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Water, Food and Agricultural Sustainability in Southern Africa

Jamie Pittock
R Quentin Grafton
Chris White
Editors

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Jamie Pittock, R Quentin Grafton and Chris White

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About the editors

Jamie Pittock is a Senior Lecturer in the Fenner School of Environment and Society at The Australian National University. He has been Director of International Programs for the UNESCO Chair in Water Economics and Transboundary Water Governance, and also Program Leader of the Australia and United States Climate, Energy and Water Nexus Project for the US Studies Centre and ANU from 2010. Dr Pittock worked for non-government environmental organisations in Australia and internationally from 1989-2007, including as Director of WWF's Global Freshwater Programme from 2001-2007. His research focuses on better governance of the interlinked issues of water management, energy and food supply, responding to climate change and conserving biological diversity.

R Quentin Grafton has a PhD in Economics from the University of British Columbia and holds a Chair and a professorship in economics at the Australian National University. Professor Grafton holds the UNESCO Chair in Water Economics and Transboundary Water Governance. He is Director of the Centre for Water Economics, Environment and Policy at the Crawford School at the Australian National University (ANU) and is an ANU Public Policy Fellow. He is the recipient of numerous research awards and the author and/or editor of a dozen books in resource and environmental economics along with over one hundred publications in peer-reviewed journals and chapters in books.

Chris White studied Philosophy, Politics, and Economics at Oxford University before moving to the ANU to complete a Masters in Environmental and Resource Economics in 2010. Following this Chris joined the ANU as a Research Associate; working on a number of government reports, editing several books, and undertaking original academic research looking at the economics of water and biodiversity. During this time Chris also designed and edited the Global Water Forum as part of his work with the UNESCO Chair. In addition to these roles, Chris now works as an Environmental Economist for URS in London.

About the contributors

Ayalneh Bogale

Ayalneh Bogale received his PhD in Agricultural and Resource Economics from Humboldt University of Berlin (2002) and has a wide range of research experience and interest in areas of the economics of resource degradation, poverty and food security, vulnerability analysis, property rights, climate change and adaptation, and adoption of technologies. He is currently Associate Professor and Director of the African Centre for Food Security (ACFS) at the University of KwaZulu-Natal, South Africa.

Joyce Chijta

Dr Joyce Thamaga-Chitja holds a PhD in Food Security. She is an experienced agricultural scientist and food security expert with a rich understating of agriculture in South Africa. Her experience ranges from research in organic production, agricultural development, land reform, to the land claims process and its challenge. She was the Director of Operations at the Regional Land Claims Commission in 2008, and visiting scholar at Cornell University. Her current research areas include Food Security in relation to: organic farming production, small-scale farmer value chains, water and livelihoods, gender & agriculture, land reform and vulnerability.

Derick du Toit

Derick du Toit is an ecologist by training but specialises in environmental learning and professional development. He has worked for a number of years at the Desert Research Foundation of Namibia on translating scientific research into learning programs. He has subsequently worked on education reform in Namibia, Botswana and South Africa. He currently is Project Manager with the Association for Water and Rural Development (AWARD) in South Africa.

Jacqueline Goldin

Professor Jacqueline Goldin has a strong academic and extensive empirical background. As a "numerate" anthropologist, she has conducted many large-scale and smaller household poverty surveys and numerous long-term and short-term evaluations across government and community projects and programs covering a wide range of development topics. Jaqui is Professor Extra-Ordinary in the Faculty of Natural Sciences at the University of the Western Cape, a position that is held under the UNESCO Chair for Groundwater and Society.

Donna Hornby

Donna Hornby is currently completing her PhD on the Besters land reform farms in northern KwaZuluNatal.

Unathi Kolanisi

Dr Unathi Kolanisi is a lecturer at the University of KwaZulu-Natal, in the African Centre for Food Security, a Centre of Excellence for Vulnerability Assessment and Analysis for the Southern African Development Community (SADC) region. Her research interests are food security (food access, food storage for food security, monitoring and measuring); consumer behaviour; sensory evaluation; and gender and agricultural production resources and institutional organisation.

