time and effort to complete, especially in a system where identifying and assembling the stakeholders with the necessary skills and competencies is quite difficult (Argent *et al.,* 2016; Zare *et al.,* 2019).

It was also important to consider stakeholders with diverse knowledge and experience in the modelling process in order to develop a model that is inclusive, practical, and easy to use. It was also important to keep the number of participants small for easy management of the groups, and to record all the important contributions of the stakeholders. Many of the stakeholders were participating in this exercise for the first time and had no prior knowledge of modelling. However, they found the entire process to be simple and transparent. The stakeholders stated that the CLD modelling process gave them a visualisation map to see the interaction between the different drivers affecting water and food systems. Stakeholders expressed satisfaction in the way the process was conducted, and the simplicity of the model building process. The stakeholders also saw sufficient value in the process to suggest that policymakers should adopt this approach for effective and practical policies that will target the needs and desires of water users in South Africa. This approach is therefore recommended for future participatory research and policy design.

It is important to note that the models presented in this study are the ideas and thought processes of the stakeholders that participated in the workshops. As such, the categorisation of the sub-models, the integrated model, causal-relationships, and loops are the biases and assumptions of those stakeholders who were involved in the participatory exercises across South Africa.

7.6 Conclusion

This paper used a multi-stage participatory modelling approach based on the principle of system dynamics to engage a diverse group of stakeholders in water and agriculture in order to develop an integrated qualitative, conceptual causal-loop model that would inform policymakers and all relevant stakeholders of the feedback structures and behaviour of the complex water and agriculture system in South Africa. The 2014-2018 drought in South Africa has given this model even more relevance because it will serve as a decision support tool to enhance sustainable management of water and food systems in South Africa. This is the first study that has attempted to develop an integrated model for coupled water-food systems, including multiple drivers, through the active participation of a diverse group of stakeholders in South Africa. The use of CLDs was chosen for this study because it provides a simple visualisation tool that captures the causal and non-linear relationships that exist between ecological, socio-political, and economic drivers interacting with each other to influence water management and agricultural development in South Africa. The use of CLDs identified major causal-relationship and key feedback loops, and their polarities. The results of this study show that CLDs are very useful in a participatory modelling process that includes a diverse group of stakeholders, some of whom might not have any modelling experience in the development of conceptual models – involving several drivers of change – to solve complex water management and agricultural development issues.

The integrated model developed in this study identified several feedback processes that are interacting to influence water management and agricultural development in South Africa. The model shows 8 balancing (negative) feedback loops and 13 reinforcing (positive) loops, meaning that South Africa has a complex system governed by multiple drivers. The model is dominated by positive feedback loops. The very fact that there are 21 loops points to a dynamic system. All stakeholders agreed that water management was especially an issue in the Western Cape. Stakeholders believed that radical actions are needed by all relevant stakeholders to ensure the equitable and sustainable management of water resources in South Africa. Stakeholders agreed that economic, social, and environmental policies were crucial in the management of water resources in South Africa. Investment in new water infrastructures, maintaining existing ones, population, land reform policy, water allocation (water re-distribution), accountability of relevant government structures, and cooperation between government structures were proposed as key strategic focus areas that can ensure sustainable management of water resources and food production in South Africa.

Most stakeholders had no prior experience in modelling and were happy with the model they had developed, the transparency of the workshops, and the general feedback from all stakeholders. Most of the stakeholders indicated that they were willing to participate in future participatory workshops for policy development, and recommended that this approach be used to solve other socio-economic and environmental issues in South Africa in general. To develop realistic scenarios regarding water management and agricultural development in South Africa, a quantitative system dynamics model must be built so that proposed policy recommendations from the stakeholders can be tested using real data. This will enable practical scenarios to be developed.

The next chapter show the results of the quantitative model capable of simulating alternative scenarios to support decision-making in water resource management and agricultural development in the Breede river catchment. Sufficient robustness exists to expand the model to the rest of South Africa.

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8 A SYSTEM DYNAMIC SIMULATION OF COUPLED WATER-FOOD SYSTEMS IN SOUTH AFRICA.

8.1 Introduction

Challenges to the sustainable management of water and food systems constitute a serious environmental and economic problem, and are fast becoming a serious limitation to global socio-economic development (Expósito *et al.,* 2020). Efficient and integrated management of water, energy, and food systems is vital for sustaining human and natural resources (Purwanto *et al.,* 2020). Progress has been made around the world in reducing the prevalence of hunger and food insecurity due to increases in the efficiency and productivity of food systems (Ericksen, 2008). Socio-economic and political changes in the 21st century are increasing the pressure on water and food systems, especially in developing countries. Socio-economic drivers such as hydrological cycles, unsustainable water policies, uncertain future climate, and diverse stakeholder perspectives are some of the complexities that are increasing challenges related to water management at the river-basin scale, particularly in developing countries (Kotir *et al.,* 2016). Ensuring the sustainability of freshwater resources to meet increasing water demand is challenged by large uncertainties due to constantly changing climatic conditions, deteriorating water quality, and increasing competition between water users (Hanjra & Qureshi, 2010; Rasul, 2016; Poff *et al.,* 2016). Decision-makers in water-stressed regions need to implement policies and practices for sustaining water resources to meet the demand of all water users (De Fraiture *et al.,* 2010; Kahil *et al.,* 2019). Furthermore, water management at a river-basin scale is complex because there are multiple drivers of change interacting to produce several dynamic system feedbacks, thereby making it difficult to understand the behaviour of the system at any given time (Sivapalan & Blöschl, 2015; Li *et al.,* 2018; Pan *et al.,* 2018).

Recently, the concept of non-linear thinking has become very popular for solving complex system problems, providing an opportunity to move away from conventional, reductionist-linear thinking to improve the understanding of some complex systems (Fish & Hardy, 2015; Turner *et al.,* 2016). The non-linear thinking approach is increasingly being applied to natural resource management, especially to water resource management, agricultural sustainability, and energy management (Rammel *et al.,* 2007; Kotir *et al.*, 2016). A holistic approach is needed to understand the interactions between the interdependent and interrelated sub-systems that make up the system. A systems thinking framework provides tools and techniques for applying non-linear causal thinking to manage the sustainability of water systems (Mirchi *et al.,* 2012). Water management is very important in the analysis of water and food systems because water availability directly affects food production at different spatial and temporal scales. According to Kahil *et al.* (2019), water modelling tools should be able to concurrently integrate the different sectoral objectives and resource constraints rather than looking at a water sector in isolation. As a result, system dynamic modelling (SDM) based on the principle of systems thinking is a tool for holistically modelling complex system problems.

SDM is used to model dynamic complex systems driven by multiple feedback structures (Tedeschi et al., 2011; Neuwirth *et al.,* 2015). It has been used to assist policymakers to develop policy-based scenarios for solving complex system problems (Fontes *et al.,* 2018; Enteshari *et al*., 2020). System dynamics modelling provides both qualitative and quantitative modelling tools. Qualitative SDM involves the construction of conceptual models using Causal Loop Diagrams (CLDs) to show the causal-relationships between drivers and dynamic feedbacks that exist in a system, while the quantitative SDM quantifies and simulates the important feedbacks using Stock and Flow Diagrams (SFDs) (Sterman, 2000; Narayana *et al.,* 2018). According to Purwanto *et al.* (2020), CLDs and SFDs in SDM are complementary. SDM is a tool for identifying and simulating dynamic complex system problems through structural identification of feedback, and delay processes that influence the behaviour of the system (Walters *et al.,* 2016; Kotir *et al.,* 2016; Pluchinotta *et al.,* 2018). Therefore, SDM provides a holistic platform to analyse and understand problems in water and food systems.

SDM has been applied to water resource management (Kojiri *et al.,* 2008; Khan *et al.,* 2009; Sušnik *et al.,* 2012; Pluchinotta *et al.,* 2018), agricultural production systems (Sušnik et al., 2012; Monasterolo *et al.,* 2015; Walters *et al.,* 2016; Chapman & Darby, 2016), and to water and food systems (Sušnik *et al.,* 2013; Aivazidou *et al.,* 2015; Kotir *et al.,* 2016) with a high degree of success. In South Africa, Marandure *et al.* (2020) applied SDM to evaluate the sustainability of low-input ruminant farming systems in the Eastern Cape Province. Queenan *et al.* (2020) applied SDM to model the livestock-derived food system in South Africa. Jonker *et al.* (2017) applied SDM to examine the implications of biofuel production in the Western Cape Province, South Africa. Von Loeper *et al.* (2016) and Musango *et al.* (2015) used SDM to analyse challenges facing smallholder farmers, and the implications of a green economy transition in South Africa, respectively. Furthermore, Carnohan *et al.* (2020) used SDM to model climate change adaptation in rural South Africa using stakeholder narratives.

The diverse application of SMD in natural resource management has increased the understanding of the dynamic behaviour of such systems (Kotir *et al.,* 2016). Despite the application of SDM to natural resource management at different spatial and temporal scales, no study has attempted to apply SDM to understand the complex and dynamic behaviour of water and food systems in South Africa. System dynamic models are needed in South Africa to integrate socio-economic, environmental, and political drivers, and to understand the dynamic feedback processes influencing current and future dynamics of water and food systems. This study fills this knowledge gap by applying a quantitative SDM to understand the systemic behaviour of water and food systems in South Africa.

This chapter presents a description for an integrated system dynamics simulation model built as a decision support system for sustainable management of water resources and agricultural development in South Africa. The overall aim is to develop an integrated model for South Africa. Due to the complex nature of developing such a model for South Africa, it was advisable to select strategic catchments for the model development. The goal is to simplify the model at the catchment level, which will form the basis for understanding the functioning of water management systems and agricultural development in South Africa. The quantitative model developed for this study simulates the dynamic interactions and feedback processes between the surface water resources, groundwater, agricultural sustainability, and population sub-sectors of a catchment. The SDM developed by Kotir *et al.* (2016), which simulated the dynamics of a basin in Ghana over a long period, laid a strong foundation for the development of this dynamic model.

8.2 Methodological Approach

8.2.1 Selecting a Study Area to Test for Robustness

The systems thinking approach and the principle of system dynamics was applied in the Breede river Catchment, in the Western Cape province, South Africa. The Breede river catchment was selected as study area to test the model for robustness because Breede river catchment is one of few catchments in South Africa with reliable data. It is one of the strategic catchments in the Western Cape province. The Breede river is the engine driving the economy of the catchment, especially in the upper and middle areas of the catchment, whose economy is driven by the agriculture sector (Gcanga *et al.,* 2018). The catchment occupies an area of 12,384 km2 and has a length of 337 km. According to the Breede catchment strategy, there are 15 dams within the Breede river catchment. The biggest dam (Brandvlei dam) has a capacity of 475 million m3 while the smallest dam (Pietersfontein dam) has a capacity of 2 million m3 (See Fig 1). Seven of the dams within the Breede river catchment are used for agricultural irrigation, one is used for urban water usage and the rest are used for both urban and irrigation. The population of the catchment is estimated to be an estimated 300 000 people (Seeliger *et al*., 2018). According to Seeliger *et al.* (2018), agriculture is the main economic driver and accounts for an estimated 87% of annual water demand, making the sector the largest water user in the catchment.

Commercial agriculture is the major activity dominating land use in the catchment. Agriculture in the catchment is dominated by intensive irrigation for wine and table grapes, dairy and deciduous fruit production as well as extensive rain-fed (dry land) for cereal cultivation and livestock farming. Agricultural processing and packaging are also important economic activities in the catchment. The catchment is very crucial to agricultural development in South Africa because 70% of all table grapes, apples, and fynbos in South Africa are produced in the catchment (Western Cape Government, 2018). The catchment is also strategic to agricultural development in South Africa because agricultural products produced in the catchment are consumed locally and internationally.

Population growth, infrastructure development, pollution, climate change, and increases in water demand are putting enormous pressure on land and freshwater resources in the catchment. Agricultural development combined with socio-economic development and ecological factors are interacting to influence water resources in the catchment. Therefore, as stated in the Western Cape Government (2018:57), *“policies are needed to balance the water-dependent requirements of economic development, social justice and ecological sustainability in this region”.*

The catchment like most of the Western Cape province has a winter rainfall climate. The catchment experiences extensive rainfall during the winter months and very little or no rain during the other seasons. Rainfall can exceed 1800 mm in the western mountainous areas of the catchment and as low as 300 mm/a rainfall lower eastern areas of the catchment. Additional surface water through rainfall run-off is recorded during winter months and shortages outside the winter months.

A map of the Breede River catchment is shown in Figure 8.1

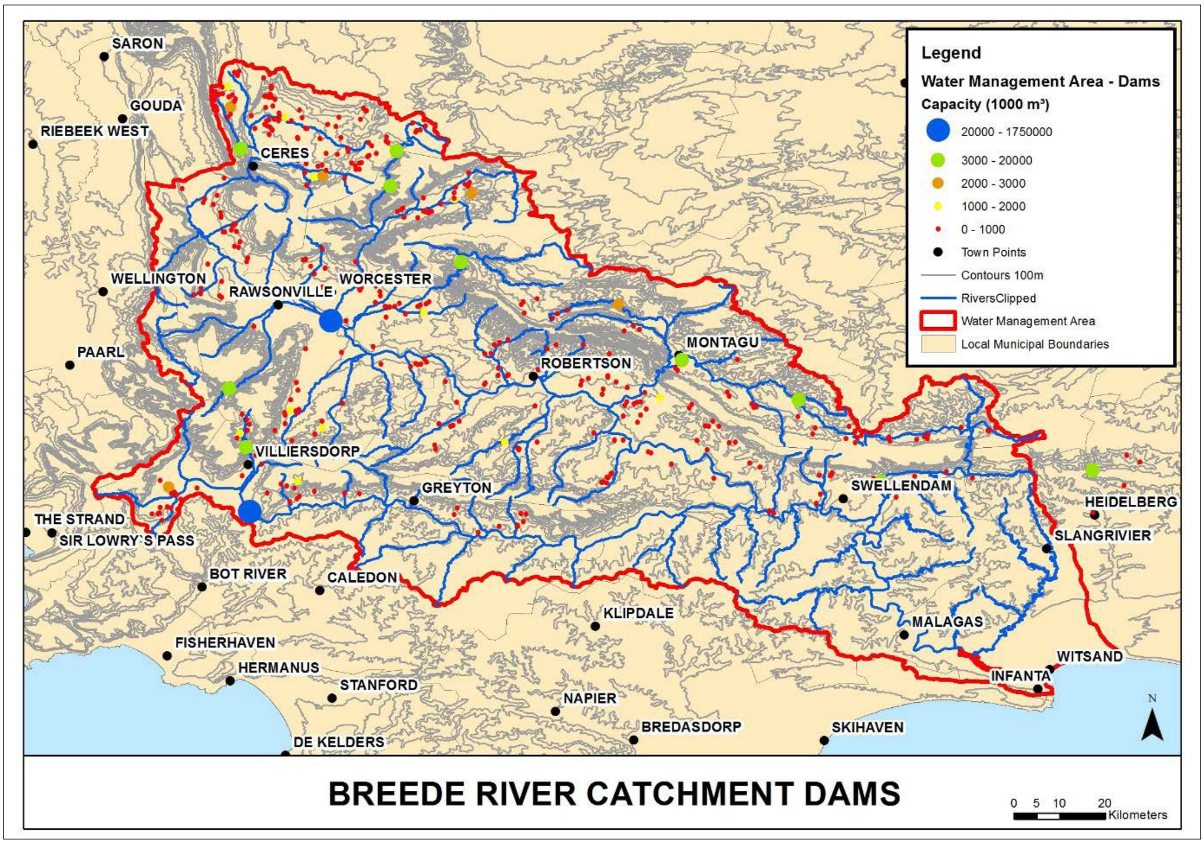


Figure 8.1: Map showing Breede river catchment

8.2.2 System Dynamics Modelling Approach (SDM)

SDM consists of qualitative modelling (causal loop diagrams) and quantitative modelling (stock and flow diagrams). Causal loop diagrams (CLDs) are very useful for representing interdependencies and dynamics feedback processes inherent in a complex system (Gillespie et al., 2004; Walters et al., 2016; Elsawah et al., 2017). CLDs represent the first phase of the modelling process, as they capture the mental models of relevant stakeholders and modellers regarding the structure and behaviour of the system (Sterman, 2000; Prusty et al., 2017). However, CLDs are limited in that they are unable to capture the stock and flow structure of systems (Hjorth & Bagheri, 2006; Schaffernicht, 2010). Stock and flow diagrams (SFDs), on the other hand, consist of stocks, flows, auxiliary variables, and a definition of the system boundary (Tulinayo et al., 2018; Purwanto et al., 2020). SFDs are used to model and simulate the dynamic effects of drivers of change, and their interaction (Antunes et al., 2015; Selvakkumaran & Ahlgren, 2020).

Qualitative system dynamic models can assist policymakers to understand, and improve their understanding of, the long-term dynamic behaviour of a system, and as well as provide a useful tool for developing plausible policy-based scenarios for ensuring the sustainability of water and food systems (Castella et al., 2007; Ison et al., 2011; Kotir et al., 2016). Like Kotir et al. (2016) and Walters et al. (2016), system dynamics modelling approach was preferred for this study for its proven ability to use non-linear dynamics to simulate the dynamic interactions between drivers of change in the Breede River catchment. The modelling process begins with the development of a dynamic hypothesis (qualitative modelling) using CLDs, and the important feedback loops are quantified and simulated using SFDs (Sterman, 2000; Mirchi et al., 2012).

8.2.3 The Development of the Qualitative Model (CLD)

A participatory modelling approach including relevant stakeholders in the water and food sectors in South Africa was used to build the qualitative integrated model. The model was built using CLDs, which are useful qualitative analytical tools for representing causal-relationships among drivers of change and their dynamic feedback structures (Sterman, 2000; Kotir, 2016). The Breede river catchment conceptual model (Figure 8.1) was developed through a multi-stage participatory modelling approach based on the principle of system dynamics (Voinov & Bousquet, 2010; Voinov et al., 2016; Voinov et al., 2018), to engage a diverse group of stakeholders in the water and agricultural sectors. To capture the mental models of diverse stakeholders from different sectors, 10 stakeholder workshops were organised engaging more than 70 individual stakeholders across South Africa.

Chapter 6 has explained in detail the process of selecting the stakeholders and the process of developing the CLDs. The qualitative conceptual model described in chapter 7 forms the basis for developing the quantitative SDM presented in this study. The integrated model as shown in Figure 8.2 has 36 variables representing several causal relationships. The model shows 21 major loops consisting of 13 reinforcing (positive) loops and 8 balancing (negative) loops. Important loops were captured and simulated in this study. For example, loop R4 shows that the population and labour dynamics was an important loop. This loop shows that population growth will increase the labour force needed for food production. An increase in food production will increase crop yield, food availability, and population growth. Loops R8, R9, R10, B1, B2, and B3 were also considered very important and have been simulated in this study. Furthermore, loops R1, R2, R3, R13, and B8 are also important loops that have been simulated in this study.

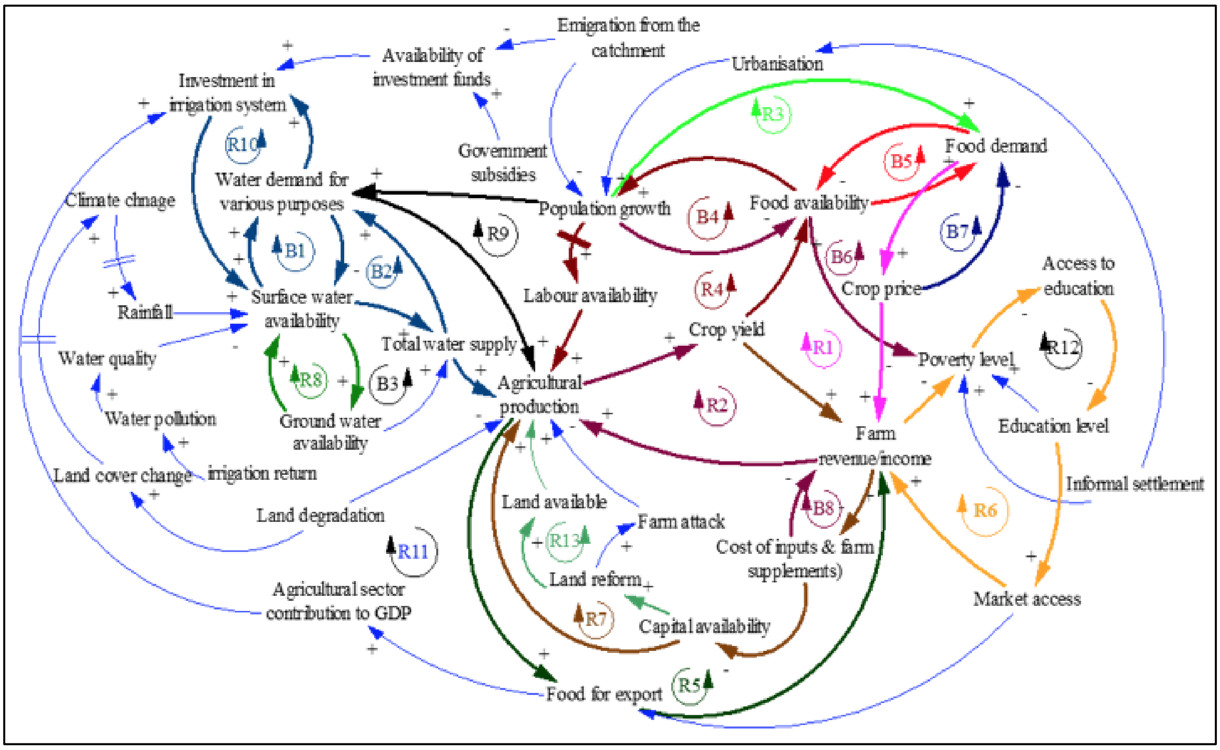


Figure 8.2: Breede river catchment conceptual model

8.2.4 The Quantitative SDM Development Process

Quantitative SDM uses stock and flow diagrams (SFDs) to simulate dynamic feedbacks in a complex system. SFDs provide a platform to mathematically estimate system dynamics models (Sterman, 2000; Forrester, 1961). Stocks and flows and dynamic feedback structures form the basis of dynamic systems theory (Sterman, 2000). This model used dynamic SFDs to model and simulate dynamic feedbacks in the Breede river catchment. Due to the complexity of the Breede river system, it was necessary to demarcate the model into sub-systems for a simpler representation of the system. The model was divided into four sub-systems in order to capture all the relevant drivers and feedbacks presented in Figure 8.1. These sub-systems include population, surface water, groundwater, and agricultural sub-systems. The four subsystems are linked, thus depicting the dynamic interaction between the water resource management (surface and groundwater), population dynamics, and agricultural production in the catchment for a period of 20 years (i.e. 2010-2030). The year 2030 was chosen for the model because it represents the year South Africa intends to achieve the goals of the national development plan (NDP). The model was simulated with Stella Architect® (student version), by iseesystems (isee systems, www.iseesystems.com). The model used a time step of 0.25 years, meaning that values for stocks, flows, and converters are calculated every ¼ year for the entire simulation run (Kotir et al., 2016). It should be noted that the system dynamics simulation model for sustainable water resources management and agricultural sustainability developed by Kotir et al. (2016) was modified and adapted to this study. Though this model was initially developed for the Volta River Basin in Ghana, we found the model structure and behaviour to be similar to the system behaviour of the Breede river catchment. All four sub-systems are defined and presented in the following sections.