Hodson Makurira

Dr Hodson Makurira is a Senior Lecturer and current Chairman of the Department of Civil Engineering at the University of Zimbabwe. He lectures in water-related courses at undergraduate and postgraduate levels. He has carried out extensive research and consultancy in integrated water management within the southern African region. Before joining the university, Hodson worked for the Government of Zimbabwe and the National Water Authority as a water engineer.

Brian Mandikiana

Brian Mandikiana has been involved in the field of agricultural economics as a tutor, researcher and author. His core interests are food security for smallholder farmers. He studied agricultural economics and has contributed to modelling the adoption of innovations associated with crop improvements.

Mutsa Masiyandima

Mutsa Masiyandima leads water research at AfricaRice (formerly the West Africa Rice Development Agency). Her research is on water use in rice-based production systems in Africa and the impacts on water resources of rice expansion in inland valleys. She previously worked on wetlands management in southern Africa, groundwater management, and trade-offs between water use for agriculture in wetlands and other ecosystem services offered by wetlands. Previously she has worked for the Africa Program of the International Water Management Institute, the Natural Resources and Environment Unit of the Council for Scientific and Industrial Research (South Africa) and the University of Zimbabwe.

Albert T Modi

Professor Albert T Modi is the Dean and Head of School of Agricultural, Earth and Environmental Sciences at the University of KwaZulu-Natal. His career in crop science and agronomy includes extension services for Pioneer Hi-Bred International and lecturing at the University of KwaZulu-Natal. His current research focus is on underutilised crops and seed science.

Maxwell Mudhara

Dr Maxwell Mudhara is a lecturer in the Food Security Programme at the University of KwaZulu-Natal. He holds a PhD in Food and Resource Economics from the University of Florida. Dr Mudhara has developed expertise in impact assessment studies of rural development programmes, and in the assessment of the food security effects of government policies. His research interests include: rural development, climate change, food security, governance, HIV/AIDS, poverty, small scale irrigation, and development policies and strategies.

Jean-marc Mwenge Kahinda

Dr Jean-marc Mwenge Kahinda is a Senior Catchment Hydrologist at the Council for Scientific and Industrial Research (South Africa) in the Natural Resources and Environment Business Unit, a lecturer at the University of South Africa and a visiting lecturer at the University of Zimbabwe. His skills and expertise are in hydrological modelling, climate change, water resources management, and integrating catchment water and ecosystem management processes, particularly as they relate to anthropogenic activities such as agriculture.

Germaine Owen

Germaine Owen is a student and research assistant at the Faculty of Natural Sciences at the University of the Western Cape. Her main focus is on water and society. Her MSc degree investigated how enhanced youth capabilities could have a positive impact on water and food security. She has a passion for wetlands and is currently a PhD candidate looking at wetlands values and management through the lens of the Capability Approach.

Sharon Pollard

Dr Sharon Pollard is Executive Director of the Association for Water and Rural Development (AWARD), a small research-based NGO that operates in north-eastern South Africa. She is an ecologist whose key interests lie in freshwater systems, their wise use and management, and in the interface between rural communities and natural resources. Sharon started her career in Amazonas, Brasil. She returned to South Africa in 1991 to head a number of integrated catchment management initiatives for various funders.

Richard Stirzaker

Dr Richard Stirzaker is Principal Research Scientist at CSIRO Land and Water in Canberra. His research focuses on water use of dryland and irrigated farming systems, agroforestry and salinity. His particular interest is in developing monitoring tools for farmers that can be used in the context of adaptive learning. Much of his research is carried out in west and southern Africa. He holds a honorary professorship at the University of Pretoria, South Africa.

Amy Sullivan

Dr Amy Sullivan is a Program Manager in the Natural Resources and Environment cluster for the Food, Agriculture and Natural Resources Policy Analysis Network (FANRPAN) in Pretoria, South Africa. She coordinates the Limpopo Basin Development Challenge under the Challenge Program for Water and Food, seeking to increase productivity and reduce risk in rain-fed smallholder systems. She is a social scientist focusing on agricultural water management, gender and smallholder livelihood systems.