8.2.4.1 Population sub-model

Population growth was identified as one of the main drivers influencing water management and agricultural development in the Breede river catchment (Nyam *et al.,* 2020). Population growth influences food and water demand for different uses (Mirchi *et al.,* 2012). Similar studies have identified population growth as a strong driving force influencing water resource use and agricultural production in river basins (Williams *et al*., 2016; Kotir *et al.,* 2016; Chapman and Darby, 2016). The population sub-sector of is shown in Figure 8.3. The model estimates population dynamics, is strongly influenced by rates of emigration and immigration (including informal settlements), birth and death rates, as well as the availability of food for human consumption.

For this study, the population stock is the total population of the catchment (made up of children and adults). We decided to keep the model as simple as possible. As a result, not all factors that influence population dynamics were incorporated. Factors such as nutrition, access to health care, pollution, and crowding all depend on the size and wealth of the population, thereby creating several feedbacks. These are omitted from the current model.

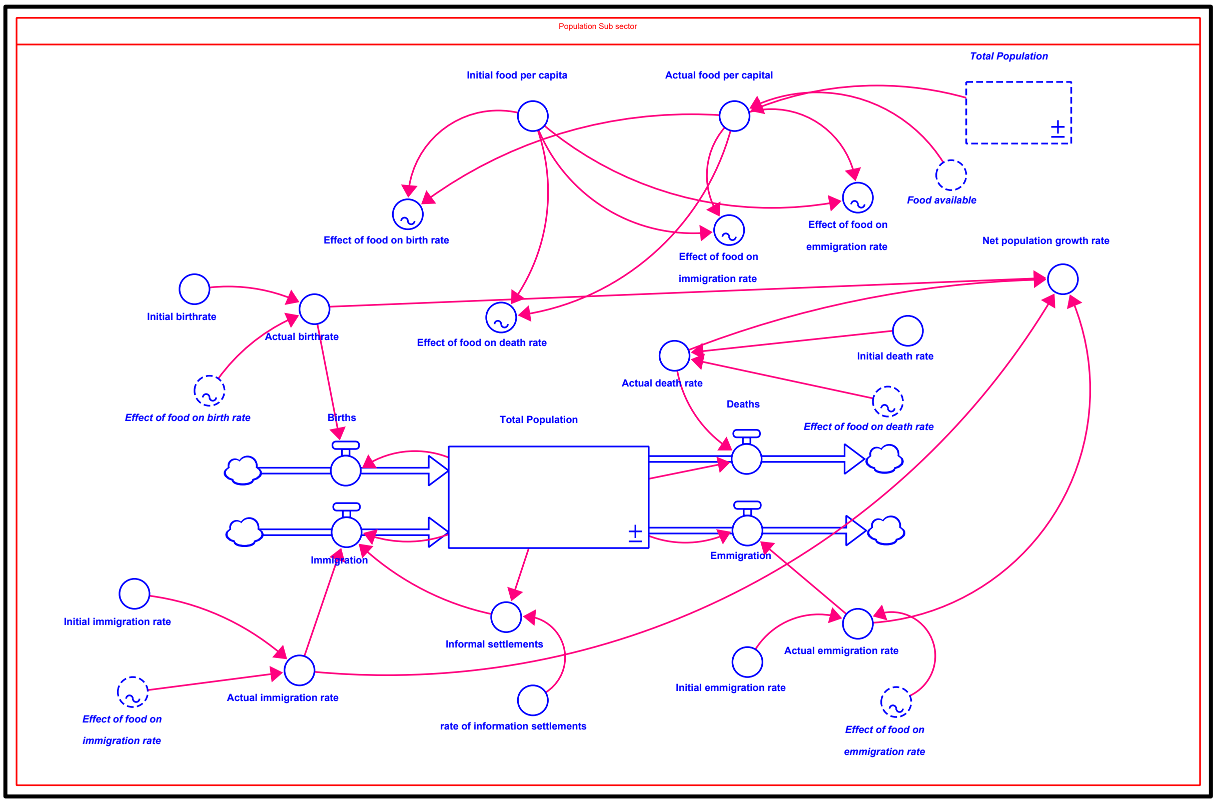


Figure 8.3: SFD of the population sub-sector

8.2.4.2 Surface water resources sub-sector

Water resources come from both surface water and groundwater resources (Kotir et al., 2016). The surface water resources sub-sector is depicted in Figure 8.4. This sub-sector represents surface water availability and demand within the catchment. Surface water is the first choice to meet the water needs of the economies in the catchment, while groundwater is used when the surface water supply is not available. Several factors govern surface water availability, including the amount of precipitation, runoff, surface water inflows and outflows, evapotranspiration, and infrastructure conditions. The total annual runoff for the Breede river catchment is estimated to be 1904 million m^3 (Breede-Overberg Catchment Management Strategy, 2012), and 173 million m^3/yr is transferred out of the catchment. Quantification of water demands was based on water demand for agriculture (irrigation), and urban use; relatively little water is used for industrial purposes. Domestic water demand was expressed as a function of population (Davies & Simonovic, 2011; Kotir *et al.,* 2016). Agricultural water demand in the catchment generally accounts for more than 80% of the total water demand, with more than 70% used for irrigation agriculture (Breede-Overberg catchment Management Strategy, 2012). Total water withdrawal from the catchment was estimated as the sum of agricultural and domestic water demands. As the Breede river catchment is very large and open, with an outlet to the sea, spillage represents water that cannot be stored and which flows into the sea.

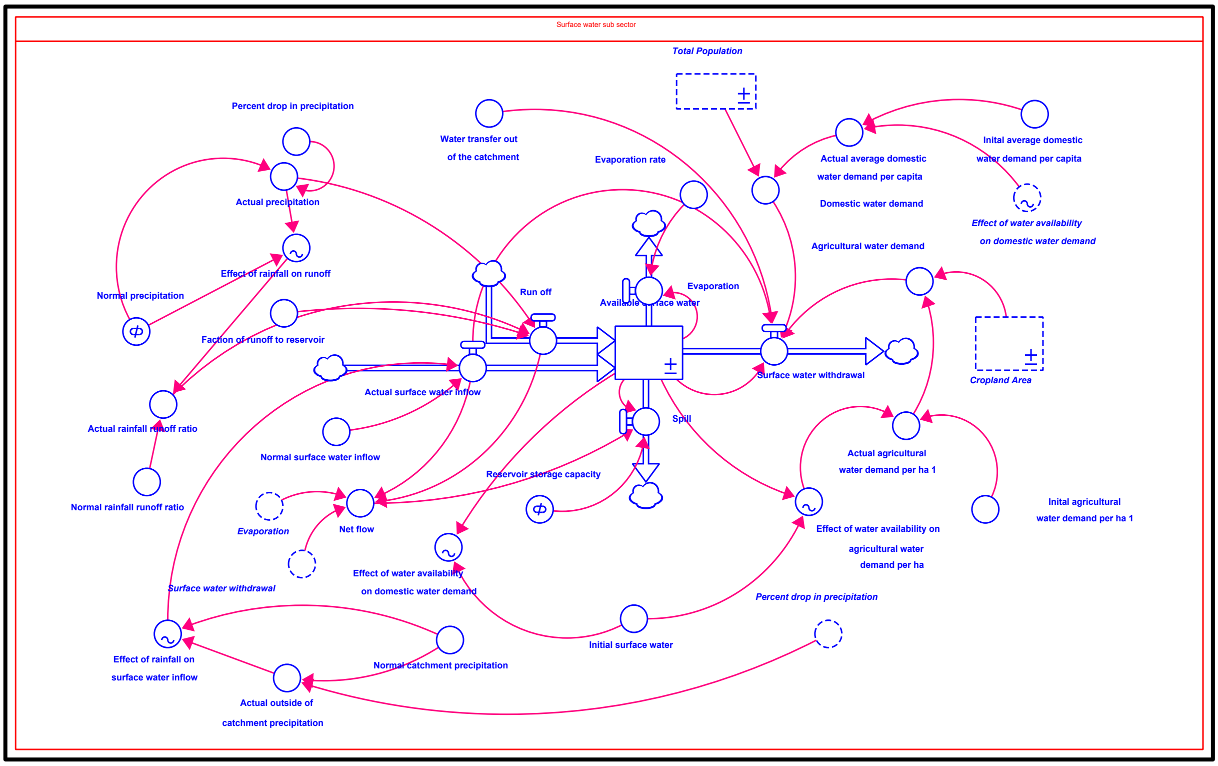


Figure 8.4: SFD of surface water resources sub-sector

8.2.4.3 Groundwater resources sub-sector

The groundwater sub-sector is depicted in Figure 8.5. This sub-sector represents groundwater resource availability in the catchment. Groundwater is a very important source of fresh water when surface water sources are no longer enough to meet the demands of water users (Siebert *et al.*, 2010). Groundwater resources are vital for intensive agriculture, as they provide a reliable and flexible source of freshwater resources for irrigation (Tian et al., 2015). Groundwater use in the Breede river catchment is estimated at 103 million m^3/, most of which supplies irrigation from farmers' boreholes (Midgley et al., 2005). Quantification of groundwater demands – like that of surface water – was based on water demand for agriculture (irrigation), and urban use; relatively little water is used for industrial purposes in the catchment. For this reason, industrial groundwater use in the catchment was not included in this study. Therefore, total groundwater withdrawal was estimated as the sum of actual agricultural and actual domestic water demands. Domestic groundwater demand is influenced by population growth and the quantity of groundwater available.

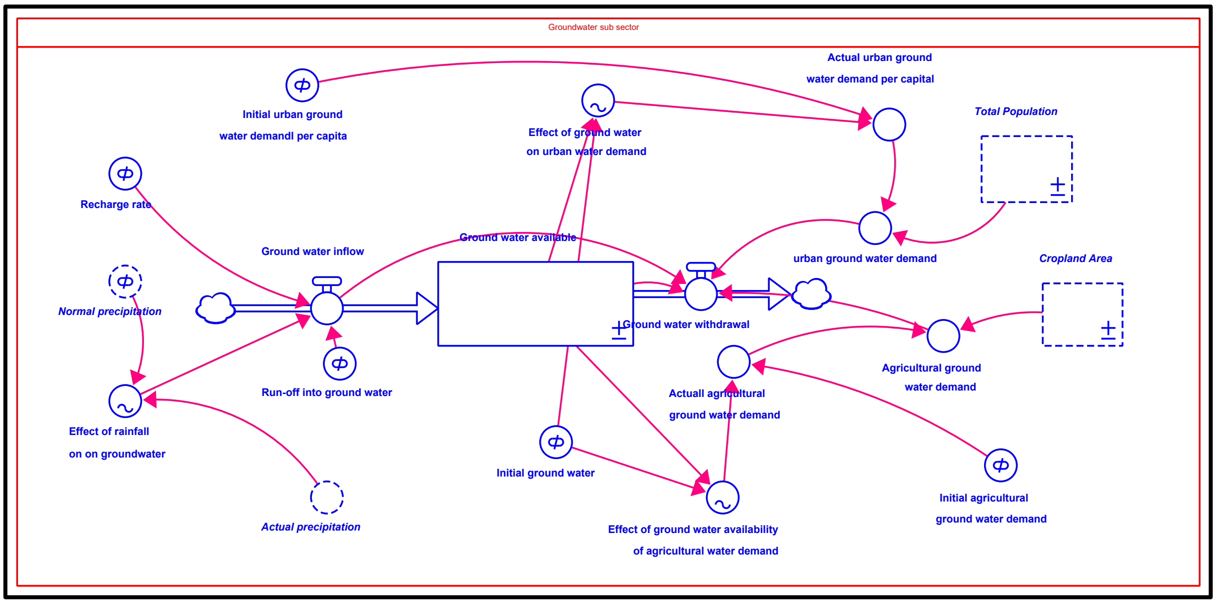


Figure 8.5: SFD of groundwater resources sub-sector.

8.2.4.4 Agricultural production sub-sector

The agricultural production sub-sector is depicted in Figure 8.6. Agriculture is the main economic driver of the Breede river and accounts for an estimated 87% of annual water demand, making the sector the largest water user in the catchment. Commercial agriculture is the major land use activity in the catchment, and water use is dominated by intensive irrigation for wine and table grapes, dairy and deciduous fruit production, as well as extensive rain-fed (dry land) for cereal cultivation and livestock farming. Agricultural processing and packaging are also important economic activities in the catchment. The catchment is crucial to agricultural development in South Africa because 70% of all table grapes, apples, and fynbos in South Africa are produced in the catchment (Western Cape Government, 2018).

The catchment is also strategic to agricultural development in South Africa because agricultural products produced in the catchment are consumed locally and internationally. Crop yield depends on the cropland area, water, agricultural investment, and land reform. Cropland area availability is equally influenced by population growth, change in cropland area, the demand for food, total agricultural land, and the change in crop yields. As the focus is on fruit yield, the cropland area was estimated based on the area under fruit production.

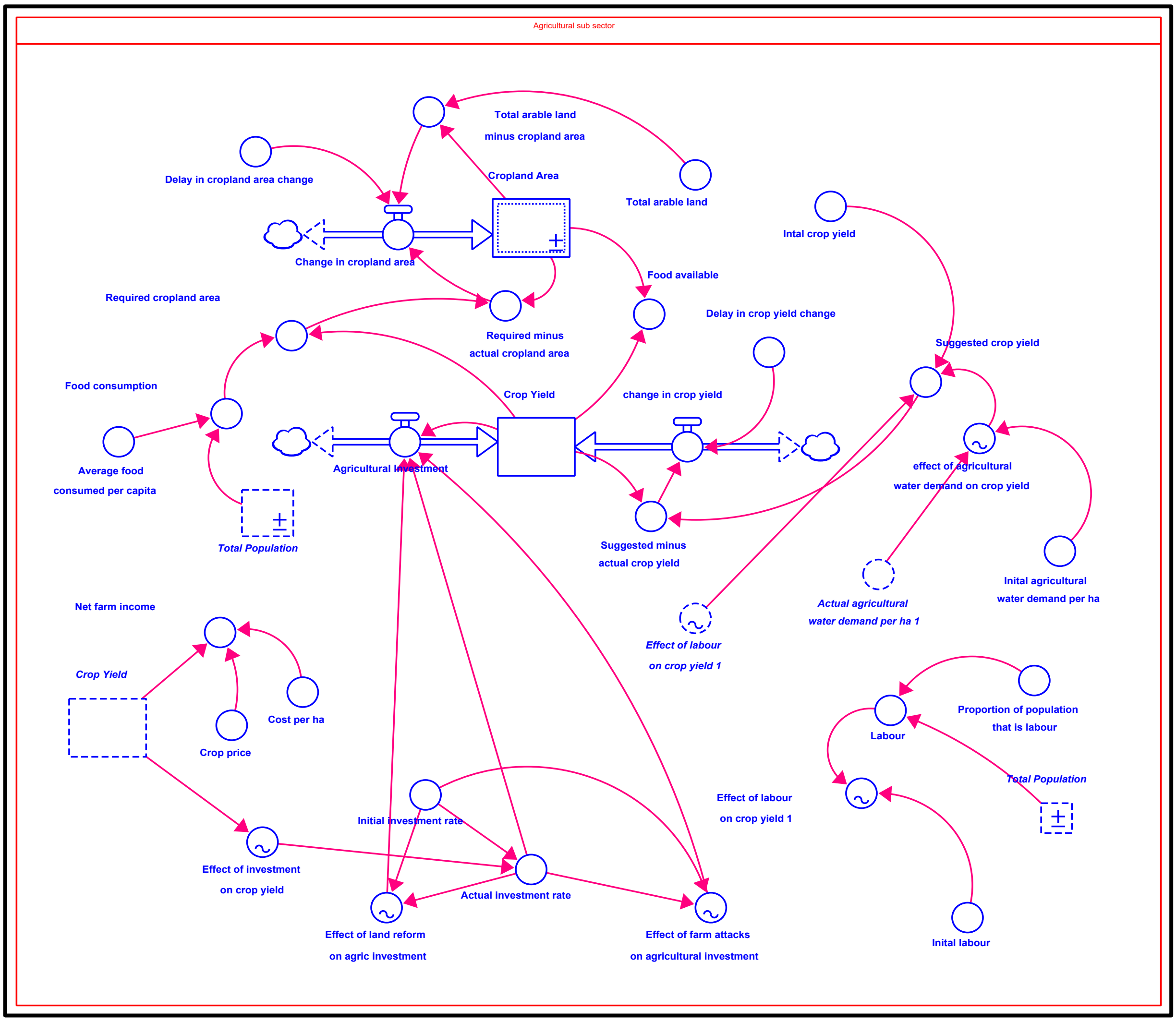


Figure 8.6: SFD of the agricultural production sub-sector.

8.3 Input Data and Model Parameterisation

Getting accurate historic data for all the variables included in the SFDs was a challenge. Several attempts to get specific Breede river catchment data from the authorities were not successful. As a result, most of the data used in the model were obtained from online databases and published articles. Where catchment specific data were not available, national figures were used, and in instances where data were unavailable at national and catchment level, estimates were used in the model. As such, population and demographic figures were estimated based on census data available from published studies about the catchment. Crop yields, cropland area, and food production and consumption data were obtained from the Breede-Overberg Catchment Management Strategy (2012). The initial values for available surface water, reservoir storage capacity, water transfers, and demands were obtained from the Breede-Overberg Catchment Management Strategy (2012). The model was parameterised with data from the year 2010 and simulated until 2030. The simulation was done based on the stakeholder assumptions regarding water and food systems during the stakeholder workshops. Some key parameters used in the model and their corresponding values are described in Table 8.1.

Table 8.1: Key variable data and sources of the data for the model

Variables	Initial values	Source
Mean Annual Runoff	1904 million m^3/yr	Breede-Overberg catchment management strategy (2012)
Runoff Loss	121 million m^3/yr	Breede-Overberg catchment management strategy (2012)
Evaporation rate	0.06355042	Breede-Overberg catchment management strategy (2012)
Capacity (million m^3)	1001 million m^3	Breede-Overberg catchment management strategy (2012)
Surface water used for irrigation	681 million m^3/yr	Breede-Overberg catchment management strategy (2012)
Groundwater used for irrigation	134 million m^3/yr	Breede-Overberg catchment management strategy (2012)
Water use per hectare (table grapes)	5000 m^3/ha	Breede-Overberg catchment management strategy (2012)
Urban* (million m3 /a)	30 million m^3/yr	Breede-Overberg catchment management strategy (2012)
Transfers out	173 million m^3/yr	Breede-Overberg catchment management strategy (2012)
Population	300 000 people	Cullis et al. (2018)
Birth rate	20.5/1000	World Bank (2018)
Death rate	9.44/1000	World Bank (2018)
Immigration rate	11/1000	Estimated
Emigration rate	6/1000	Estimated
The proportion of the population that is in labour	0.67 (%)	Provincial economic review and outlook 2016
Food available per person	265 (kg/ha /yr.)	This study
Per capita food consumption	495 (kg/capita)	This study
Total food consumption	250 (kcal/capita)	This study
Cropland area	5432 (per 1000/ha)	This study
Crop price	63.55 (USD)	This study
Cost per ha	381.25 (USD)	This study
Net-farm income	593.88 (USD)	This study
Delay in cropland area change	7 (years)	This study
Crop yields	2500 (kg/ha)	Breede-Overberg catchment Management Strategy (2012)

8.4 Model Testing and Sensitivity Analysis

A series of validity tests were performed to observe the behaviour of the model. The tests suggested by Sterman (2000) and applied by Kotir *et al.* (2016) and Purwanto *et al.* (2020) were used to test the validity of the model. Validity tests are important because they measure the accuracy of a model against a real system, and include a parameter confirmation test, dimensional consistency test, integration error test, and a behaviour pattern test (Kotir *et al.,* 2016). Some variables were chosen based on the availability of data to perform the validity tests. Maximum relative error (M), coefficient of determination

R^2) and discrepancy test (U_0) are the three validity tests used in this study to examine the behaviour of the observed data against the simulated data between 2010 and 2020. As a result, variables such as population growth, crop yield, net farm income, and agricultural water demand were used. These tests were used to examine the behaviour of the model for observed data against the simulation data for the selected variables. M measures the possible divergence between model (observed) (Y_{obs}) and simulated data (Y_{sim}); R^2 measures the variance of simulated data explained by the observed data, and has a score between 0 and 1, with values closer to 1 indicating best-fitted model; and U_0 measures the predictability of the model, and equally has a score of 0-1, with 0 indicating best prediction and 1 indicating worst prediction (Moriasi *et al.,* 2007; Qin *et al.,* 2011; Wu *et al.,* 2013; Kotir *et al.,* 2016).

$$M = \frac{\sum(Y_{sim} - Y_{obs})}{\sum Y_{obs}} \quad (1)$$

$$R^2 = \left(\frac{Cov(Y_{sim} - Y_{obs})}{\sigma Y_{sim} \sigma Y_{obs}}\right)^2 \quad (2)$$

$$U_0 = \frac{\sqrt{\sum(Y_{sim} - Y_{obs})^2}}{\sqrt{\sum Y_{sim}^2} + \sqrt{\sum Y_{obs}^2}} \quad (3)$$

Source: Sterman (2000); Kotir et al. (2016); Purwanto et al. (2020)

A sensitivity analysis was done to further validate the behavior of the model. According to Sterman (2000), a sensitivity analysis is important because it determines how robust the model is, given the uncertainty in certain model variables. Sensitivity analysis explains how robust policy recommendations are over a given period under different scenarios and given uncertainties. Furthermore, according to Sušnik *et al.* (2012), sensitivity analysis helps to identify the critical model parameters influencing the behaviour of the model under different policy scenarios. Sensitivity analyses were performed to test the robustness of the model by simulating the model using a 10% change in the following variables: total population, crop yield, net farm income, cropland area, and agricultural water demand. During sensitivity analysis, only the value of the tested variables was changed while the other variables were held constant at their observed values.

8.5 Policy Scenarios

Sensitivity analysis allows different policy scenarios to be designed and simulated over a certain period. In this study, policy scenarios were designed and simulated from 2010 to 2030 (i.e. 20 years). The model was simulated to understand the dynamics of population growth, policy uncertainty, and water resource utilisation, and their implications for agricultural development in the Breede river catchment. This process is characterised by assumptions about the systems and trial and error to determine the effectiveness of different policy interventions (Kotir *et al.,* 2016). To begin the process, the Business-as-usual (BAU) scenario – also known as the baseline scenario – was run from 2010 to 2030.

The BAU assumed a steady-state in the system; that is, the prevailing conditions in the system regarding water resource management and other socio-economic factors will remain the same for the simulated period. In addition to the BAU, three additional policy scenarios were designed based on the discussions with stakeholders in the participatory workshops.

8.5.1 Scenario 1: Investment in innovative technologies and infrastructure in water and food systems.

It has earlier been established that agriculture is the highest user of freshwater resources in South Africa, accounting for approximately 61% of overall water use, mainly for irrigation. At the same time, the agricultural sector losses approximately 30% of its water use due to inefficient technologies and a lack of investment in water infrastructures (Mukheibir, 2008; Ruiters, 2013). It is stated in the National Development Plan (NDP) of South Africa vision 2030 that South Africa needs to invest in water infrastructures in order to achieve the mid-and long-term goals of food production for sustainable development in the country. According to Oberholster et al. (2017), it seems highly unlikely that South Africa's water resources will be able to sustain current patterns of water use and waste discharge due to estimated growths in population and socio-economic development. Against this backdrop, investment in the construction of dams, reservoirs, and smart agricultural techniques that can supply reliable sources of freshwater and boost agricultural production is highly recommended. These dams and reservoirs can store large quantities of water during periods of water abundance for use during seasons of scarcity in order to bridge the water deficit gap (Lehner *et al.,* 2011; Di Baldassarre *et al.,* 2018). Reducing the water deficit gap will ensure water availability for food production and energy generation (Flörke *et al.,* 2018). As a result, a 65% increase in reservoir capacity was simulated in the first year. Several climate models predict wetter years in most parts of South Africa in the best-case scenario (Jordaan et al., 2018). This study also simulated an increase of 15% in precipitation in the best-case scenario

8.5.2 Scenario 2: Population growth

The effect of population growth on water resource management and food production was equally simulated within the Breede river catchment. The Western Cape province is one of South Africa's economic hubs, and is attracting many migrants mainly due to the area being an employment hub (Jacobs & Du Plessis, 2016). The province is supported by industrial development and a striving agricultural sector. The economic growth of the province makes it strategic for a variety of economic activities, which attracts people. Unfortunately, the province is struggling to keep up with the pace of migration, especially of informal settlers, as they increase pressure on the province infrastructure, especially its water and land resources (Cross, 2001). Rapid population growth increases food consumption and increases competition for land within the agricultural sector (Barthel *et al*., 2019). At the same time, rapid population growth can increase labour available for agricultural production, given the agricultural sector is labour intensive (Dorward, 2013; Senyolo *et al.*, 2018). The model simulated a population increase of 20% and its effect on water resources, water demand, and food production.

8.5.3 Scenario 3: Land reform and policy uncertainty

In an effort to reduce inequality and increase land ownership, especially among black South Africans, the government of South Africa proposed a land reform policy (Nyam *et al.,* 2020). This policy aims to increase land ownership, reduce poverty and inequality, and increase agricultural productivity. However, it is still not clear exactly how the government plans to implement this policy. As a result, this has caused so much uncertainty, especially among private investors. This uncertainty is forcing investors to withhold their investment, as they want to observe and see the outcome of the policy. This will limit agricultural investment and food production. Some of the stakeholders in the workshops stated that any dilution of property rights would inevitably hurt agricultural stability, food security, investment and economic growth in South Africa. Due to uncertainty and insecurity over land, agricultural investment will decrease in the long run, and consequently, food production will reduce. This scenario simulated a 60% decrease in agricultural investment and its effect on food production, farm income, water supply, and demand. The descriptions of the simulation scenarios and the percentage (%) in model variables are summarised in Table 8.2. The results of these scenarios were compared to the BAU scenario to examine the overall policy implications.

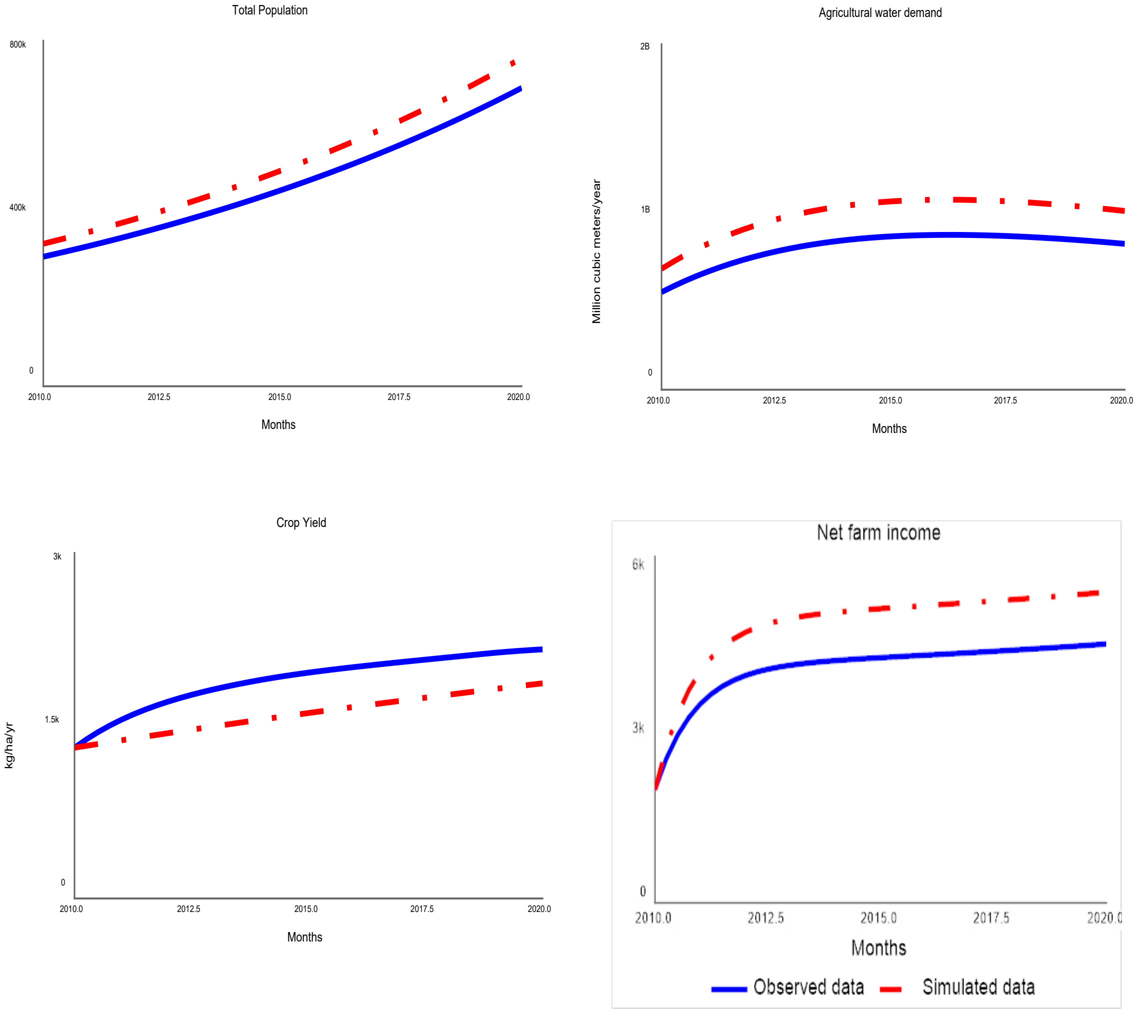
Table 8.2: Description of selected policy scenarios.

Policy scenario	Description of scenarios
Scenario 1	Reservoir storage capacity is increased by 65%; available surface water is increased by 65%; precipitation is increased by 15%; agricultural water demand per ha is increased by 25%. Effects of agricultural water demand are changed by 10%. All other variables are at their baseline values.
Scenario 2	Population growth is increased by 20%. Effects of agricultural and domestic water demand are altered by 25%. All other variables are at their baseline values.
Scenario 3	Agricultural investment is decreased by 60%. Precipitation is decreased by 40%; available surface water is decreased by 65%. Effects of agricultural water demand changes by 30%. Agricultural water demand per ha is decreased by 25%. Effects of agricultural water demand changes by 20%. All other parameters and graphical relationships are held at their baseline values.

8.6 Results

8.6.1 Reference model behaviour

The results of the model test are presented in Table 8.3 and Figure 8.7 (a,b,c,d). The results shown in Figure 8.6 compare the simulated data against observed data for the period 2010-2020. Generally, the model behaved as expected, because the simulated data follows almost the same pattern and trends as the observed data. This result confirms the robustness of the model and demonstrates that the model is capable of adequately capturing the dynamic behaviour and historical trends of water and food systems in the catchment.



Figures 8.7 (a,b,c,d). Water and Food model validation with a comparison between observed and simulated data

The statistical values presented in Table 8.3 (M, R^2, and U_0) show that the model fits the available data used. All the variables tested have low M values of less than 10%, while the R^2 statistical values range from 0.76 to 0.93, and U_0 statistical values range from 0.08 to 0.31. These statistical tests show that the values for all the selected variables are within the threshold, and demonstrate that the model is a good model fit. It should be noted that the model developed in this study is useful for explaining and understanding the dynamic behavioural patterns of important variables in the system, and to develop a relevant policy scenario. Therefore, the model should not be regarded as a predictive tool. It is common to hear among system modellers that *"all models are wrong but some models are useful"* (Forrester, 1961; Sterman, 2000). This simply means that no model can predict real-world events with 100% accuracy, and that models are based on the assumptions of the modeller and those involved in building the model.

Table 8.3: Statistical test of selected variables (2010-2020)

Variable	M	R^2	U_0
Population growth	2.33%	0.93	0.31
Net farm income	1.25%	0.76	0.11
Crop yield	2.02%	0.91	0.25
Crop area	3.11%	0.81	0.16
Agricultural water demand	2.17%	0.79	0.08

8.6.2 Policy Scenario Analysis

This section analyses the potential policy scenarios.

8.6.2.1 Business as usual scenario (BAU)

The BAU scenario (referred to as the baseline scenario) shows a steady state in the system and is presented in Figure 8.8. The results show that available surface water increases, and plateaus around 2022 until 2030 (line 1). Similarly, crop yield plateaus around 2016 (line 2). However, the total population and domestic water demand grow exponentially (lines 3 and 5). Agricultural water demand grows and starts declining around 2017 (line 4). This could be explained by the drought that affected South Africa between 2014 and 2018.

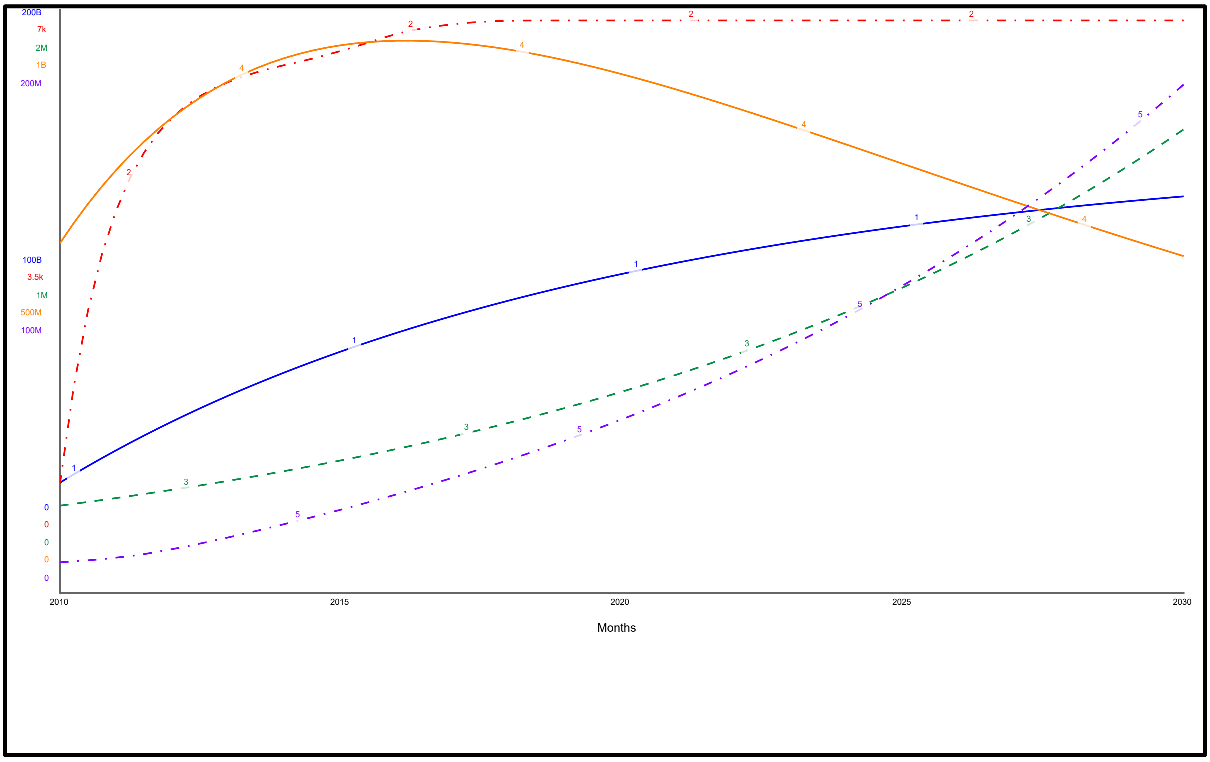


Figure 8.8: Model results of selected variables at baseline model run (BAU)

The exponential growth in population and domestic water demand could increase the water deficit in the region, given that available surface water is plateauing in the region. This will negatively affect food production and food security in the catchment as exhibited by plateauing crop yield in the catchment.

8.6.2.2 Analysis of designed policy scenarios

The results of the policy scenarios design show three distinct scenarios: the best-case scenario (scenario 1), average conditions (scenario 2), and worst-case scenario (scenario 3). All these scenarios were compared to the BAU scenario and is illustrated in Figures 8.9 (a,b,c,d,e).

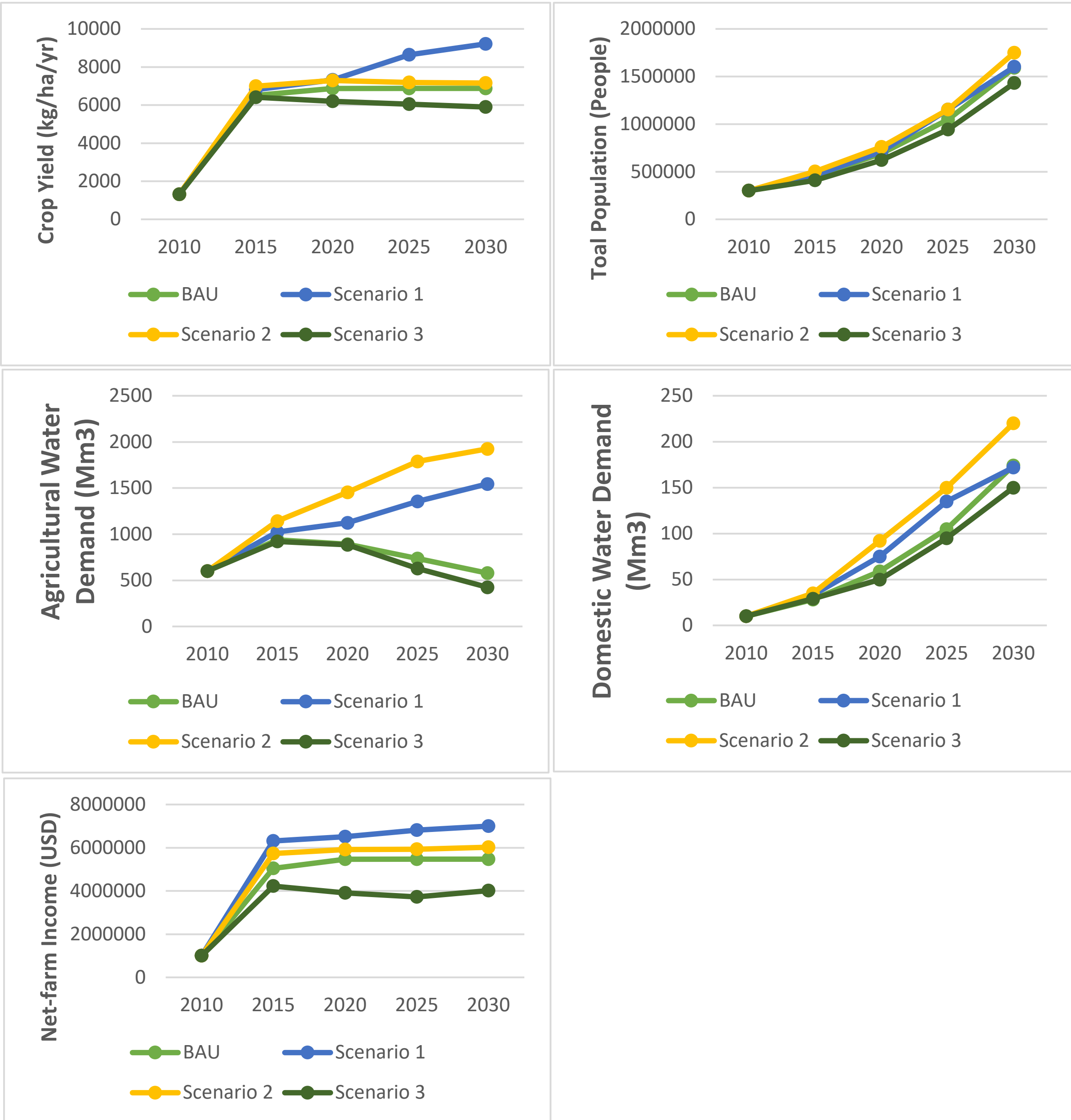


Figure 8.9 (a,b,c,d,e). Model results of selected variables under different policy scenarios (2010–2030).10.1 t0o 10.5

The results suggest that the system will experience maximum growth in all sectors with a good functioning system under scenario 1 (development of innovative capacity in the water and food systems), and a poorly functioning system under scenario 3 due to increasing policy uncertainty Total population growth and domestic water demand increase exponentially under all scenarios, while the rest of the variables experience limits to growth. According to Meadows *et al.* (1972), *'limit to growth'*, demonstrates how continuous growth (or expansion) in demand of a system, driven by positive feedbacks, will eventually encounter pushbacks from the systems as a result of limited resources.

Under scenario 1, crop yield experiences exponential growth and peaks in 2030. Crop yield also increases under scenario 2, but at a slower and steady rate, and experiences a steady decline under scenario 3. Crop yield reaches limits to growth in 2020 under BAU and scenario 2; in 2025 under scenario 1, and in 2015 under scenario 3. Limits to growth in net farm income is expected to occur around 2030 under scenario 1, in 2020 under the BAU and scenario 2, and in 2015 under scenario 3. The trends in agricultural water show an exponential increase in agricultural water demand under scenarios 1 and 2. This is because developing innovative capacity in water and food systems will increase water availability and improve agricultural production techniques. This will increase water demand in the agricultural sector due to increases in food production. Likewise, population growth will force an increase in food production to meet the demands of the growing population. However, under the BAU scenario, agricultural water demand peaks in 2015 and then declines at a steady rate. This could be explained by the fact that water resources in South Africa were constrained due to the devastating drought that lasted from 2014-2018. Domestic water demand increases exponentially with population growth under scenario 2, and then declining slightly due to a lack of investment in innovative technologies to increase water supply (scenario 3). Domestic water demand begins to plateau under scenario 1 indicating that water supply cannot sufficiently meet the water demand. Domestic water demand is expected to decline slightly under scenario 3 because of restrictions on water use due to a lack of capacity of water supply to meet demand.

8.7 Discussion of Results

The results have presented different scenarios that could unfold in the next 20 years in South Africa, including best-case and worst-case scenarios. The worst-case scenario (scenario 3) presents an alarming situation for the water and food sectors in the catchment. The effect of land reform (especially expropriation without compensation (EWC) on water and food systems has been analysed qualitatively, and presented in Chapter 7. It is worth mentioning that scenario 3 is a real possibility if proactive measures are not implemented to ensure effective and efficient land reform policies, and an end to farm attacks in South Africa. It should be noted that, given the level of uncertainty around the implementation of the policy at the moment, only the negative consequences of this policy were analysed. A lack of investment in infrastructural development in water and food systems could mean that all water supply to agricultural and urban sectors will be insufficient in the future, which will severely affect food production and food security in the catchment. This result is consistent with the findings of Kotir *et al.* (2016), who had similar results in the Volta River Basin, Ghana. According to Boshoff *et al.* (2018), *"a* *programme of mass land expropriation will result in a protracted period in which there is no net new investment in agriculture, which means no growth in agricultural output as well as no growth in the agribusiness sector. This is because commercial farmers, regardless of race, who have not (yet) been expropriated, are hardly likely to start new investments, and because the new farmers would not have the necessary means to invest*". Secure property rights are vital for establishing a capital investment in the agricultural sector (Wulf *et al.,* 2010).

As shown in scenario 1, investing in water infrastructure development and smart agricultural techniques will increase crop yield, net farm income, and food security in the catchment. Increasing agricultural yields and net farm incomes is a good strategy to reduce inequality, increase social cohesion and uplift people out of poverty, especially in disadvantaged communities (Meinzen-Dick *et al.,* 2012; Devereux, 2016). Furthermore, according to Kotir *et al.* (2016) and Béné *et al*. (2016), almost all sectors in the economy depend on water for their ultimate survival, and as such, ensuring water security would enhance food production and food security, and economic development in the economy. Given the cost factor involved in developing water infrastructure and smart agricultural techniques, policymakers must engage investors at local and international levels, and the public and private sectors. Policymakers must engage stakeholders at all levels in the value chain in decision-making regarding water management and agricultural development in the catchment (Carmona *et al.,* 2013; D'Agostino *et al.,* 2020).

All the scenarios presented in this study demonstrate an increasing trend in total population growth, which would drive an increase in agricultural water demand through food production and domestic water demand, and a decrease in agricultural land through an increasing rate of urbanisation. This result is consistent with the findings of Carnohan *et al.* (2020), who found an increasing trend in water demand in the lower Olifants river catchment in South Africa. Efficient water management in the catchment requires strong leadership, good governance, collaboration between different management units, social cohesion, and a participatory approach to water management (Warner, 2016). Policymakers must regulate urbanisation and informal settlement growth, adopt smart agricultural techniques, and invest in innovative techniques in water management and the effective monitoring and control of water demand and supply in the catchment in order to reduce the water deficit gap. Given that this study attempts to include stakeholders in the modelling of water and food systems, the purpose of the model developed in this study is to improve the understanding of the long-term dynamic behavior of the system and inform policymakers about the potential consequences of their actions, or inactions.

The model developed in this study is expected to improve the general understanding of water resources management and agricultural sustainability in the catchment. It should be noted that the model presented in this study is based on the assumptions and limitations of the modellers and the stakeholders who participated in the workshops. According to Sterman (2002), *"all models are wrong, but some are useful"*. The model developed here is not perfect or complete – several variables were omitted, either due to lack of available data, or for the purposes of modelling simplicity – but is useful for understanding water and food systems in the catchment, and as a key contribution to the broader understanding of water resources management and agricultural sustainability in South Africa.