Preface

This book has its origins with the need to share key insights on sustainable farming, food and water security, and poverty reduction in Southern Africa. Most of the chapters were provided by African researchers and collaborators associated with the Australian National University (ANU)-UNESCO Chair in Water Economics and Transboundary Water Governance. The ANU-UNESCO links the university to UNESCO's International Hydrological Programme, and many other partners, with a primary focus of assisting Africans to achieve their Millennium Development Goals related to water.

Most of the research upon which the chapters in this book are based was funded by the Australian Centre for International Agricultural Research (ACIAR) and by the Australian International Food Security Centre in a project led by Dr Jamie Pittock (Director of International Programs) and Professor Quentin Grafton (Chairholder), at the ANU-UNESCO Chair. The insights in this volume provide a framework to promote sustainable agriculture and water use in Africa – two key goals of the ANU-UNESCO Chair.

Chapter 1

Why water and agriculture in southern Africa?

JAMIE PITTOCK

Food security and Africa

This book explores the interlinked issues of enhancing agriculture and food security while sustaining freshwater resources and ecosystems in southern Africa from a number of perspectives. We have chosen to focus on southern Africa in keeping with the research location of many of the contributors, but the issues raised may have broader application across the continent.

By 2050, global population will increase from seven to more than nine billion people and this will increase demands on food and water systems, already under pressure from climate change and overuse. By 2050 global food production may need to increase by more than 70 percent (CAoWMiA 2007; Rockstrom & Karlberg 2010). Sub-Saharan Africa is the region that has the highest prevalence of under-nourishment relative to its population, 32 percent, and where more than 60 percent of the rural population lives in poverty on less than US$1.25 a day (IFAD 2010), and thus greater food security is a priority for African governments, donors and other international agencies.

Food security is defined by the Food and Agriculture Organization as 'when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life' (CWFS 2012). The Australian International Food Security Centre emphasises that '[f]ood security is underpinned by having sustainable, healthy food systems in place in-country, and access to regional and global food systems, including through trade. Improving food security requires improving the three interrelated elements of availability, access and utilisation' (AIFSC 2012).

This volume has been prepared in response to increasing interest in agriculture in Africa and is based in large part on research funded by the Australian Centre for International Agricultural Research and the Australian International Food Security Centre in 2010–12. Contributions to this volume focus on southern Africa as a region where there has been collaboration between researchers in Africa and Australia based in large part on lessons that can be shared for sustainable development of agriculture in regions subject to water scarcity and extreme climatic variability.

Irrigation for food security could take a number of forms. Reduction of poverty through subsistence agriculture at a local scale and increasing resilience to climate variability and change could require an emphasis on irrigation technologies that may be applied at smaller scales in a broader range of localities where people live. Alternatively, production of staples to secure food supplies and lower food prices at a national or regional scale could favour irrigation technologies that can be applied at key locations at a large scale. Consequently, there are decisions that African governments and their partners need to take as to what scale and type of irrigation technologies to invest in, depending on the type of food security desired and the model favoured for poverty reduction.

A number of African governments have made the development of irrigation a priority under the Comprehensive African Agricultural Development Plan (CAADP), as outlined by Sullivan and Pittock (this volume). The CAADP was established under the Maputo Declaration and commits African governments to investment of ten percent of national budgets to enhance agricultural production. It is essential to ensure such agricultural development attains the food security goals without the pitfalls already experienced with irrigation development, as Stirzaker and Pittock outline (this volume).

Considerable research has been directed at enhancing food and water security in the region but this has not been as successful as desired (Kahinda & Masiyandima, this volume; Stirzaker & Pittock, this volume). Often research and policies have focused on expanding large-scale irrigation schemes or on empowering previously disadvantaged groups to take up this kind of farming. These reform schemes are frequently poorly conceived or often conducted in isolation of water resources planning, resulting in premature failure (Pollard *et al.* this volume; Stirzaker & Pittock, this volume). Some reasons include inadequate investment in the people and institutions needed for successful agriculture, poor integrated and multi-scale governance, and lack of social learning (Pollard *et al.* this volume; Stirzaker & Pittock, this volume). Less work has been directed at enhancing the productivity of poorer, small-scale farmers (Makurira, this volume; Pollard *et al.* this volume). For instance, the rate of uptake of rainwater harvesting practices is low, and only 0.2 to 2.4 percent of the crop area of these countries is under conservation (Kahinda & Masiyandima, this volume; Makurira, this volume).