8.8 Conclusion

This study presents a system dynamic model (SDM) that captures the dynamic feedbacks loops in four sub-systems in the Breede river catchment, South Africa. The model simulated the dynamic interactions between variables in the population sub-sector, surface water resource sub-sector, groundwater sub-sector, and agricultural production sub-sector. The development of the model followed a logical approach of identifying and analysing drivers of change influencing water and food systems, and mapping the mental models of relevant stakeholders. The important feedback loops that were identified in the mental modelling (conceptual modelling) were simulated and presented in this study under the business-as-usual scenario and three other distinct scenarios. This model was developed to improve the understanding of policymakers and relevant stakeholders of the long-term dynamics and behaviour of the catchment regarding efficient water management and agricultural sustainability. Structural and behavioural pattern tests and a sensitivity analysis were performed to test the fit of the model to the data available and the validity of the model. Investment in innovative technologies and infrastructure in water and food systems (scenario 1), population growth (scenario 2), and land reform and policy uncertainty (scenario 3) were simulated against the business-as-usual scenario over 20 years (i.e. between 2010 and 2030). Limits to growth were experienced in all scenarios except for population growth and domestic water demand that show exponential growth in all scenarios. Equally, farmers experience maximum crop yield and net farm income under scenario 1.

SDMs have been applied to examine water resource management and agricultural development in Africa and elsewhere around the world. Some studies in South Africa have attempted to apply SDMs to agricultural production and energy management but this is the first application of SDMs in coupled water and food systems in South Africa in general, and the Breede river catchment in particular. It is worthy to note that Carnohan *et al*. (2020) have applied SDM in the lower Olifants river catchment in South Africa using a stakeholder narrative. However, this chapter focused on analysing climate-change impacts on biodiversity whereas this study engaged a wide range of stakeholders and policymakers in the model development process, thereby improving policymakers’ and stakeholders' understanding of the dynamic behaviour of the Breede river catchment for 20 years leading up to 2030. The model will inform decision-making regarding sustainable water management and agricultural development in the catchment.

8.9 References

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9 SCENARIOS FOR AGRICULTURAL WATER MANAGEMENT IN SOUTH AFRICA

9.1 Introduction

In a world where the human knowledge base is growing faster than usual, coupled with increasing uncertainties and changing human and natural environments, there is a need for organisations, policymakers, and business leaders faced with increasing uncertainties to respond quickly to these changes. With the continuous growth in population, income, food consumption, global complexities and changes, policymakers will need to be thorough in their ability to determine the forces of change and anticipate possible solutions to potential problems (Roubelat, 2006). In terms of policy organisational planning, strategic planning has been the most commonly used approach to plan and cope with future changes. Uncertainty is one of the most important factors policy/decision-makers, planners, and leaders should consider when making decisions about the future (Chermack *et al.,* 2001). Though strategic planning has been very useful when planning, coping and anticipating future changes, it does very little to inform leaders, policymakers, and planners about crucial economic, environmental, social, and political changes that will occur in future (Chermack *et al.,* 2001; Varum & Melo, 2010).

A new strategy for planning under uncertainty was developed some decades ago called scenario planning. Rather than just predicting and forecasting future occurrences, scenario planning examines plausible and possible future occurrences. Scenario planning is crucial for policy planners because it reveals what could happen in the future if certain decisions are made today. The approach focuses on long and short terms changes that can occur and forces planners and policymakers to consider methods and procedures that will challenge their current state of thinking. Scenario planning has been used as a great tool for examining future uncertainties in a comprehensible, reliable, and plausible way such that it has been broadly used for strategic planning and policy-making (Yoe, 2004). Furthermore, scenario planning has been used as a great management technology to examine alternative futures and to help managers make better decisions (Martelli, 2001). Konno *et al.* (2014) argue that scenario planning is the method of choice for planners and policymakers for planning in the face of uncertainty. In such a rapidly changing environment, the ability of business leaders, planners, and policymakers to adapt quickly to crucial changes and uncertainties will determine and shape the future. In short, scenario planning encourages policy planners to *"think the unthinkable"* (Shadbolt *et al.,* 2017).

9.2 Scenario Building Process

Scenario development through the consultative workshops and contributions from stakeholders considered all ten drivers as important, but the major red flag highlighted was South Africa's economy, which in turn depends mainly on a stable environment. The major driving forces behind a stable economy – especially one in the face of potential exogenous shocks such as pandemics, international conflict, and climate change – are the Government, specifically pertaining to political will and developmental policies – civil society, and the private sector. All stakeholders agreed that a strong economy combined with governmental service delivery should ensure employment, poverty alleviation, food security, and, as a result, less civil conflict.

The scenario development in this project largely followed a process described by Meinert & Sacha (2014) namely:

- Decide drivers of change and assumptions
- Bring drivers together into a viable framework
- Produce 7-9 initial mini-scenarios
- Reduce to 4 scenarios
- Draft the scenarios
- Identify the issues arising

There was one major difference to the process in this project: the framework was conceptualised before the identification of drivers. The framework is discussed in detail in Chapter 3. We applied the community capitals as a basis and also the disaster vulnerability and resilience framework proposed by Jordaan *et al.* (2017). We grouped potential drivers into several clusters to ensure structured discussions during workshops. The clusters served as a framework for stakeholders to identify and categorise drivers under each cluster. The following clusters were identified:

- Human
- Social
- Cultural
- Economy
- Environment / ecology
- Infrastructure
- Organisations
- Institutions
- Technology
- Political

Originally the clusters are grouped as (i) social, (ii) economical and (iii) environmental, but it was found that the 10-cluster framework provided for better discussion and more detailed identification of drivers (Jordaan et al., 2017)

9.3 Decide Drivers of Change

The drivers of change were identified by the water management stakeholders through the consultative workshops and with the support of the systems thinking modelling developed by Nyam (2020) as part of this project. The project team followed a slightly different approach than what is proposed by Meinert & Sacha (2014) in that the framework with the ten clusters was conceptualised first. Details of this process is discussed in Chapter 2 and the results in Chapter 7. The modelled results are discussed in Chapter 8. The scenarios presented in this chapter as based on feedback from consultative workshops, expert inputs and modelling results.

9.3.1 Produce Initial Scenarios

Twelve initial scenarios were developed. The first set of four scenarios were developed after the initial consultative workshops with leaders from the represented organised agricultural sector namely AFASA, AgriSA, and NAFU. The second set of four scenarios were constructed by government officials in the agricultural and environmental spheres, and water managers; and the third set of initial scenarios focused on the issue of conflict over water resources.

9.3.2 First Set of Initial Scenarios

The results of the first set of preliminary scenarios are presented in Figure 9.1. It is important to note that these were the first set of mini-scenarios conceptualised from the first phase workshops. The two-axes initially identified were (i) political will and support, leadership, and good governance on the vertical axis, with, (ii) innovation, technology, and private sector initiatives on the horizontal axis. The four scenarios were given the following preliminary names: (i) *Z* or *Chaos* scenario, (ii) *Frustration* or *Polarisation* scenario, (iii) *Traditional* scenario, and (iv) *Best-case* scenario.

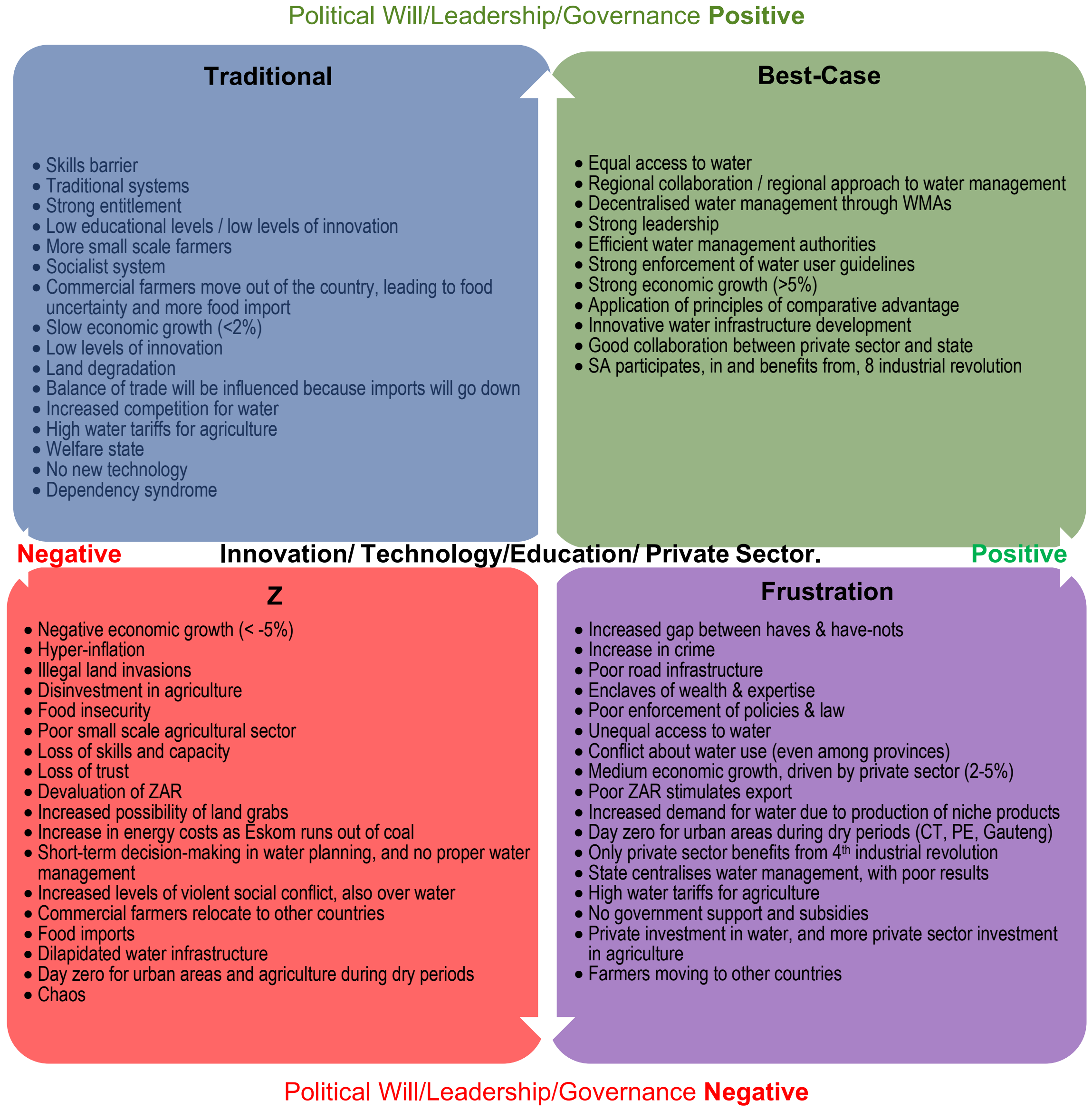
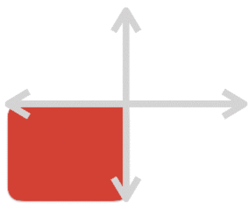
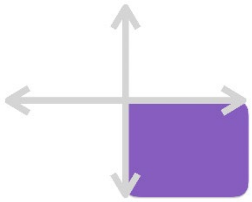


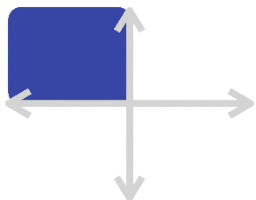
Figure 9.1: Initial agricultural water scenarios for SA (phase 1).



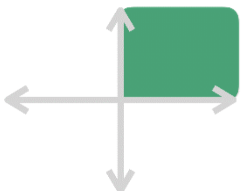
The ***Z*** or ***Chaos*** scenario is the result of poor leadership in both the political and water environments, with low education standards, and a private sector that withdraws from the national discourse due to extreme polarisation between private sector and Government. The country will experience continuous recession with negative economic growth. Unemployment will increase dramatically, and the safety and security situation will get out of hand. Violent civil unrest will be a daily occurrence with security forces (SAPS and SANDF) using deadly force to control the masses. There will be an increase in the number of commercial farmers abandoning their farms and moving to neighbouring and other countries. Food insecurity will dramatically increase. South Africa will become a net importer of food, and the World Food Program will become active in SA to help to avoid famine amongst the poor. In this scenario, water infrastructure is not maintained and rivers and dams are heavily polluted. This is scenario is very similar to Zimbabwe today.



The ***Frustration*** or ***Polarisation*** scenario is the result of poor governance and political leadership, but with a strong private sector that is still functioning in a hostile political climate. More people are educated, and civil society takes responsibility for its functioning. The gap between the haves and have-nots will continue to increase, with the poor dependent on the State who is nationalising all resources. Economic growth stumbles along at about 2%, mainly driven by the private sector. Only the private sector will benefit from the advantages of the 4^{th} industrial revolution, with the State still working with outdated systems and not able to apply regulations and policies. The State needs investment, but the private sector will invest the bulk of its funds in other countries. The private sector will also take responsibility for water management, where it is possible, but an increasing number of towns and cities will experience day zero scenarios during dry periods because of poor management at all governance levels. Agriculture will be heavily taxed, with high water and electricity tariffs. Production from commercial agriculture will slow down, with many farmers investing in other countries. South Africa will become a net importer of staple food for 5 out of 10 years.



The ***Traditional*** scenario is characterised by political leadership taking strong action to reduce corruption and increase productivity and good governance in the State. The private sector, however, views it as a short-term trend and, due to low education levels, starts investing more in other countries. Distrust remains high between the private sector and Government. This scenario will see slow economic growth of less than 2%, and little innovation in the water sector. Farmers do not trust Government, and food production will slow down with an increasing number of farmers investing in other countries. The smallholder sector will increase dramatically, with the government enforcing more policies that are socialist and shifting towards a welfare state. Land and other resources are nationalised, with new farmers having no title deeds for their land. Food insecurity will increase, and South Africa will become a net importer of staple food for 7 out of 10 years.



The ***Best-case scenario*** emerges from strong leadership, good governance, more people receiving a good education, and a private sector who works together with the Government to reduce unemployment rates and increase efficiency in production and water use through innovative new technologies. Economic growth increases to more than 5%. All sectors and people have more equitable access to resources. The smallholder sector receives good extension support from Government, and commercial agriculture actively assists with the mentoring of new farmers. South Africa remains a net exporter of food, even during dry years. The exchange rate is stable, and global markets react positively to developments in the country. New water infrastructure is built with the newest technologies. Current infrastructure is well maintained, and pollution levels in all rivers and dams are within “specs”. The country as a whole is benefitting from the 4^{th} industrial revolution.

It must be noted that the above scenarios are the first draft, and mainly based on feedback from the symposium and mini-workshops.

9.3.3 The Second Set of Initial Scenarios with Focus on Environmental Issues

The second phase of consultations focused on government officials in the agricultural and environmental spheres, and water managers. The difference in opinions between farmer representatives and officials that work in the water and environmental sector became clear after the second phase of scenario development. The water management officials placed a higher value on the influence of natural capital, and regarded climate change, land degradation, and water resources as key elements. Farmers and role players from the private sector, on the other hand, highlighted new technology and private sector influence. Other issues highlighted by the water management officials were political stability, social unrest, and security. The results allowed the proposal of an alternative set of four scenarios to those that emerged in the first series of workshops. In these scenarios, natural capital, linked to climate change, land degradation, and water resources are on the horizontal axis, and political stability, social unrest, and security on the vertical axis.

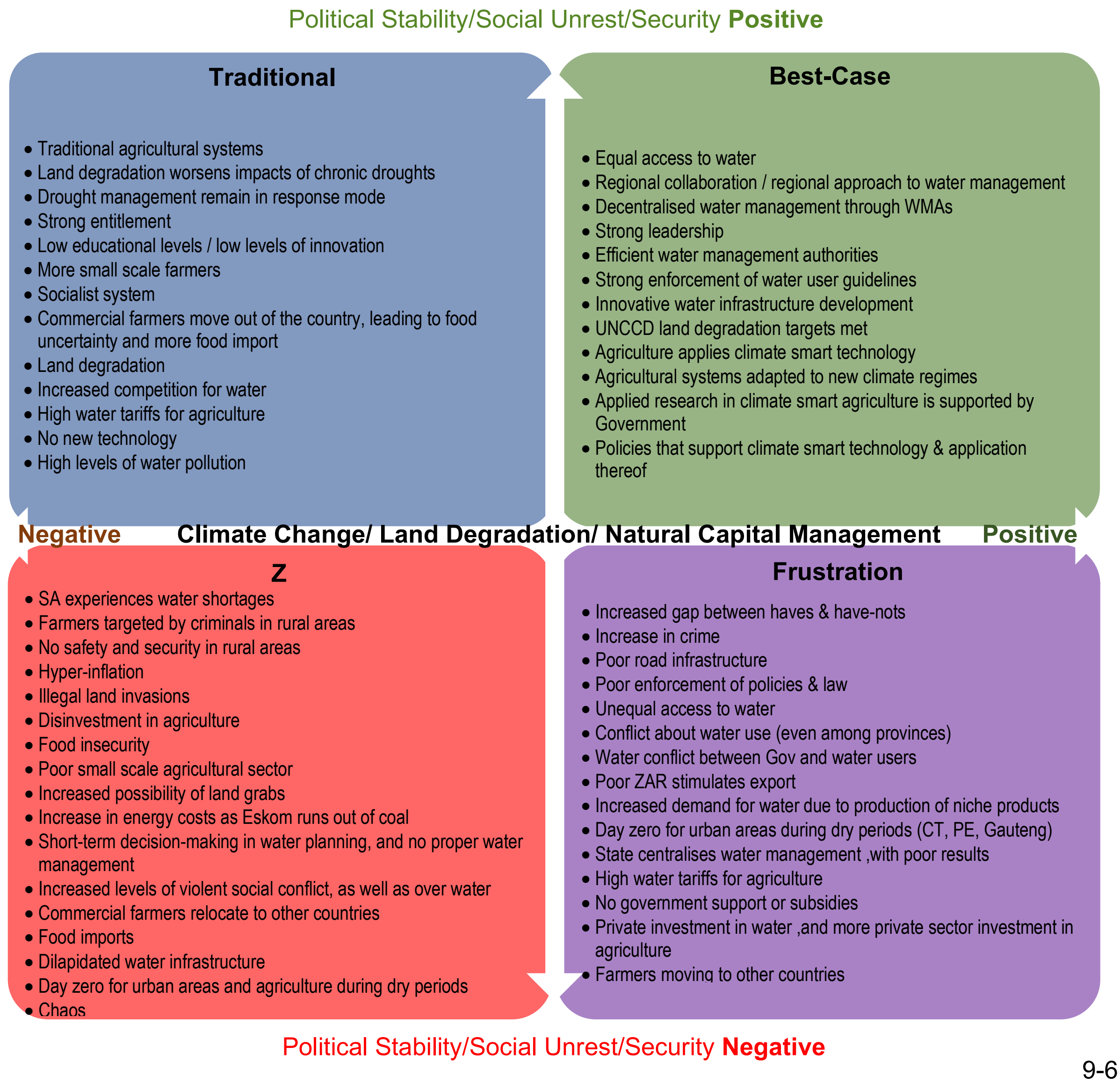
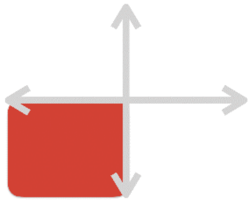
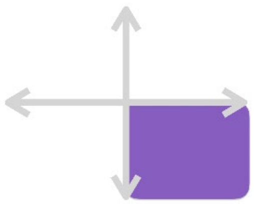


Figure 9.2: Agricultural water management scenarios from environmental perspective (Group 2). (FIGURE APPEARING ON PREVIOUS PAGE)

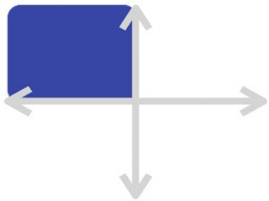
The results of the second set of scenarios are presented in Figure 9.2. The four scenarios were given the same names as those identified in the first set, namely *Z* or *Chaos* (ii) *Frustration* or *Polarisation*, (iii) *Traditional*, and (iv) *Best-case* scenario.

The ***Z*** scenario in this group is the result of political instability, social unrest, and conflict with a government so occupied to hold onto power that they cut budgets on climate change adaptation, water management, and environmental programs. The private sector withdraws from the national discourse due to extreme polarisation and conflict between the private sector and government. The country does not reach the UNCCD goals of land degradation neutrality, and agriculture is slow to adapt its systems to climate extremes that are now experienced regularly. Safety and security in rural areas has become a problem, and more and more commercial farmers are relocating to neighbouring African countries. New farmers that benefit from the land reform program are not well trained or supported by the government, with the result that commercial agricultural production has declined. As a result, food becomes extremely expensive, with civil unrest is common because of high food prices. The threat of an *"Arab Spring"* event causes panic in government that the safety and security situation will get out of hand. Indeed, violent civil unrest becomes a daily occurrence with security forces (SAPS and SANDF) resorting to deadly force to control the masses. More than half of the population is food insecure. South Africa becomes a net importer of food, and the World Food Program becomes active in SA to help to avoid famine amongst the poor. Water infrastructure is not maintained and rivers and dams are heavily polluted. This is the chaos scenario – very similar to Zimbabwe today.

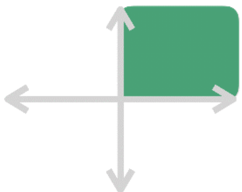




The ***Frustration*** or ***Polarisation*** scenario is the result of social unrest, conflict, and poor governance but with a period of good rainfall, few climate extreme events, and land degradation that is under control. More people are educated and the private sector and water users realise their responsibility to preserve and maintain natural capital such as water and soil. The gap between the haves and have-nots will continue to increase, with the poor dependent on the State, who is nationalising all resources. The State is so occupied with civil unrest and conflict that it allows the private sector to manage natural resources. A wetter period with good rainfall allows agriculture to produce enough food for the country, but land invasions on farms force commercial farmers to relocate to neighbouring countries. The private sector, however starts to invest the bulk of its funds in other African countries due to increased levels of civil unrest and insecurity in SA. Agriculture is heavily taxed, with high water and electricity tariffs. South Africa becomes a net importer of staple food for 3 out of 10 years, despite positive climate conditions for agricultural production.



The ***Traditional*** scenario emerges where political leadership takes strong action to reduce corruption and implement popular policies to avoid civil unrest and conflict. The security forces (SAPS & SANDF) have a strong influence in society; as a result levels of crime and unrest are managed. Climate extremes, however, disrupt normal agricultural production, and South Africa experiences more dry periods and droughts than ever before. Despite all efforts from the government and society to adapt to the climate, food production is not sufficient to feed 70 million people, resulting in high food prices. Land degradation continues at an alarming rate and water resources remain polluted. To maintain peace and limit civil unrest, the government decides to speed up the land reform process by focusing on growing the smallholder sector. However, it's an empty victory for those farmers – they will not have title deeds. Overgrazing and land degradation increases dramatically. Food insecurity increases and South Africa becomes a net importer of staple food for 7 out of 10 years.



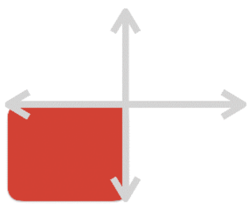
The ***Best-case*** scenario is the result of a stable civil society with low levels of conflict, and safety and security under control through good law enforcement practices. Negative climate change scenarios did not materialise, and South Africa experiences a wet climate cycle with few climate extremes and a climate conducive for rain-fed agriculture. Civil society and the government realise the importance of preserving the country's natural capital, and climate change adaptation programs are mainstreamed in all policies and projects. The land degradation neutrality targets set by UNCCD is met. The government invests in water infrastructure projects with the newest technology, which ensures sufficient water resources for future development. Water infrastructure in the country is well maintained and the quality of all water resources is monitored and maintained within international specifications. All sectors and people have equitable access to natural resources. The smallholder sector received good extension support from government, and commercial agriculture actively assists with the mentoring of new farmers. South Africa remains a net exporter of food even during dry years. The exchange rate is stable and global markets react positively to developments in South Africa.

It must be noted that the above four scenarios were strongly influenced by the Western Cape workshop with participants that are biased toward environmental issues.

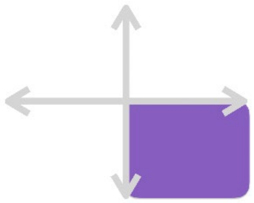
9.3.4 The Third Set of Initial Scenarios with Focus on Issues of Potential Conflict

The conflict scenarios share similar axes as the first set of initial scenarios, namely issues around private sector involvement on the horizontal axis and Governance on the vertical axis, but with more of a focus on issues that have bearing on potential conflict. The same scenario names were used. The results are presented in Figure 9.3. It is important to note that this is one part of the final set of scenarios

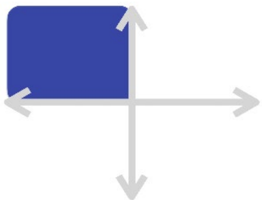
Figure 9.3: Potential conflict scenarios



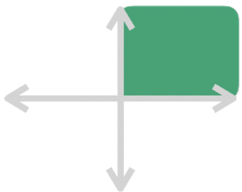
The ***Z*** scenario takes shape around a collapse of governance at all levels and an uncooperative private sector riven with competition for ever-declining water resources. The result is running violent conflicts between thirsty community members and municipalities. Many communities will be without water, and the government cannot deliver water while the private sector views water management as a government responsibility and withdraws critical resources. Gangs and violent groups fight for territory over what water resources remain, and vandalise water infrastructure to obtain control over communities. These gangs sabotage efforts from the government to provide water services to water-stressed areas, and control water supply by obtaining contracts through ‘tenderpreneurs’. Politicians will (mis)use water as a tool to lobby and threaten people in exchange for votes.



The ***Frustration*** scenario represents strong private sector involvement to try and offset poor and corrupt governance at all government levels. Under this scenario, the gap between the haves and have-nots will reach a breaking point and where water could be the trigger for large-scale social collapse. Public water infrastructure is poorly maintained, and drinking water in most towns is dirty and smelly. Citizens protest violently. Agriculture will continue to produce food, but competition between agriculture and mining for water will become serious.



The ***Traditional*** scenario is shaped by relatively stable (political) governance at all three spheres of government. However the stability is not translated into effectiveness, and the private sector becomes frustrated with the Government and largely withdraws from collaborating. During this scenario, conflict emerges between water users. Neighbouring farmers steal water from each other, and towns start running out of water due to huge backlogs in water infrastructure. Citizens react by protesting violently, and the government reacts by suppressing these riots with matching force and a strong police presence. Gangs and monopoly groups misuse the water shortage for their benefit, and water infrastructure is vandalised to create alternative opportunities for water supply. Water is misused as a political tool to leverage support and votes for the governing party.



The ***Best-case*** scenario will see both the private sector and government – and civil society – working together to preserve water sources and use water responsibly. Conflict about water use is dealt with responsibly. Water users respect water tariffs and pay for water as required. The private sector assists the government to supply water to communities that experience water shortages. There are outbreaks of civil unrest in areas with poor quality drinking water, but the government deals with the challenges effectively. The conflict between agriculture, mining, industry, and water for domestic use is still prevalent, but resolved responsibly through a proper licensing system.

9.3.5 Post Covid-19 and Agricultural Water Management Scenarios

The Covid-19 pandemic caught the whole world off-guard. Governments panicked in fear of high mortality rates and drastic steps were taken to prevent high mortalities. South Africa managed to control the initial phases of the pandemic with strict lockdown regulations with devastating impacts on the economy. Millions of people lost their income and the poorest of the poor were the people who suffered the most. Businesses closed down or entered into liquidation. The way people do business has changed forever, and only those who adapted could survive.

The weaknesses in the water sector were highlighted with communities exposed where they did not have enough water to perform basic sanitary measures required under Covid-19 regulations. The agricultural sector could continue to a large extent with normal on-farm activities, and businesses directly linked to the food chain could continue with operations. It's expected, however, that the

Covid-19 pandemic fast-tracked the implementation of the 4th industrial revolution (4IR) and that it will also impact future water management scenarios.

Technology and innovative solutions to water management will be fast-tracked and implemented, mainly as a response to food security challenges, and investment could be from both the Government and the private sector.

9.4 Consolidated Agricultural Water Management Scenarios

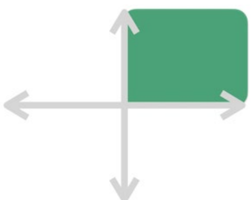
The fourth step in scenario development was to consolidate the initial scenarios into one final set of scenarios. Those initial scenarios were:

- Scenarios from the perspective of farmers. Farmers included commercial as well as small scale and subsistence farmers. The emphasis on water use and the impact of government and governance featured very strongly in these scenarios.
- Scenarios from experts in water management and environmental management. The influence of climate change, biodiversity, ecology, and land degradation featured strongly amongst within this group and in their scenarios.
- Scenarios focused on water conflict and security – issues that were mentioned by all groups, but one group used these issues as their focus. The role of government and future governance again featured very strongly in this scenario.

Overlaid on these scenarios were the onset of the Covid-19 pandemic and the subsequent strategies – i.e. lockdowns and the ongoing priority to manage and control the pandemic, including the procurement and rollout of vaccines.

Figure 9.4: The Consolidated Water Management Scenarios for South Africa

9.4.1 The Best-case Scenario

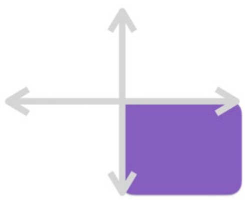


[Summary: political stability, leadership, social cohesion and security are all positive, as is the natural capital, and the management thereof. The two work hand-in-hand to produce a sustainable environment for the growth and development of the water and agricultural sectors, with a direct benefit for the South African economy].

- Water in the agricultural sector is seen as a strategic resource.
- Regional collaboration ensures good management (both from a commercial and food security perspective).
- Strong leadership enhances good governance.

- The private sector works well with the Government, and optimises their collaboration.
- There is strong investment, using new technology, into existing water infrastructure and new water infrastructure projects (with private sector innovation and inputs).
- South Africa experiences a wet climate cycle.
- Climate change adaptation programmes are mainstream in all policies and projects.
- Water resource allocations are well managed, with no conflict between agriculture and the mining and industry sectors for water.
- Water allocation is in line with national food security targets.
- Efficient water management authorities are in place, including an independent water regulator with a clearly defined role.
- There is strong enforcement of water use guidelines.
- Increased efficiencies in production and water use is achieved through innovative technologies.
- Smallholder farmers receive good extension support and mentoring through a well-structured and efficient development programme.
- Black farmers have equal access to water resources, and are growing in farm sizes and numbers.
- Young people are entering the sector due to a good and inclusive education system, increasing the diversity of the players in the sector.
- Water is seen as a flux, as opposed to a finite, resource; and with policy certainty and a clear national water resource strategy, it plays an important role in developing a strong and inclusive agricultural sector, and in turn, growing South Africa's economy

9.4.2 Frustration

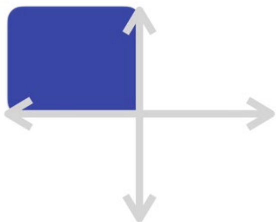


[Summary: despite the fact that political stability, leadership, social cohesion and security are all negative, the natural capital, and the management thereof, somehow still manages to remain positive. This is driven mainly by a private sector that manages to bypass unclear and contradictory Government policies. The result is high levels of frustration felt by all players in the agricultural sector. This scenario represents the 2020 status quo.]

- A hostile political climate exists, deepening mistrust between the agricultural sector and the Government.
- The result is poor governance and increased social unrest.
- The wealth trap – the gap between the haves and have-nots – widens as commercial farmers are able to effectively and efficiently, whilst the smallholder farmers are struggling.
- Land invasions are on the increase, and some farmers are relocating outside of South Africa, taking experience and skills out of the sector.
- This leads to increasing conflict about water use and between water users and the Government.
- Violent civil action erupts around water supply (this is exacerbated by the pandemic, highlighting poor water management by the Government).

- The private sector, however, is strong and functioning efficiently.
- Water efficiency is good in the private sector, and farming methods and water management are enhanced by innovations driven by technology (the 4th industrial revolution).
- The private sector manages its natural resources, and takes responsibility for water management.
- Good rainfalls enhance production.
- Land degradation is under control.
- A functioning education system leads to the responsible maintenance of natural capital (or at least an understanding of what needs to be done).
- However, it comes at a cost – water and electricity tariffs are high.
- The agricultural sector is heavily taxed.
- This scenario is a paradox of strong and weak, and good and bad, and, overall, is sub-optimal in relation to its potential.

9.4.3 Conventional Wisdom

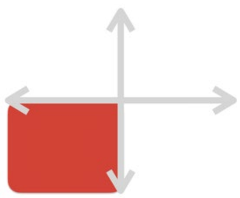


[Summary: despite the fact that political stability, leadership, social cohesion and security are all positive, the natural capital, and the management thereof, still declines. This is because the Government has invested significant resources into agriculture, but the priorities are skewed towards smallholder farming at the expense of commercial farmers, with unfortunate results].

- Political leadership is strong, and focuses on reducing corruption.
- There is strong Government investment in agricultural production, but it is skewed.
- Government policies enable an increase in smallholder farming, and aspirant black farmers.
- Nationalisation is a key focus area for the Government, and parts of the agricultural chain are absorbed into the state machinery.
- Land reform policies lead to an increase in the smallholder farming sector, changing the farming landscape.
- There is increasing distrust between the private sector and the Government.
- Food production declines due to changing farming methods, the degradation of soils, and climate change volatility, which is not well-managed due to low levels of innovation in the sector.
- Climate extremes continue to disrupt normal agricultural production.
- The poverty trap continues, becoming more pronounced.
- Food insecurity increases.
- Farmers are stealing water from each other in order to survive.
- Water infrastructure is also constantly vandalised.
- Many towns are without water as there is poor or no infrastructure.
- Security forces have a strong influence in society.
- Levels of conflict between water users is high.

- Water resources are polluted.
- Due to low standards of education, skills within the sector are thin, and experienced farmers are relocating to 'greener pastures'.

9.4.4 Z Scenario



[Summary: collapsing political stability, leadership, social cohesion and security are so widespread that the natural capital, and the management thereof, cannot escape. This is the worst-case scenario.]

- Poor leadership, both within government and the water management sector leads to policy uncertainty.
- The Government is holding on to power, and is cutting budgets for dealing with climate change (as focus has shifted more towards issues around health).
- The Government and the private sector are polarised.
- Water is exploited for political leverage and votes.
- The level of conflict between different sectors is not only high, but also highly politicised.
- Citizens and businesses are not paying their water bills, and mismanagement opens up space for further corruption.
- Water infrastructure is not maintained, and is becoming dilapidated.
- Dams and rivers are highly polluted.
- Water theft is rife.
- A functioning education system results in low capability and capacity – lowered skills – to understand water and the complexities of water management.
- Skills within the agricultural sector are dwindling.
- Commercial farmers are leaving South Africa and relocating.
- High levels of insecurity in rural areas.
- Farmers are increasingly targeted by criminals.
- Unrest and unemployment are on the increase.
- Food insecurity is one of South Africa's major risks and outcomes of this scenario.

9.5 Current Position

The current position and possible directions of movement are shown in Figure 9.6 below. The actual direction of movement that will play out depends on the next steps. These are the identification of options and the key short-, medium- and long-term decisions that need to be made in order to move to the *Best-case* scenario. The shift from the *Frustration* scenario is only possible through integrated and cooperative actions by all role players. The required activities to prevent the *Z* scenario, and shift instead to the *Best-case* scenario are discussed in Chapter 10.

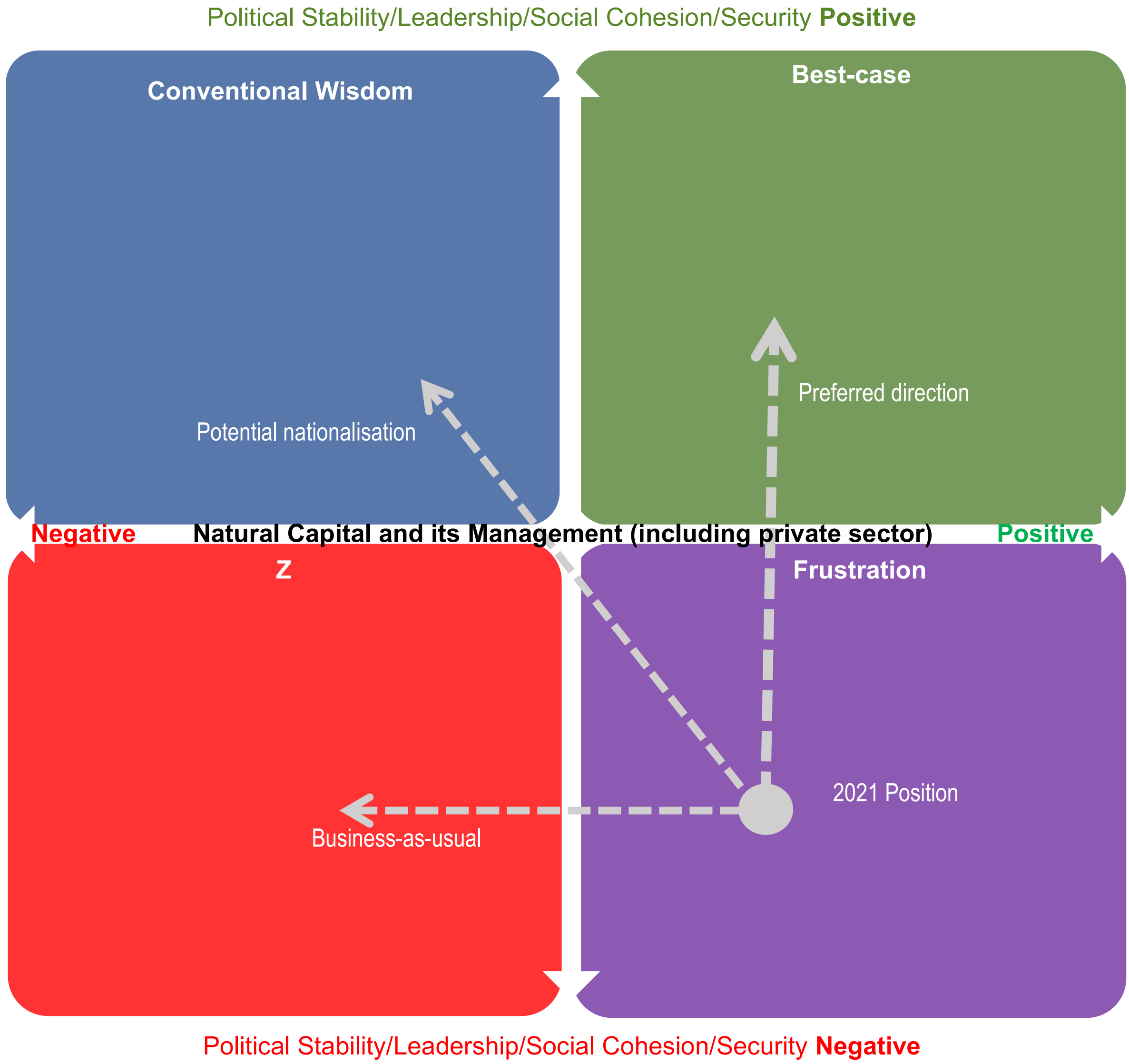


Figure 9.5: The current position and possible directions of movement

The 2021 position is characterised by frustration for all stakeholders – and this frustration might propel the country to the *Z* scenario with devastating impacts on future water management if not managed properly.

The Government should be frustrated because they are struggling to manage the Covid-19 pandemic and they cannot rid themselves from the negative impact of Covid-19 on the economy, and on the daily lives of citizens. In addition, the Government sits with the albatross of corruption – and the impact of corruption on State-owned enterprises and the economy – around its neck, and its leaders seemingly do not succeed in taking decisive action. The perception amongst the general public is of a government not really in control, while the Government uses the Disaster Management Act to show its capacity to lead.

The psychological impact of the pandemic on society is immeasurable, but evident – people are losing jobs, their livelihoods are being destroyed, and fear of the disease is rampant. Frustration with how the Government is handling the crisis is high.

The private sector is frustrated because it seems that the Government has become more centralised and autocratic in its actions. The handling of the Covid-19 pandemic strengthens this perception in that extreme power is located in the hands of the Minister of COGTA under a declaration of a national sate of disaster, and the Government intends to centrally control the roll-out of the vaccine program. Centralisation of water management and policies interfering with the free-market system – such as expropriation without compensation – contributes to the frustration of the agricultural sector. Agriculture and related private sector enterprises have the potential to propel the country to the *Best-case* scenario, but only if the Government creates the environment for entrepreneurship and innovation.

As the primary users of agricultural water, farmers are frustrated because of the failed land reform programme, for which they are largely blamed. The safety of farmers in rural areas are under threat; they recently faced one of the most extreme droughts in South Africa; their future is insecure with the threat of expropriation without compensation of their farms; and they are not sure if their future water rights are secure. Black farmers, on the other hand, are frustrated because of the slow pace of successful land and water reform that should redress the injustices of the past.

9.6 Red Flags

It is possible to identify a large number of things that might propel South Africa, and specifically agricultural water management, in the wrong direction. It became clear during discussion with stakeholders that a few red flags hold the potential to dramatically shift the outcome. Red flags identified here are specifically relevant to agriculture.

The first red flag is the absence of a social pact between the major stakeholders, i.e. the Government, agribusiness, farmers, farm workers, and society at large. The distrust between the Government and the commercial farming sector, and negative statements from political leaders, are issues that need to be addressed.

The second red flag is the capacity of the Government to govern without the albatross of corruption and corrupt leaders still around its neck. This distracts attention from good governance, and forces leaders to focus on party-political issues instead of on the needs of the state. This is especially relevant at municipal level where water quality and water availability is determined by proper service delivery and the maintenance of water infrastructure. Poor governance at municipal level is also driving frustration within the citizenry and the increased levels of intolerance.

The third red flag is centered around the economy and its resilience to withstand the negative impacts of, firstly, the 2015-2019 drought, and, secondly, the 2020-2021 Covid-19 pandemic. Millions of people have lost their jobs, and the Government has provided social grants to support the poorest of the poor; but this cannot continue indefinitely. The Government borrowed money to manage the pandemic, and that needs to be paid back at some stage.

The fourth red flag is the absence of successful land and water reform. Few of the land reform beneficiaries – newly established black farmers – are successful, due to various reasons. The lack of progress in land and water reform sends out a negative message to citizens, and commercial farmers are blamed for not making land available for land reform (which is not the case since the Government holds titles for millions of hectares of unproductive land). Learning from the example of Zimbabwe, it is clear that the lack of progress with successful land and water reform hold the potential to fast-track South Africa to the *Z* scenario.

9.7 Conclusion

The scenarios presented in this chapter represent the inputs of various stakeholders with diverse backgrounds, experience and expectations. The contributions from probably the two most diverse groups – communal farmers, new black commercial farmers and traditional white commercial farmers – are surprisingly very similar; an indication that challenges facing farmers are very similar, irrespective of the scale of farming. Farmers differ on the relative importance of the different drivers but not on the potential outcomes. Government officials, business people and experts such as agricultural economists are also in agreement on the potential scenarios in spite of diverse opinions on the relative importance of different drivers.

Developing the final scenarios was eventually relatively easy considering the similarity in opinion regarding potential outcomes, which is also supported by the mathematical systems thinking model. The methodology applied to develop different sets of scenarios promotes better understanding of a complex issue such as water management and potential impact of good or poor water management. Water affects almost all aspects of life and almost all sectors; therefore the need to develop different sets of scenarios, which were named as initial scenarios in context of this research.

The worst-case scenario is characterized with a failed state characterized by collapsing political stability, leadership, social cohesion and security are so widespread that the natural capital, and the management thereof, cannot escape.

The traditional wisdom scenario is characterized by a government with centralised policies, that do not promote private sector investment and entrepreneurship. Despite the fact that political stability, leadership, social cohesion and security are all relatively positive, the natural capital, and the management thereof, still declines. This is because the Government has invested significant resources into agriculture, but the priorities are skewed towards the subsistence, smallholder farming at the expense of commercial agriculture, with unfortunate results.

The frustration scenario is characterized by a strong private sector and civil society involvement but poor governance. Despite the fact that political stability, leadership, social cohesion and security are all negative, the natural capital, and the management thereof, somehow still manages to remain positive. This is driven mainly by a private sector that manages to bypass unclear and contradictory Government policies. The result is high levels of frustration felt by all players in the agricultural sector. This scenario represents the 2020 status quo.

The best-case scenario is the "strive for" political stability, leadership, social cohesion and security are all positive, as is the natural capital, and the management thereof. The two work hand-in-hand to produce a sustainable environment for the growth and development of the water and agricultural sectors, with a direct benefit for the South African economy.

9.8 References

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10 RECOMMENDATIONS, CONCLUSION AND STUDY LIMITATIONS

10.1 Introduction

The potential scenarios discussed in chapter 9 are a cause of great concern if water stakeholders in South Africa continue to ignore the 'red flag' issues. Agricultural water cannot be separated from any other water because it depends on surplus water after domestic, industry and energy use. Agricultural water, however, is not limited to irrigation. The larger portion of agricultural production is rainfed, and in that sense, agriculture is the first user of water. Agricultural water management therefore needs to consider the total hydrological cycle. Water management at all governance levels, including at municipal level, has a direct influence on agricultural water, and therefore cannot be separated from it.

The three 'negative' scenarios presented in the previous chapter are avoidable, but only through coordinated efforts by all stakeholders. Corrective action, or 'must do' activities, for different category stakeholders are presented in this chapter – grouped according to the 10 clusters – in a summarised format, with potential action plans and/or strategies for future sustainable agricultural water management. Amongst the most crucial for the shift to the *Best-case* scenario is for all stakeholders to make a paradigm shift in order to better understand water and its challenges for sustainable management. The following section, argued by Prof Anthony Turton, proposes that paradigm shift in water management as a pre-requisite to prevent the negative scenarios as depicted in Chapter 9.

10.2 Paradigms of Water Resource Management

A paradigm is defined as a distinct set of concepts or thought patterns, including theories, research methods, postulates and standards for what constitutes legitimate contributions to a field. The famous scientist Thomas Kuhn wrote a book in 1962 entitled *The Structure of Scientific Revolutions* in which he defined a paradigm as "*universally recognized scientific achievements that, for a time, provide model problems and solutions for a community of practitioners"* (Kuhn, 1962; 1974). This defined what is to be observed, what questions are asked in the pursuit of problem-solving, how the problem-solving exercise is structured, the nature of the predictive potential of the problem-solving exercise, how data are interpreted, and therefore how conclusions are ultimately drawn.

From this definition it is clear that paradigms are not neutral tools, for the paradigm used naturally selects the problem being solved, reinforcing this by determining which data are used and how the results might eventually be interpreted. The paradigm initially selected ultimately determines the outcome of the problem-solving endeavour. We can think of a paradigm as an intellectual scaffold that creates structure to the jellylike ideas that collectively form a conclusion about anything being analysed or studied in a systematic way. Therefore, if the paradigm is one of water scarcity, then your solution will always be biased in a certain way by being forced to view the solution as being the construction of dams to manage that scarcity.

Paradigms matter, so let us understand some fundamental facts to assess the viability of a change in paradigm from one of scarcity, to one of abundance. The Paradigm of Scarcity is the dominant one in South Africa. It dates to the Cape Colony, where the first book ever written on water was published in 1875 and authored by a gentleman named JC Brown. It had the grand title of "*Hydrology of South Africa; or Details of the Former Hydrographic Conditions of the Cape of Good Hope, and causes of its Present Aridity, with Suggestions of Appropriate Remedies for this Aridity"*. Clearly Brown saw aridity as the absence of water, so he proposed the idea of conserving rainwater to create prosperity in an area of poverty (Brown, 1875). Brown expanded on – as he saw it – the problem of water scarcity in his second book published in 1877 entitled "*Water Supply of South Africa and the Facilitation for the Storage of It"* (Brown, 1877). Yet again the bias is clearly evidenced in the title betraying the emergence of a paradigm. If water scarcity is the problem, then the solution must be storage. Brown's second book coincided with the promulgation of the Irrigation Act of 1877.

A decade later, Thomas Bain, a road engineer who had read Brown's book, was travelling in the arid areas of the Northern Cape around present day Upington where he saw a prosperous community that had diverted water from the Orange River, and from this had created viable economic development. Being a mapmaker, Bain investigated the contours, and found that it was possible to divert water from the Orange River, into the Port Elizabeth area. He drew a map of this diversion and published a book in 1886 entitled "*Water-finding, Dam-making, River Utilization, Irrigation*" feeding into the Paradigm of Scarcity (Bain, 1886). Bain became the Secretary for Irrigation as a result of this work. His vision for the diversion of the Orange all the way to Port Elizabeth remained nothing more than an idea written on a map and published in his book until 1961.

When South Africa became a Republic in 1961, Bain's idea about diverting the Orange was revisited considering the success that was being demonstrated in the Tennessee Valley Authority of the USA. In 1966 the Commission of Enquiry into Water Matters was tasked with the development of a national strategy for economic development within the constraints of water availability. The first plan that was considered was that of Bain, and so the HF Verwoerd Dam (now Xhariep) and Orange-Fish-Sundays Inter-Basin-Transfer was created. This ushered in the aggressive phase of the "*South African Hydraulic Mission",* based entirely on dam building and river diversion, which sustained decades of economic growth in the order of 7% per annum (Postel, 1999; Turton, 2001). Ambitious plans were developed for the diversion of water from the Zambezi and Okavango into the Goldfields of Gauteng.

In 1994 South Africa became a democracy. The first legislation passed in terms of the newly promulgated Constitution was the National Water Act of 1998. This was a radical act because it nationalised the water resource, placing it firmly under the custodial role of the State. It removed water rights from land rights as a deliberate instrument for land redistribution, and it created the legal reserve, being the water needed for basic human needs and the environment. This new act also mandated the reconciliation between demand and supply every five years in what was called the National Water Resource Strategy. The first NWRS published its findings in 2003, and the result was startling. In effect, if the legal requirements of the Reserve were factored in, then South Africa had already allocated 98% of its total water resource, leaving just 2% still to be developed (NWRS, 2004). Subsequent research found that the total resource availability had been over-calculated because of algorithm problems. The issue of climate change as a factor in rainfall variability and water availability in rivers was also ignored.

From the NWRS quantification of the total national water resource, the following numbers are important (Middleton & Baily, 2008), and have major implications for our immediate future as a viable economy. The naturalised mean annual runoff (MAR) is 49.2 billion m^3 per annum. The utilisable groundwater exploitation potential (UGEP) is 10.3 billion m^3 in non-drought years, but this is not sustainable. The total national water resource, being the sum of MAR and UGEP, is 59.5 billion m^3 in non-drought years, but this is not sustainable. The full supply capacity of all dams in South Africa, assuming that none have succumbed to sedimentation caused by excessive soil erosion, is 31.7 billion m^3. The total surface resource capture (TSRC) is 64.4%, the result of the decades of inter-basin transfer IBT development, which is extremely high, with known ecological consequences that will need to be carefully managed in future. The total surface resource capture in the Orange River basin, the most economically important of all, is 271%. The fact that the ecological reserve had to now be factored into all future planning, meant that, in effect, South Africa had suddenly transitioned into a water-constrained economy (Ashton, Hardwick & Breen, 2008).

Data from the National Water Resource Strategy showing finite limitations to the economy on different development trajectories.

Scientists remained strongly supportive of the Government despite these early warning signs. This sentiment is captured in a published analysis by one of the top aquatic scientists at that time. It is also clear that both the volume and the quality of water available per person will decline as the population of South Africa continues to grow. South African water resource managers face considerable difficulties when they attempt simultaneously to improve the lot of the poor by providing them with formal water supplies (thereby increasing water demand), while trying to reduce the overall (national) demand for water. Given the rate at which development took place in South Africa during the last century, it was inevitable that the growing demand for water would eventually exceed the capacity of the available supply systems – See Figure 10.1.

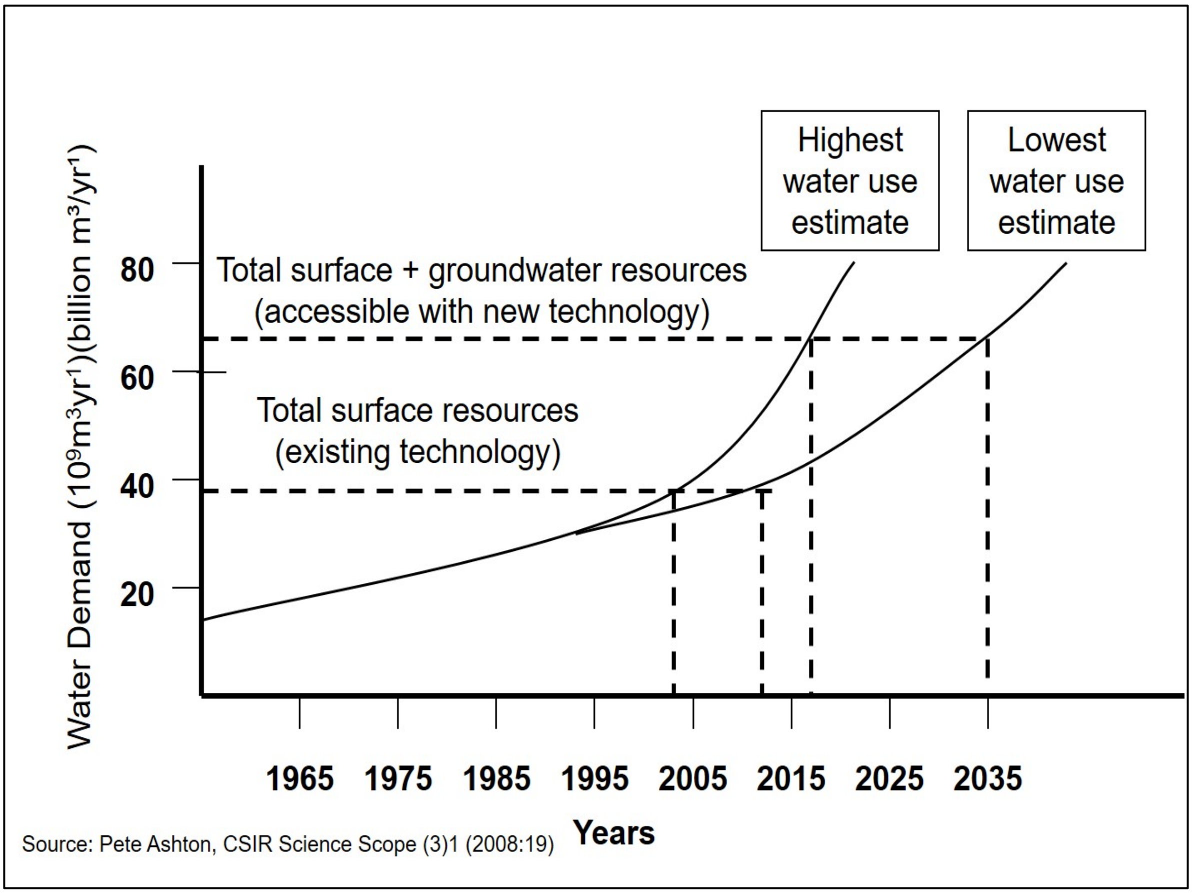

Figure 10.1: Water demand estimates based on different scenarios
Source: Ashton et al., 2008

Unfortunately, while this feature was foreseen and regularly announced by water resource managers, this was not acted upon by politicians until relatively recently. While the sweeping South African water law reforms have great potential to improve the efficiency and effectiveness of water resource management, little progress has so far been made with the initiation of large-scale actions to curb water demand and improve water-use efficiency in all water-use sectors. Strong partnerships must be forged between the state and the public, while the implementation of Catchment Management Agencies must be finalised. There is good evidence that a growing water deficit will exert increasing pressure on the country's processes of economic and social development. New technologies and approaches that can cost-effectively 'create' new freshwater resources will need to be developed. It is anticipated that these approaches will have to form the driving force behind the shift in water resource management needed to support economic growth, as the country enters a situation of water deficit in the future. (Ashton et al., 2008; Workman, 2009).

The National Water Act of 1988 entrenched the notion of Integrated Water Resource Management (IWRM), then fashionable in the global water sector. IWRM is based on the Dublin Principles, and these are at the heart of the Paradigm of Scarcity. Sadly the National Water Act failed to recognise the debilitating impact of a water constrained economy, because the entire logic is based on a single flawed premise – that water is a finite stock.

The four Dublin Principles are as follows (ICWE, 1992):

- **Principle # 1.** Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment.
- **Principle # 2.** Water development and management should be based on a participatory approach, involving users, planners and policymakers at all levels.
- **Principle # 3.** Women play a central part in the provision, management and safeguarding of water.
- **Principle # 4.** Water has an economic value in all its competing uses and should be recognised as an economic good, considering affordability and equity criteria.

Therefore, the prevailing paradigm of water resource management, to which the South African government subscribes, is IWRM that views water as a "*finite and vulnerable resource*". Central to this paradigm is the view of water as a stock in a natural environment. It is therefore blind to the fact that *"New Water*" can be created by the application of technology and capital, so it fails to recognise that water is a flux and is thus potentially infinite. This locks us into a harsh reality in which our national economy will increasingly be water constrained, and therefore food security and job creation will become more relevant in the years to come.

Returning now to the power of paradigms, we can see the logical outcome in the next diagram, Figure 10.2

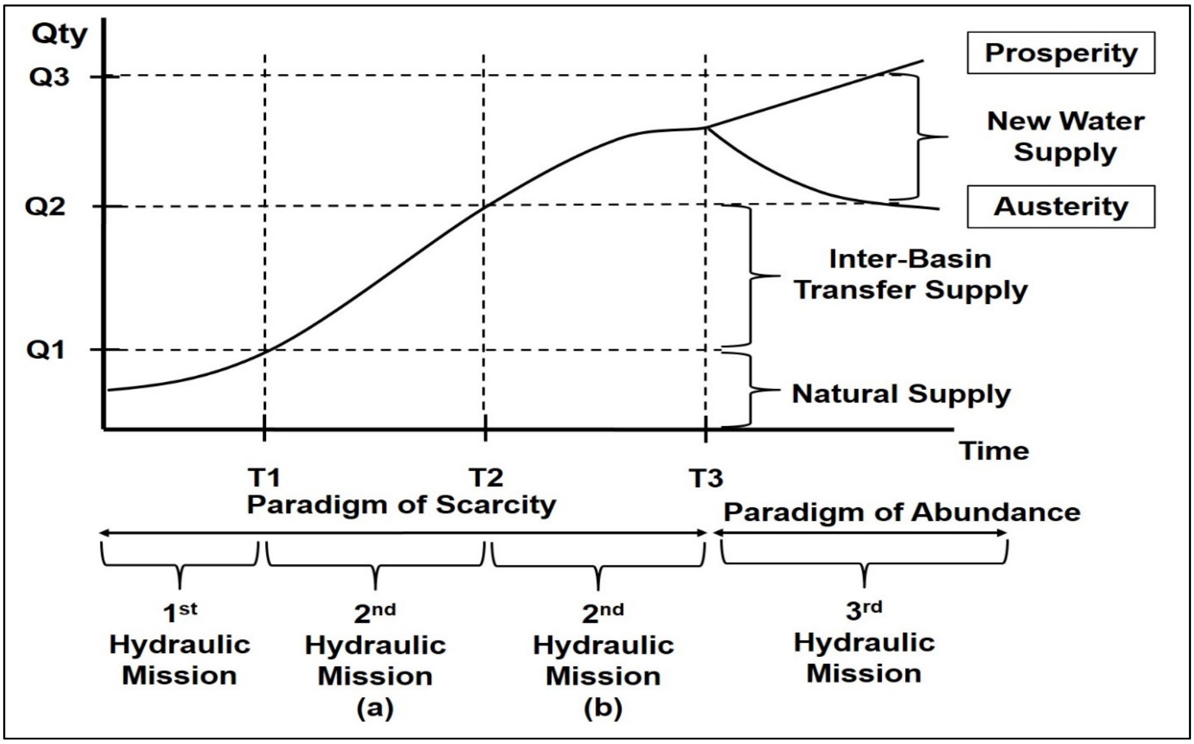

Figure 10.2: Impact of paradigm of abundance on water supply
Source: Ashton et al., 2008

Volume of water is shown on the vertical axis with time on the horizontal axis. Onto this we can plot the first and second hydraulic missions in South Africa. The first was about agricultural water, and the second was about water for industry and inter-basin transfers, as rivers were connected to one another. Time T3 is where we are today. Our demand has overshot supply, and we are unable to mobilise more water from simply building dams. On top of that, sewage return flows into our rivers are reducing the quality of water available, so we are faced with a harsh choice as a future Vision of Prosperity or Austerity. If we continue to manage water as a finite stock, then we are obliged to reduce our demand to the levels defined by Q2, as the total volume available at a high assurance of supply level within the constraints of available strategic storage (±38BCM). This means that job creation and food security will be impossible to achieve in a sustainable way, and policy choices will need to factor in these two realities. The alternative is to create a new policy of prosperity that embraces the Paradigm of Abundance. This alternative paradigm is based on the scientific fact that water is a flux, moving in time and space, so it is an infinitely renewable resource. This is a direct challenge to the Dublin Principles, so these will have to be revisited in policy reform (Ashton *et al.,* 2008). The national water security model illustrated in Figure 10.2 showing the two Hydraulic Missions within the Paradigm of Scarcity, and the transition at point T3 to a future Paradigm of Abundance if we are to become a prosperous state once again.

This New Paradigm of Abundance will be based on the following key elements:

- Water will be recovered wherever possible, and reused as appropriate.
- Water of different quality and price will be used for different purposes in different parts of the country.
- Technology and capital will be incentivised to upgrade the 824 wastewater treatment works (WWTWs) in order to recover water from waste.
- Technology and capital will be incentivised to desalinate seawater wherever appropriate, on a utility scale where the economics make such an investment viable.
- Strategic water storage will be shifted from dams into aquifers, where advanced technologies will be applied to inject surplus water created from the recovery process in WWTWs, for the creation of water banks of a strategic nature.
- Water recovered from waste will be blended with seawater where appropriate, to reduce the osmotic pressure and therefore alter the economics of desalination to reduce the cost of recovered water to that of currently available surface water.

The message inherent to the New Paradigm of Abundance is that South Africa does have a future, in which all citizens can reach their full potential, irrespective of colour or political persuasion. It creates the foundation for economic revival, based on a dual-stream reticulation economy, where water of different price and quality is used for different purposes at different times and places in the country. This is consistent with beneficiation, so it unlocks the value-add opportunities arising from processing minerals, rather than exporting them in their raw state. It converts the current pattern of value consumption, inherent to the Zuma-led plunder of national assets, into a new pattern of value creation, in an inclusive economy that tries to achieve full employment at dignified wage levels. More importantly, the use of special purpose strategies overcomes the constraints posed by the existing uninvestable status of most government departments. It can unlock the trillions of rands currently held on the balance sheets of existing companies, fearful of investing because of uncertainty over land and water rights (Priscoli, 2007; Turton, 2001).

The New Paradigm of Abundance has the potential to become the Third Hydraulic Mission, fully owned by government, restoring them to their rightful place as government of a rejuvenated economy driven by the diversity of its vibrant multi-cultural citizens. By so doing, we can create enduring WEALTH and bring about prosperity for all citizens. The foundation of that WEALTH is a cohesive policy based on six specific elements.

- **"W"** is for water, seen as the foundation of all socioeconomic wellbeing, and because it's a flux, it is infinitely renewable.
- **"E"** is for ecosystem integrity, which needs to be restored. More than a century of goldmining has left a uranium legacy for future generations, and half a century of pushing rivers around, has destroyed the flood pulse, so we need to restore both if we are to thrive as a nation once again.
- **"A"** is for accountability, most notably for those calling for war, but also for those that have plundered and stolen from a nation. Without this we can never move forward, for the credibility of the ruling party is directly linked to this single aspect.
- **"L"** is for legal certainty, because without it we can never attract capital, and we can therefore not employ the 26 million 'born frees' who will become revolutionaries and overthrow the current regime that has failed to deliver on a core promise.
- **"T"** represents the technology that we will need to manage water as a flux, so we can speak of recovery and recycling of waste, as well as the desalination of mine and sea water where appropriate.
- **"H"** is all about health, which starts with ecological restoration, but continues with economic wellbeing that eventually leads to social harmony between all races and all social strata.

This is an entirely logical way out of the conundrum posed by the structural adjustment that will accompany any application to the World Bank for a bailout as the fiscal cliff wreaks havoc, and to avoid the unpleasant repercussion of a regime change that will always be unpredictable. It is in our collective best interest to avoid all these unpleasant things.

10.3 Potential Actions and Strategies to Enable the "Strive for the *Best Case* Scenario" and "Avoid the *Z* Scenario"

Five tables are provided in order to focus on different stakeholder groups. The different stakeholder groups are:

- Table 10.1: Government organisations.
- Table 10.2: Water Supply Agencies (WSA) and municipalities.

- Table 10.3: Private sector, NGOs research and education organisations.
- Table 10.4: Civil society and individual water users.
- Table 10.5: Farmers.

Each table contains the 10 clusters that we proposed at the onset of the project. These clusters guide us to identify not only focused challenges but also focused solutions and action steps. Note the following as a reminder of the different cluster characteristics:

- **'Human'** deals with individual characteristics / indicators such as education, expertise, experience, and age.
- **'Social'** deals with social structures, social behavior, social conflict, civil strife, social cohesion, etc.
- **'Culture'** deals with norms, principles, attitudes, and behavior.
- **'Economic'** deals with the economy, financial resources, etc.
- **'Infrastructure'** deals with infrastructure impacting water and water management.
- **'Natural'** resources are water, land, climate, etc.
- **'Technology'** deals with new water technology, precision agriculture, remote sensing monitoring, and early warning, etc.
- **'Organisations'** deals with organisations such as government departments, agricultural businesses, formal farmers associations, etc.
- **'Institutional'** deals with acts, policy, regulations, and agreements.
- **'Political'** deals with the Government itself – not the State – political conflict, corruption, etc.

Table 10.1: Action steps required by Government and State organisations

	Cluster		Government / State responsibility
A	Human	1	Appoint qualified engineers and hydrologists in State Departments.
		2	Develop skills and capacity of officials in all Government departments.
		3	Strict selection of land reform beneficiaries.
		4	Increase the pool of technical competence to enrich decision-making.
		5	CMAs to appoint qualified staff
		6	Develop, or adapt, courses at university and high school level to include some of these principles.
		7	Support and motivate education organisations to use internationally available material on water use for remote classes and course work focusing on water in semi-arid areas.
B	Social	8	Government to agree on social pact with society to provide responsible leadership.
		9	Engage in discourse to evaluate the potential for 'new water' from wastewater treatment works in need of refurbishment.
		10	Engage in discourse about the role of water as an economic enabler.
		11	Social pact between civil society, farmers, Government and other stakeholders is a precondition for the Best Case scenario.
		12	Urban.
C	Cultural	13	Leadership set example of respect for natural resources.
		14	Use social media to create water awareness.
		15	Develop a paradigm of water abundance.
		16	Communicate positive paradigm towards farmers as food producers, and, especially, to urban poor.
		17	Openly acknowledge the strategic role of agriculture as suppliers of affordable and quality food.
D	Economy/financial	18	Ensure sufficient budgeting for maintenance of current water infrastructure.
		19	Post-Covid-19 economic recovery plan to focus on 'new water' infrastructure development.
		20	Provide sufficient funding for CMAs
		21	Support, through subsidies and advocacy, "*Water-Energy-Food Nexus"* tools to optimise water use across sectors.
		22	Provide subsidies for farmers as bridging capital to shift to conservation agriculture.
E	Infrastructure	23	Reconsider wastewater treatment works as a source of 'new water'
		24	Implement planned national infrastructure developments without further delay, e.g. Lesotho Highlands Phase 2
		25	Plan water infrastructure with 50-year-and-beyond planning window, with consideration of projected population growth, climate change and economic development.
		26	Seriously implement and/or refine due diligence on water infrastructure development from Zambezi and Kongo rivers.
		27	Penalise WSAs (municipalities) that neglect infrastructure maintenance.
E	Natural resources	28	"Create" new freshwater resources.
		29	Adopt and implement UNCCD Land Degradation Neutrality (LDN) strategy.

	Cluster	Government / State responsibility
		30 Enforce the Soil Conservation Act, and act against landowners that allow over-grazing, soil erosion and land degradation. 31 Increased monitoring of degraded land and enforcement of Soil Conservation Act. 32 Implement and enforce the UNCCD Land Degradation Neutrality (LDN) strategy.
G	Technology	33 Government to provide incentives for implementation of water-saving technology. 34 Support research funding into new water technology. 35 Provide subsidy incentives for water users that implement water-saving technology. 36 Provide subsidy incentives for water users that implement water recycling technology.
H	Organisations	37 Support CMAs for full functionality. 38 The DHSWS need to improve its functionality.
I	Institutional	39 Establishment of National Water Regulator. 40 Implement Integrated Water Resource Management (IWRM). 41 Ensure the equitable allocation of irrigation water to formerly disadvantaged farmers. 42 Provide additional support to land reform beneficiaries for the access to, and sustainable use, of irrigation water. 43 Develop and implement a coordinated drought management framework. 44 Participation and adherence to international agreements such as the Sendai Framework for Disaster Risk Reduction. 45 Support and promote the establishment of all CMAs as envisaged in the Water Act. 46 Implement and manage drought according the drought classification system. 47 Improve water use monitoring and enforcement of regulations by the Blue and Green Scorpions.
J	Political	48 Implementation of sustainable economic-growth focused policies. 49 Government to set example and actively rid State organisation of corrupt practices. 50 Articulate a clear policy preference for the incentivisation of investment into technology for the creation of 'new water' by processing waste more effectively. 51 Take decisive action against politicians at all governance levels, who use water as a political tool for votes.

Table 10.2: Action Steps required by municipalities and water supply agencies

	Cluster		Municipalities responsibility and action steps
A	Human	1	Appoint qualified engineers and hydrologists in municipalities.
		2	Develop skills and capacity of officials in all municipal departments.
		3	Increase the pool of technical competence in municipality to enrich decision-making.
B	Social	4	Municipalities to agree on social pact with society to provide responsible leadership.
		5	Engage in discourse about the role of water as an economic enabler.
		6	Use social media to create water awareness.
		7	Support citizen mobilization for clean water
		8	Support citizen efforts to assist with maintenance of infrastructure
		9	Engage with retired experts offering their advice within the municipality
C	Cultural	10	Leadership in municipality to set example of respect for natural resources.
		11	Create culture of service delivery.
		12	Create paradigm shift of abundance rather paradigm of scarcity.
D	Economy/financial	13	Ensure sufficient budgeting for maintenance of current water infrastructure.
		14	Post-Covid-19 economic recovery plan to focus on 'new water' infrastructure development within municipality.
E	Infrastructure	15	Reconsider wastewater treatment works as a source of 'new water'.
		16	Ensure regular maintenance of infrastructure.
		17	Limit leakages to the minimum.
E	Natural resources	18	Prevent pollution into water recourses.
G	Technology	19	Provide incentives for business and water users for implementation of water-saving technology.
		20	Focus on incentivising water recovery systems that enable a dual-stream reticulation economy to emerge.
		21	Work with private sector to develop and apply new technology for water monitoring and measuring.
H	Organisations	22	Provide opportunities for NGOs and private companies to engage with water users.
		23	Seek cooperation for projects, farmers days and other publicity about good water management.
		24	Municipalities to ensure own organisation structures provide for water experts.
I	Institutional	25	Implementation of local coordinated drought management framework for municipalities.
		26	Development of bylaws that regulate water use.
		27	Enforcement of bylaws related to water use and exploitation.
		28	Implement bylaws that require water-saving technology in all new developments.
		29	Develop and implement bylaws that require a dual-water reticulation system.
		30	Articulate a clear policy preference for the incentivisation of investment into technology for the creation of 'new water' by processing wastewater more effectively.

	Cluster	Municipalities responsibility and action steps
		31 Monitor and 'police' – with warnings and fines – for poor water use. 32 Provide accurate water data to DHSWS and NDMC. 33 Participate actively in NDMC drought monitor project. 34 Develop drought contingency plans for each drought category. 35 Develop drought recovery plans for each drought category.
J	Political	36 Implementation of sustainable economic-growth focused initiatives at local level. 37 Municipal councilors lead municipality with focus on service delivery 38 Support the notion that water is an economic enabler 39 Municipal councilors refrain from using water as a political tool 40 Articulate a clear policy preference for the incentivisation of investment into technology for the creation of 'new water' by processing waste more effectively. 41 Offer incentives at local and tribal level for good long-term water sustainability activities. 42 Involve NGOs in policy development.

Table 10.3: Action steps required by agri-businesses, NGOs & research organisations (Universities)

	Cluster		Private organisations' action steps
A	Human	43	Appoint qualified engineers and hydrologists.
		44	Develop skills and capacity of new specialists, especially in the water sector.
		45	Increase the pool of technical competence to enrich decision-making.
		46	Develop, or adapt, courses at university and high school level to include some of these principles.
		47	Use internationally available material on water use for remote classes and course work focusing on water in semi-arid areas.
B	Social	48	Enter into a social pact with Government and the agricultural sector, and society at large.
		49	Engage into discourse about the role of water as an economic enabler.
		50	Assist students to mobilise for water security at all levels
C	Cultural	51	Leadership examples of respect for natural resources.
		52	Assist to create a culture of water awareness
D	Economy/financial	53	Ensure sufficient budgeting for maintenance of current water infrastructure.
		54	Post-Covid-19 economic recovery plan to with a focus on the development of new water infrastructure.
		55	Invest in water infrastructure.
		56	Invest in the development of new water-saving technology.
		57	Invest in technology for the creation of 'new water'.
E	Infrastructure	58	Be willing to engage over new business models that create 'new water' from waste water treatment.
E	Natural resources	59	Protect water resources if they are privately owned.
		60	Develop water sources for optimal use.
		61	Prevent water pollution.
G	Technology	62	Government to provide incentives for implementation of water-saving technology.
		63	Consider implementing water recovery systems that enable a dual-stream reticulation economy to emerge.
		64	Develop new technology – apps and equipment – for precision agriculture.
		65	Develop new technology – machinery and equipment – for conservation agriculture.
		66	Develop new technology – apps and equipment – for precision monitoring of water use and optimal application.
		67	Continuously develop new water-saving irrigation technology – drip / micro / underground.
		68	Promote water-related research into indigenous knowledge
H	Organisations	69	Develop own organisational structures to provide for water or drought management
I	Institutional	70	Participation and adherence to international agreements such as the Sendai Framework for Disaster Risk Reduction – private sector involvement is one of the requirements.
		71	Ensure adherence to national, regional and local water regulations.
		72	Adhere to water allocation limits.

	Cluster	Private organisations' action steps
		73 Ensure proper licensing and approval of all water use points including boreholes.
J	Political	74 Obtain political buy-in to water sustainable projects and developments 75 Encourage visits from decision-makers at all political levels – local, tribal, municipal, provincial. 76 Offer incentives at local and tribal level for good long-term water sustainability activities. 77 Involve NGOs in water management programmes.

Table 10.4: Action steps required by water users and society in general

	Cluster	Society and water users' action steps	
A	Human	78	Individual development to understand water challenges.
		79	Develop individual knowledge on how to save and preserve water.
		80	Develop individual understanding of paradigm of abundance and its implications.
B	Social	81	Citizens enter into social pact with each another.
		82	Society to enter into social pact with governance organisations such as municipalities and Government.
		83	Put water discussions on agenda of social clubs, study groups, savings clubs.
C	Cultural	84	Take ownership and responsibility of water management.
		85	Develop a culture in communities to save water.
		86	Take responsibility to repair broken infrastructure and leakages if possible.
		87	Develop a paradigm of abundance and view water as a flux.
D	Economy/financial	88	Invest in water-saving measures for household environments.
		89	Invest in water-saving technology for household use.
E	Infrastructure	90	Report water leakages.
		91	Report infrastructure vandalism.
		92	Take ownership of public water infrastructure as if it is your own.
E	Natural resources	93	Take care of water sources.
		94	Prevent and report water pollution.
G	Technology	95	Implement at household level technology that enables 'new water' to be generated from wastewater.
H	Organisations	96	Motivate own organisations to enter into discussion regarding water as a strategic resource.
I	Institutional	97	Respect and adhere to water-saving regulations.
		98	Report non-compliance of regulations to authorities.
		99	Ensure proper licensing and approval of all water use points, including boreholes.
J	Political	100	Enter into social pact with politicians including councilors at municipal level.
		101	Do not participate or condone political rhetoric at the cost of sound governance.

Table 10.5: Action steps required by farmers

	Cluster	Farmers' action steps
1	Human	102 Train workers to manage and apply water infrastructure effectively. 103 Capacitate and educate workers to understand importance of water as an economic enabler at farm level. 104 Develop own individual understanding of water management. 105
2	Social	106 Enter into a social pact with Government, private sector and society at large. 107 Use media to create awareness regarding the contribution of agriculture to food security. 108 Apply self-monitoring of water use through water user organisations and farmers' organisations. 109 Involve land reform beneficiaries in farmers' and social activities such as farmers' days and study groups on a regular basis.
3	Cultural	110 Leadership should provide examples of respect for natural resources. 111 Develop positive attitude to Government and society at large from grass-root level. 112 Change the 'we vs them' attitude amongst certain groups of farmers. 113 Create understand and respect for water amongst all people staying on a specific farm – workers, families, visitors – use prizes and benefits as reward for better use of water. 114 Water users to commit themselves to honesty and openness in water use reporting and measuring / monitoring. 115 Initiate evaluation of past cultural 'rules' used for farm activities, and review benefits.
4	Economy/financial	116 Invest in water-saving technology at different scales. 117 Invest in conservation agriculture – equipment, machinery, and information packages. 118 Invest in precision agriculture principle. 119 Measure yield on irrigated land in terms of water use, e.g. output / m^3 water instead of output / ha. 120 Consider using water-energy-food nexus tools to optimise water use across sectors.
5	Infrastructure	121 Maintain irrigation canals and water infrastructure – should be joint responsibility of WUAs and farmers. 122 Prevent leakages in water infrastructure, and repair and do maintenance on a regular basis. 123 Install environmentally friendly infrastructure – e.g. multi-use covers for canals that are also solar energy panels.
6	Natural resources	124 Prevent water pollution in dams and rivers. 125 Ensure sustainable use of groundwater, especially during drought years. 126 Maintain active healthy wetlands – not ploughing or draining them.
7	Technology	127 Implement conservation agriculture principles. 128 Apply precision agriculture principles – develop new technology – apps & equipment. 129 Apply the use of remote sensing technology for improved measuring and monitoring – also via apps and platforms (e.g. FruitLook) 130 Apply technology for precision monitoring of water use and optimal application.

	Cluster	Farmers' action steps
		131 Apply water-saving technology in irrigation such as drip irrigation.
8	Organisations	132 Larger farmers or farming companies to provide for trained water specialists in organizational structure 133 Ensure water discussions at farmers' organization meetings
9	Institutional	134 Respect and adhere to water use regulations. 135 Develop and respect own regulations for equitable water use at local level. 136 Ensure proper licensing and approval of all water use points including boreholes.
10	Political	137 Obtain political buy-in to water sustainable projects & developments at farm level. 138 Encourage visits from decision-makers at all political levels – local, tribal, municipal, provincial – to successful farm level projects 139 Involve NGOs in water management programmes.

10.4 Conclusion

As stated at the beginning of this study, agricultural water management in South Africa is complex because the system is governed by multiple drivers, multiple stakeholders with varying opinions and interests, and several dynamic feedback processes. This project aimed to develop qualitative and quantitative scenarios for sustainable agricultural water management in South Africa. In so doing, qualitative and quantitative system dynamics models capable of developing relevant policy-based scenarios and intervention strategies for the sustainable agricultural water management in South Africa. Equally, several qualitative scenarios based on best- and worst-case scenarios have been developed.

The following objectives were framed and fulfilled in this study:

- To determine the current status of agricultural water management in South Africa,
- To review and provide critical analysis of current social, political and ecological scenarios
- To identify socio, environmental and economic indicators to measure different scenario outcomes. These indicators were sub-categorised in ten drivers (capitals) namely, human, social, cultural, political, institutional, economic / financial, environmental, technological and infrastructure, and
- To develop a dynamic decision support tool based on real-time indicator values and changes.
- To recommend some policy and action plans for sustainable agricultural water management based on four main scenarios,

The identification and analysis of drivers of change using a participatory approach showed that population growth, urbanisation, poverty/inequality, climate extremes, water availability, land degradation, soil erosion, land reform policies, mismanagement of public resources, internal power struggles, political understanding of agriculture, energy prices, the profitability of farmers, capital availability, net agricultural exports, and investment were categorized as very influential in water resource management and agricultural sustainability.

The influential drivers identified and analysed were used as a guide for developing a qualitative integrated model. The integrated model developed in this study indicates several feedback processes interacting to influence water management and agricultural development in the catchment. The model shows 8 balancing (negative) feedback loops and 13 reinforcing (positive) loops, meaning that the catchment has a complex system governed by multiple drivers. The model is dominated by positive feedback loops some of which are very important in determining the dynamic behaviour of the catchment. These feedback loops are dominated by issues such as available surface and groundwater resources, population growth, crop yield, agricultural production, farm income, land reform, and agricultural investment.

Furthermore, dominant feedback loops in the conceptual model were quantified and used to develop the simulation system dynamics model. The model was simulated for a period of 20 years (from 2010 to 2030). The model consisted of four sub-models: population sub-model, surface water resources sub-model, the groundwater sub-model, and agricultural sub-model. Various structural and behavioural pattern tests were conducted and a sensitivity test was used to evaluate and validate the behaviour of the model. The results of the tests performed showed the model behaved well and can represent real-world circumstances. Three distinct scenarios were developed from the simulation of the model with scenario one being the best-case scenario and scenario 3 being the worst-case scenario.

From the discussion presented above, this study has fulfilled its objective and has successfully developed qualitative and quantitative system dynamics models that are highly adaptable to different socio-ecological systems in Africa and around the world. The study has successfully answered the important research questions in this study

This study has developed a practical theoretical framework for solving environmental problems especially in complex systems with multiple drivers and diverse stakeholders who might have different perspectives and interests. This study has equally demonstrated that it is possible to apply system dynamics modelling to coupled water and food systems to identify leverage points and intervention strategies to ensure sustainable management of water resources and agricultural development. This suggests that no matter how complex the system is, practical models can be developed to simplify the complexity and develop practical policy-based scenarios to sustainably manage the system. The findings suggest that qualitative and quantitative tools based on system dynamics applied in this study can be used to explore and identify the key system drivers influencing the mode of behaviour and sustainability of coupled water-food systems.

Furthermore, qualitative system dynamics such as the ones developed here are capable of capturing the underlying feedback structures inherent in natural systems thereby making them valuable for sustainability planning, policy formulation, and research. The quantitative model developed in this study is expected to improve the general understanding of water resources management and agricultural sustainability in the catchment. However, it should be noted that the models presented in this study are based on the assumptions and limitations of the modeller and the stakeholders that participated in the workshops. Given the complex and dynamic systems that interact to influence the management of water resources and agricultural productivity, the dynamic behaviour of a complex system is controlled by several drivers and processes, which cannot be fully understood. One major benefit of the models developed in this study is that it can be used by both technical and non-technical experts to make decisions regarding the sustainability of natural systems. The models were developed with active stakeholder participation thereby making them very practical for use by decision-makers at public and private sectors.

This study has demonstrated the value of including stakeholders in problem-framing, policy formulation, and decision-making processes because they are core agents with perfect knowledge of the system. Integrated water resource management is not a new concept in South Africa, but this study has provided a structured methodological framework for involving stakeholders directly in the design of the models, which ensures that the models are aiming at the problems and stakeholders can use them. Conceptual modelling provides a suitable methodology for capturing the opinion of all relevant stakeholders and represent them visually for easy understanding of complex systems especially when there is uncertainty about the system or limitations of quantitative data.

This study has equally demonstrated that participatory frameworks are useful for including relevant stakeholders to constructively identify and capture important feedback loops inherent in complex systems and the dynamic interaction between important drivers thereby serving as an important framework for planning and management of water resources and agricultural sustainability. The approach equally shows policymakers can frame problems and design intervention strategies for solving them.

Finally, the development of the quantitative model followed a logical approach of identifying and analysing drivers of change influencing water and food systems and mapping the mental models of relevant stakeholders. The important feedback loops that were identified in the mental modelling (conceptual modelling) were simulated and presented in a quantitative system dynamics model using the business-as-usual and three other distinct scenarios. The simulation model is expected to improve the understanding of policymakers and relevant stakeholders on the long-term dynamics and behaviour of the catchment regarding efficient water management and agricultural sustainability.

The findings of this study have demonstrated the merits of using systems thinking approach for solving problems in complex systems. The findings suggest that using a participatory stakeholder approach for developing solutions to complex system problems could be invaluable as those directly and directly affected by the problem are involved in developing solutions to the problem. Furthermore, the findings have practically demonstrated how qualitative data obtained through workshop interactions and interviews can be combined with historical data to develop qualitative integrated conceptual models and quantitative simulation models to support decision making in a complex environmental system. Hence, this methodological approach is highly recommended to decision-makers in the public and private sectors, scientists, and researchers who want to solve complex environmental problems to combine data from stakeholder mental models with real-world data to address a complex environmental problem. This methodological approach is highly recommended for developing countries that often ignore stakeholders in the policy formulation. This will significantly reduce the unintended consequences of policy decisions and reduce policy resistance. This methodological approach can be adapted and used in different geographical contexts across the world. The approach can easily be used by experts and non-experts to solve problems confronting complex systems.

Furthermore, we applied a new strategy for planning under uncertainty called scenario planning. Rather than just predicting and forecasting future occurrences, scenario planning examines plausible and possible future occurrences. Scenario planning is crucial for policy planners because it reveals what could happen in the future if certain decisions are made today. Scenario development through the consultative workshops and contributions from stakeholders considered all ten drivers as important, but the major red flag highlighted was South Africa's economy, which in turn depends mainly on a stable environment. The major driving forces behind a stable economy – especially one in the face of potential exogenous shocks such as pandemics, international conflict, and climate change – are the Government, specifically pertaining to political will and developmental policies – civil society, and the private sector. All stakeholders agreed that a strong economy combined with governmental service delivery should ensure employment, poverty alleviation, food security, and, as a result, less civil conflict.

Four set of scenarios were developed namely;

- Scenarios from the perspective of farmers. Farmers included commercial as well as small scale and subsistence farmers. The emphasis on water use and the impact of government and governance featured very strongly in these scenarios.
- Scenarios from experts in water management and environmental management. The influence of climate change, biodiversity, ecology, and land degradation featured strongly amongst within this group and in their scenarios.
- Scenarios focused on water conflict and security – issues that were mentioned by all groups, but one group used these issues as their focus. The role of government and future governance again featured very strongly in this scenario.
- Post Covid-19 and Agricultural Water Management Scenarios. The weaknesses in the water sector were highlighted with communities exposed where they did not have enough water to perform basic sanitary measures required under Covid-19 regulations. The agricultural sector could continue to a large extent with normal on-farm activities, and businesses directly linked to the food chain could continue with operations. It's expected, however, that the Covid-19 pandemic fast-tracked the implementation of the 4th industrial revolution (4IR) and that it will also impact future water management scenarios.

Based on the scenarios, a number of red flags were identified and concluded on. Red flags identified here are specifically relevant to agriculture.

The first red flag is the absence of a social pact between the major stakeholders, i.e. government, agribusiness, farmers, farm workers and society at large. The distrust between government and the commercial farming sector and negative statements from political leaders is an issue that need to be addressed. The second red flag is the capacity of government to govern without the albatross of corruption and corrupt leaders still in its midst. That deviates attention from good governance and force leaders to focus on party-political issues instead on the state and sound governance. This is especially relevant at municipal level where water quality and water availability are determined by proper service delivery and maintenance of water infrastructure. Poor governance at municipal level also frustrated the population with increased levels of intolerance. The third red flag is centered around the economy and its resilience to withstand the negative impacts of firstly the 2015-2019 drought and the 2020-2021 Covid-19 impact. Millions of people lost their jobs and government provided social grants to support the poorest of the poor; this cannot continue forever. Government borrowed money to manage the pandemic and that should be paid back at some stage. The fourth red flag is the absence of successful land and water reform. Few of the land reform beneficiaries – newly established black farmers – are successful due to various reasons. The lack of progress in land and water reform sends out a negative message to the masses and commercial farmers are blamed for not making land available for land reform – which is not the case since government hold title for millions of ha of unproductive land. Learning from the Zimbabwe example, it is clear that the lack of progress with successful land and water reform hold the potential to fast-track South Africa to the Z-scenario.

The attempt to a best-case scenario is possible through coordinated action that is driven by a paradigm that view water as a flux. All stakeholders need to take responsibility for sustainable water use and water management. South Africa is a water stressed country with a water stressed economy and water management in agriculture is inseparable from water management in other sectors of the economy. Climate change projections of a warmer climate combined with population growth will increase water demand in urban areas; that additional water will be drawn from agricultural water for as long as we view water as a stock. It is therefore imperative to create “new water” through innovative technology and implement technology for water re-use.

Finally, it is important to mention that while the models developed in this study represent the biases, knowledge, and assumptions of the modelers and stakeholders that participated in the process, the models developed in this study were duly verified and validated to ensure they represent real-world situations.

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11 ATTACHMENT A

11.1 Introduction

The project objectives as stated in the original contract are as follows:

The main aim of this research was to:

- Develop scenarios for agricultural water management in South Africa. These scenarios considered the following dynamics: social (including issues such as poverty, employment, demographic changes, security, etc.); economic (including food production, industry, mining, global markets and trends, etc.); ecological (including land degradation, climate change and variability etc.); political (including political stability and policy);

Secondary objectives aimed to:

- Recommend some policy and action plans for sustainable agricultural water management based on four main scenarios;
- Determine the current status of agricultural water management in South Africa;
- Review and provide critical analysis of current social, political and ecological scenarios;
- Identify socio, environmental and economic indicators in order to measure different scenario outcomes. These indicators were sub-categorised into ten capitals namely: human, social, cultural, political, institutional, economical, environmental, and infrastructure, organisational and technological
- Develop the framework for a dynamic decision support tool based on real-time indicator values and changes

11.2 Project timelines:

The project contract was signed on 30 March 2017 by Dr Glen Taylor on behalf of the University of the Free State. Prof Jordaan, who proposed the project to the WRC was appointed as project leader and primary researcher with Prof) Abioden Ogundeji as his co-researcher and Ms G van Coppenhagen as the administrative officer. External experts contracted were Prof S Walker (Climate change specialist), Prof A Turton (Water management specialist), Ms C Ilbury (Scenario specialist) and Prof A Pelser (Social scientists). Prof Pelser withdraw from project due to other commitments and he was replaced with Prof D Sakulski. Prof Jordaan retired from the University due to retirement age conditions but was contracted by UFS as project leader to complete the project.

The project timeline for main activities is shown in Figure 1.

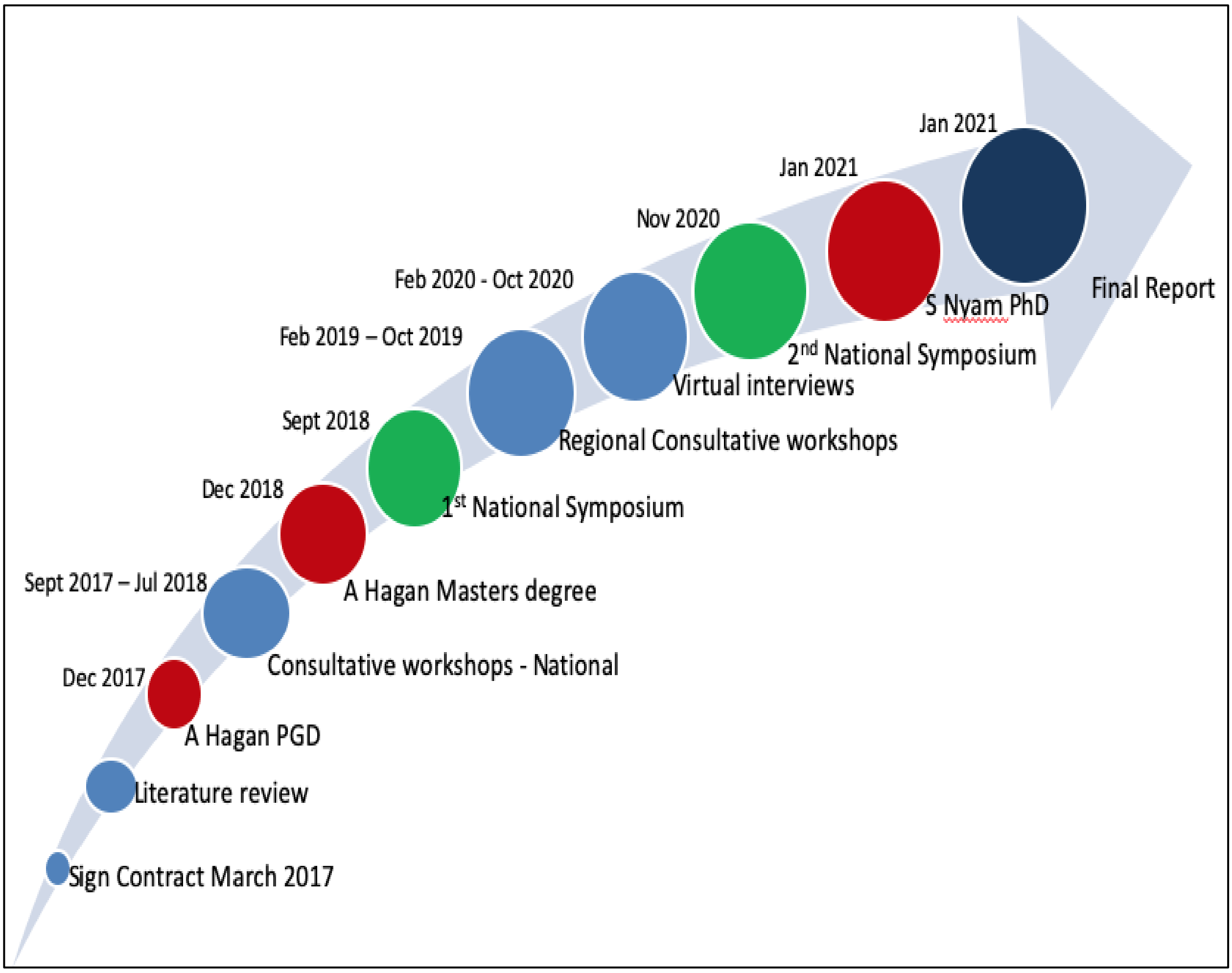

Figure 1: Main activity timeline

Activities were executed as planned except for the final stage when Covid-19 lockdown regulations prevented face-to-face workshops and discussions. We, however replaced the planned workshops with virtual discussions and we trust that it did not influence the results significantly. What we missed though, was the opportunity to share and discuss our final scenarios with different groups. The lockdown also led to the shift in deliverable dates but we still managed to complete the project within the planned financial year with no need for contract adjustments.

Deliverables as per contract submitted is shown in Table 1.

Table 1: Project deliverables

1	Report on status quo water scenarios	Critical analysis of status quo scenarios with focus on (i) demographics, social dynamics, economic development, environmental changes (including water and climate) and global outlooks.	31/07/2017
2	Report on status quo water management planning	Critical analysis of current water management plans such as national development plan and other plans.	31/10/2017
3	1st progress and capacity building report	Report first year activities and progress of students as well as interaction with other role players	24/11/2017
4	Report on indicator selection for scenario building	Selection of indicators based on capitals namely (i) human, (ii) social, (iii) cultural, (iv) political, (v) economic, (vi) institutional, (vii) environmental, (viii) infrastructure, and (ix) global	31/08/2018
5	Report on 1st national water scenario symposium	Report on feedback from 1st national water scenario symposium	31/10/2018
6	2nd progress and capacity building report	Report on project progress and students as well as interaction with other role players	23/11/2018
7	1st Scenario report	Report on climate, environmental, social, political and security scenarios	29/04/2019
8	2nd Scenario report	Report on economic development, agricultural and food security scenarios	26/08/2019
9	Water conflict scenarios	Report on water conflict scenarios. Conflict refers to conflict between water users such as agriculture, domestic, mining, industry as well as inter-country and regional water conflicts	31/10/2019
10	3rd progress and capacity building report	Report on project and student progress as well as capacity building and knowledge dissemination activities through workshops, conferences and published articles and papers	25/11/2019
11	Draft report on agricultural water management scenarios	Draft report on agricultural water management scenarios to be circulated for final commentary amongst collaborating organizations and others.	07/10/2020
12	Report on framework for dynamic scenario building	Report and program for a dynamic scenario building tool. All indicators identified during the research will be included in the program.	25/08/2020
13	Report on final national Agric management symposium	Report about the final agric water management scenario symposium	02/12/2020
14	Final report	Final report that provides reflection of all results obtained during the research. Water management scenarios will also be summarised in a policy brief format	31/01/2021
15	4th progress and capacity building report	Report on 4th year activities and report on progress with capacity building of students as well as interaction with role players	17/11/2020
	Final project report	Final project report – Not in Contract as deliverable	

Deliverable timeline is shown in Figure 2:

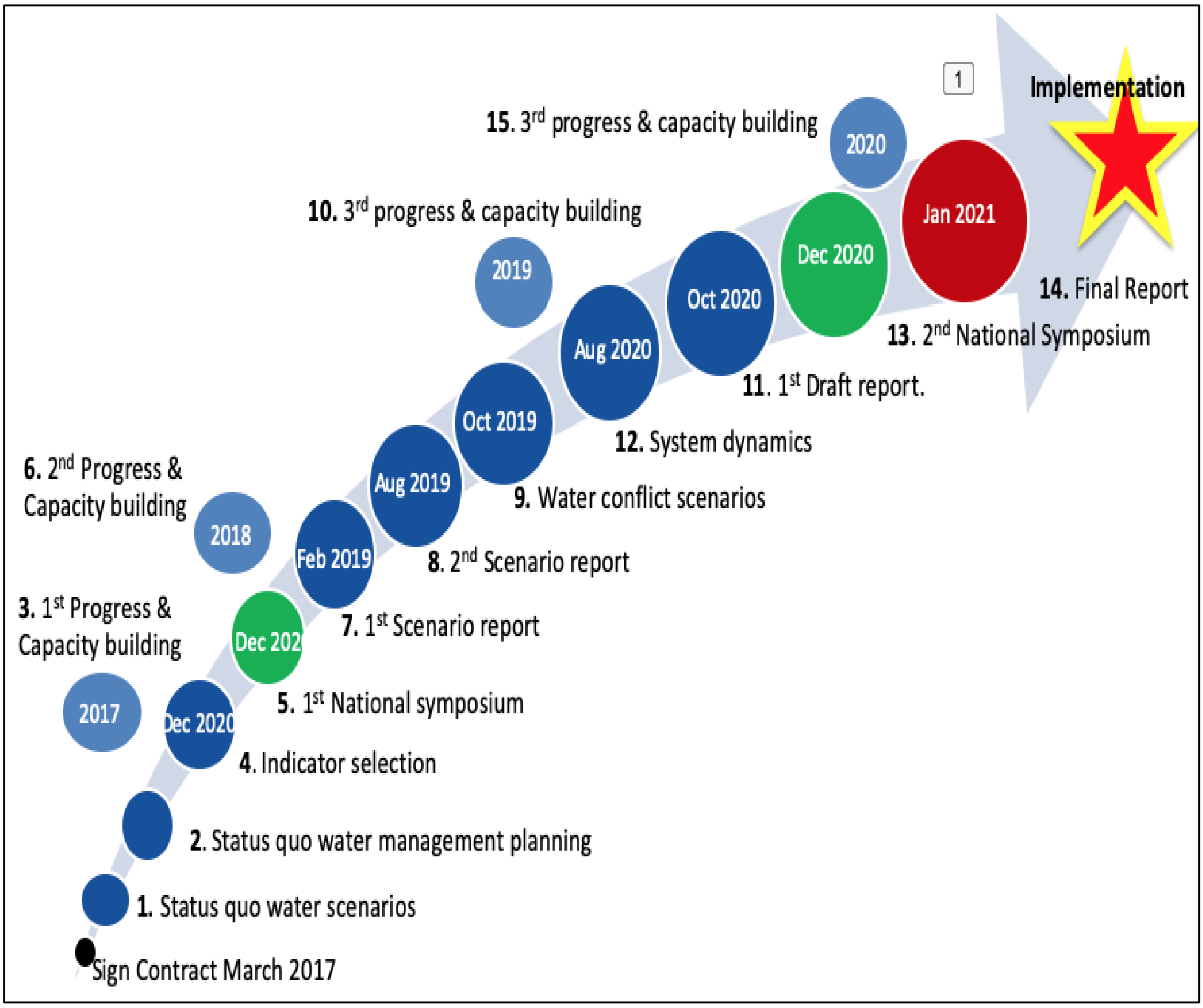

Figure 2: Deliverable timeline

11.3 Project outcomes as per contract

Apart from the scientific and academic content, the following outcomes were also envisaged from the project. This section evaluates the outcomes against original intentions as stipulated in the contract.

Knowledge dissemination

Knowledge dissemination was a key element of the project. The participatory research methodology provided the opportunity to share knowledge through eight consultative workshops and two national symposia. The workshops targeted a wide range of stakeholders and sectors. The workshops were structured in such a way that information was transferred to participants through presentations with a focus on the identification of drivers for scenario building and potential modelling thereof. That was followed by feedback from participants regarding potential scenarios according to their perspectives. Small group discussions will follow the expert presentations, thereby ensuring proper feedback and inputs from participants.

The following mechanisms were utilised for knowledge dissemination:

- Workshops that targeted organised agriculture. These include workshops with all the major organisations representing farmers such as AFASA, NAFU, and AGRISA
- Two national symposia with invitations to all stakeholders.
- Presentations at national conferences
- Publications in peer-reviewed journals

Workshops

Seven workshops with a focus on water management scenarios plus 10 workshops with a focus on drought management. The drought management workshops with different attendees were also facilitated by Prof Jordaan as part of a NDMC project to develop a drought management plan for South Africa. The two projects supplemented each other and much information and inputs were derived from the drought management workshops, while it also provides the opportunity to share knowledge and information.

National symposiums

The two national symposiums provided an ideal platform for knowledge dissemination. More than 80 people from different organisations participated in the two symposiums

Conferences

A number of conferences were cancelled during 2020 as a result of the Covid pandemic. In spite of that, 3 opportunities were utilized for presentations as follows

i. *Future Scenarios for Agricultural Water Management*. Adapting to Extremes and Limiting Disaster Loss. Annual Conference, Disaster Management Institute for Southern Africa, Hartenbos, South Africa. 18-19 September 2019.

ii. *Developing Agricultural Water Management Scenarios for South Africa.* AGRISA Water Colloqium, Somerset West, South Africa. 26 August 2019.

iii. *Management of the New Normal: Dry Periods and Drought.* Rehabilitation in Practice. 7th Annual Conference, Land Rehabilitation Society of Southern Africa. Cradle of Mankind, South Africa. 16 July 2019.

Publications

Popular media publications were the following:

i. Poor water management is risk to land reform – https://www.fin24.com/Economy/poor-water-management-is-risk-to-land-reform-agriculture-forum-hears-20190829
ii. Agbiz hosts water efficiency workshop – https://www.agriorbit.com/agbiz-hosts-water-efficiency-workshop/
iii. Poor water management is risk to land reform – https://www.wheels24.co.za/ShopBlockAd.aspx?aid=5dee71e5-4877-4c65-a1df-98e9c016124e&currentCategoryName=Test&currentCategoryBreadCrumb=Test
iv. Agriculture's Water Challenges: Drilling for Solutions – https://www.kwanalu.co.za/wp-content/uploads/2019/09/AgriSA_WaterSymposium_Report_V5.pdf
v. Water Wheel; Nov/Dec 2019. Vol 18 No 6, pp 26-29
vi. Landbouweekblad X 4 articles
vii. Farmers Weekly
viii. Plaas Media
ix. UFS. Symposium provides course of action for good water management – https://www.ufs.ac.za/templates/news-archive-item/campus-news/2020/november/symposium-provides-course-of-action-for-good-water-management
x. Water Wheel; 2021

Peer reviewed scientific publications

Five peer reviewed publications were already published. More will follow. The following are the published papers.

i. Nyam, YS., Kotir, JH., Jordaan., A, Ogundeji, AA. (2021). A system dynamic simulation of coupled water-food systems in the Breede River catchment. Journal for Environmental Management. DOI 10.1007/s00267-020-01399-x
ii. Nyam, Y.S., Kotir, JH., Jordaan, AJ., Ogundeji, AA. (2021). Developing a Conceptual Model for Sustainable Water resource management and Agricultural development: The Case of the Breede River Catchment Area, South Africa. Environmental Management; 1-16. https://doi.org/10.1007/s00267-020-01399-x
iii. Nyam Y.S., Kotir JH, Jordaan A, Ogundeji AA. (2020). Identifying behavioural patterns of coupled water-agriculture systems using system archetypes. Systems Research and Behavioral Science; 1-19. https://doi.org/10.1002/sres.2753
iv. Nyam, Y.S., Kotir JH, Jordaan AJ, Ogundeji AA, Turton AR (2020b). Drivers of change in sustainable water management and agricultural development in South Africa: a participatory approach. Sustainable Water Resources Management, 6(4), 1-20.

v. Nyam, Y.S., Kotir, J. H., Jordaan, A. J., Ogundeji, A. A., Adetoro, A. A., & Orimoloye, I. R. (2020a). Towards Understanding and Sustaining Natural Resource Systems through the Systems Perspective: A Systematic Evaluation. Sustainability, 12(23), 9871.

11.4 Innovation

"*Although the focus of the project is not on the development of new innovations we expect the development of a framework for a dynamic and interactive web based tool as an innovative idea. Such a tool will allow for dynamic scenario development with changing values for different indicators."*

The system dynamics tool is not as yet available as a web-based interactive tool but it provides the basis for such a tool for further development

11.5 Capacity Building

Two students graduated with three degrees. Summarised in Table 2.

Table 2: Summary of student details

Student	Student No	Research Topic	Student Progress Report
Aniebo Benita Hagan **(MDM)**	2009077864	**Post Graduate Diploma** in Disaster Management **Master's Degree:** Sustainability of Agricultural Water Resource Management Systems in South Africa	Graduated March 2018 – PGD in Disaster Management; UFS Graduated June 2019 – M in Disaster Management; UFS
Yong Sebastian Nyam **(PhD)**	2014218867	**PhD:** Scenarios for Agricultural Water Management in South Africa	Degree was awarded during March 2021

11.6 Institutional Development

The following was stated in contract:

- ***UFS:*** *Curriculla development or improvement of current curricula. New knowledge gained through the project should inform the development of new curricula or the improvement of current curricula in post graduate courses in the fields of (i) environmental sciences, (ii) economic sciences, (iii) political sciences, (iv) security studies, and (v) social sciences*
- ***DHSWS:*** *Scenario development should allow the DWAS to review current policies and plans and make the necessary adjustments to ensure sustainable water management.*

- ***DARDLR:*** *Scenario development should allow the DAFF to review current policies and plans and make the necessary adjustments to ensure sustainable food production and support to the agricultural sector.*

The scenario building methodology applied in this project was successfully included in the Masters course dealing with disaster risk assessment at the University of the Free State. The disaster risk assessment methodology as described in the National Disaster Management Framework (NDMF) requires scenario development as one of the core steps in the assessment process. The methodology developed and applied in this project for scenario development is extremely helpful when doing risk assessment due to the way indicators structured according to the different clusters.

The report in its entirety was prescribed as a must-read document to Master students studying disaster risk assessment at the University of the Free State. See screenshots of learning materials incorporated in risk assessment modules.

We trust that we will see the positive impact of this knowledge transfer not only in water management but also in risk assessments and disaster risk reduction.

We trust that the scenarios and potential solutions will provide information for policy and/or operational implementation at both the DHSWS and DARDLR.

11.7 Community Development

As per the contract as follows:

- ***Agricultural producers:*** *The involvement of AgriSA, NAFU, AFASA, Transvaal Agri and commodity organisations will ensure informed decision-making at agricultural production level.*

Farmers and their organisations should be able to make timely adjustments to policies and plans based on the potential scenarios to be identified in this project.

- ***Agricultural businesses:*** *Agricultural businesses is already investing in other African countries in anticipation of a geographic shift in agricultural production patterns. Agricultural water management scenarios should provide the business sector with valuable information and early warning indicators to influence their investment and development strategies.*
- ***Government:*** *Policymakers and decision makers in government will be able to use the scenarios for policy development and informed decision making.*

We trust that the outcomes and content of the project provides a clear enough message for all stakeholders. Stakeholders already reacted positively to our initial scenarios during our interaction at the workshops and symposiums. Further dissemination of the message however is required. This is not a project targeted at scientists only.

11.8 Project Management

The WRC project managers supported us with excellent support. During the course of the project, three WRC project leaders supported us. They are: Dr G Backeberg, Prof S Mpandeli and Dr L Nhamo

Sandra Fritz at WRC always provides professional administrative support.

G V Coppenhagen as part of our team helped us to focus on research while she managed all administration issues

We did not experience any administrative challenges.

11.9 Finances

The total project budget was R2,968,000 allocated as follows:

i.	Professional fees:	R1,856,000
ii.	Capital expenditure:	R 45,000
iii.	Running costs	R532,500
iv.	Minor expenses:	R284,500
v.	Uptake:	R250,000

11.10 Limitations of the Study

This study has successfully developed a practical qualitative and quantitative system dynamics model capable of informing policy formulation and decision-making regarding the sustainable management of water and food systems in the catchment in particular and South Africa. The study has successfully engaged a diverse group of stakeholders through a series of interactive workshops to examine their mental models and opinions regarding future water management and agricultural development in South Africa. Despite the holistic approach applied in this study, some factors limited the general contribution of this study. First, Covid-19 made it almost impossible to engage all relevant stakeholders in the water, food, and other related sectors in South Africa. This means that several key stakeholders were not consulted meaning that their opinions, ideas, and mental models have not been included in the models. It should be noted however that this study engaged 131 stakeholders over nine interactive stakeholder workshops plus numerous individual discussions with industry specialists and it eventually became clear that the inputs and results obtained from additional sources repeat themselves. This study consulted enough stakeholders to develop meaningful models and draw conclusions about the functioning of the systems; engaging more stakeholders would not really enrich the results of the study and increase the practicality and usability of the models. Future studies on this subject could engage more relevant technical and non-technical stakeholders. These studies should expand the model boundaries to include more strategic catchments in South Africa

In spite of the Covid-19 lockdown regulations that impacted on our planned workshops with government officials and other stakeholders during the final year, we managed to have virtual discussions with various stakeholders as individuals for example:

- Experts from Grain SA
- Experts from NWGA
- Farmers in the EC
- Farmers from AFASA
- Department Agriculture, Rural Development and Land Reform officials
- Disaster Management officials
- Department of Human Settlement Water & Sanitation officials

The finalization of the *National Integrated Drought Plan for South Africa* also provided valuable inputs to the water scenario project since drought is identified as one of the major *"triggers"* or "*tipping points"* for future water management scenarios. The drought management project was also managed by Prof Jordaan and the advantage of that was that the synergy between the two projects provided valuable information *"vice versa".*

11.11 Follow up recommendations

Scenario development in this project was unique in the sense that we combined the qualitative inputs from workshop participants and other experts with quantitative results from the systems dynamics modelling. Also unique is the use of 10 clusters to categorise the drivers of change. The methodology provides an opportunity for researchers to explore, critique and propose improvements.

The qualitative conceptual model developed in paper three revealed 21 important feedback loops, 13 reinforcing (positive) feedback loops, and eight balancing (negative) feedback loops. Owing to a lack of data and the inability to include some of the variables in the simulation model, many important feedback loops were omitted from the formal simulated model. Furthermore, as earlier mentioned, the development and parameterization of the simulation model rest on certain assumptions on the modeller's judgment and the feedback of the stakeholders that participated in the workshops. It is possible that important variables and critical issues confronting the economy of the catchment may be been ignored because the modeler and stakeholders never thought were important or due to lack of knowledge. Data for some of the important model variables were estimated by the modeler due to a lack of reliable data at catchment. This might affect the developed model. Reliable catchment level data should be used in future studies to parameterize the model and reduce the uncertainty and assumptions in the model. Important issues such as social cohesion, collaboration among public and private sectors regarding water management, and mismanagement of public resources were crucial issues among stakeholders but could not be included in the simulation model. Future models should incorporate these important issues.

It is important however, to disseminate relevant information documented in this report to decision makers, researchers and scholars. Dissemination of information should be done through symposia, workshops, training through short learning programs, inclusion of some of the information in post graduate programs and publications in peer reviewed journals as well as popular media. The contents should focus on identification of clusters and drivers, scenario building and the use of system dynamics modelling for scenario building.

11.12 Recommendations

The results of the project have already created an awareness of potential water management scenarios through the different stakeholder consultations, symposia, peer reviewed publications, and media coverage. However, further publications and training are required to obtain full advantage of the contents of this report. We recommend a post-project training, education and awareness raising program with the following objectives and activities:

- Training and education of students in scenario building methods.
- Training and education of students in the development of scenarios through mathematical modelling.
- Sharing of information with water management stakeholders.
- Sharing of information with policymakers and decision-makers in the water sector.
- A post project national symposium might provide the opportunity for further dissemination and awareness raising
- Further publications in peer review journals

Further research is also required for the following:

Recommendations for further research is summarised as follows:

The system dynamics model developed as part of the research utilised data from the Breede river catchment and further research is required to test the model for robustness and application in other catchments and the use of the model at national level. In addition, the model should be developed to become more user-friendly and available for drought monitoring and early warning.

The action plans proposed in the final chapter of the report need to be prioritised and reviewed with additional contributions from the different stakeholders.

The “too little” (drought), “too much” (floods) and “too bad” (water pollution) need to be prevented and managed in a coordinated manner. Drought management, for example, is managed by different departments with Disaster Management responsible for coordination. The Department of Agriculture, Rural Development and Land Reform (DARDLR) is primarily responsible for agricultural drought, Department of Human Settlement, Water and Sanitation (DHSWS) is primarily responsible for hydrological drought (rivers, dams, groundwater), Department of Environment Forestry and Fisheries (DEFF) is responsible for drought affecting eco-systems, land degradation; and the South African Weather Service (SAWS) is also located in DEFF; finally, the Department of Coordination and Traditional Affairs (COGTA) through the municipalities are responsible for domestic water supply. Each of these departments hosts its own drought monitor and early warning information system with little or no integration. The recently developed national drought plan for South Africa proposes an integrated drought mitigation unit as part of the National Disaster Management Centre. Further research is required to determine the best placing of such a unit, its functions and operational requirements.