Poverty reduction in southern Africa can be enhanced through water-related interventions to enhance agriculture, including water allocation reform,

decentralised strategic planning, rainwater harvesting and conservation agriculture (Kahinda & Masiyandima, this volume; Makurira, this volume; Pollard *et al.* this volume) (Faurès & Santini 2008; Rockstrom 2000). Considering Mozambique as an example of a nation substantially dependent on agriculture (20.9 percent of GDP), it is ranked 184 of 187 countries on human development indicators with an estimated 50 percent of the population living below the poverty line (UN 2011) and 64 percent of the population food insecure (FAO 2011), yet it has high potential to increase production with better access to water (Faurès & Santini 2008).

In this text we seek answers to the question: 'If irrigated agriculture has performed poorly in southern Africa to date then what are the measures that will increase food production to reduce poverty while sustainably managing water and conserving other environmental values?' We aim to provide insights from researchers and institutions that may inform the decisions of governments, other organisations and aid donors to southern African of the best focus for their investments in sustainable agriculture. We hope that contributions to this volume will influence agricultural and water policy, planning and implementation in the region.

Land, water and irrigation

The agricultural potential of Africa is enormous, in terms of uncultivated farming land, reserves of water and in the greater levels of productivity that can still be achieved; however, the land and water resources required would need to be exploited to their limits to meet forecast requirements for global food demand by 2050 (Rockstrom & Karlberg 2010). Irrigation is underdeveloped in sub-Saharan Africa, and could help increase food security. One study reported a profitable expansion potential of 24 million ha in the next 50 years over an existing irrigation area of 13 million ha (You *et al.* 2011). African countries produce 38 percent of their crops (by value) from approximately seven percent of their cultivated land on which water is managed, suggesting that additional investment in irrigation would enhance food security (Svendsen *et al.* 2009). Irrigated agricultural expansion is high on the agenda of national governments (Sullivan & Pittock, this volume) yet such schemes have performed poorly in Africa due to technical and governance problems (Stirzaker, this volume).

Greater water productivity is a priority in many regions of Africa where water is scarce or fully exploited, and where there are competing users, such as fisheries. It has been estimated that by 2050 water availability in northern, eastern and southern Africa will fall below 1 000 cu m/capita/year, with the situation in West Africa only a little better (Rijsberman 2006) and a growing number of river basins in Africa closed (Smakhtin 2008). The Great Ruaha River in Tanzania provides one such example of the trade-offs between increasing agricultural production and the other ecosystem services supplied by a healthy river.

Great Ruaha River Basin, Tanzania

Of the 29 million ha considered suitable for irrigation in Tanzania only one percent is currently utilised. President Kikwete is a major supporter of agricultural expansion, backing the 'Kilimo Kwanza' Transforming Agriculture plan. The most recent Five Year Development Plan commits to expanding irrigation areas from 330 000 ha now to 1 million ha by 2015–16. Tanzanian officials say that the scale of their land and water resources and their strategic location provide an opportunity for Tanzania to become a food basket for the Great Lake and other East African countries.

In south-west Tanzania, the upper Great Ruaha River Basin is an area targeted for irrigation expansion as part of the Southern Agricultural Growth Corridor plan. In the area around the river's headwaters, 46 percent of the 1.5 million residents live in poverty. The average income is US$0.80 per day and it is a largely agriculture-based economy. Yet downstream of this area the river passes through the Usangu wetlands and Ruaha National Park before reaching the Mtera and Kidatu hydro-power dams. The 284 MW power stations on the river generate nearly half of Tanzania's electricity. Between 1970 and 2002, the area devoted to irrigation increased from 10 000 ha to 45 000 ha. As a result, from 1993 the river ceased to flow for an increasing period during the dry season (July – November). This had serious economic consequences, as hydro-power generation was reduced, resulting in power rationing and blackouts. Further, the lack of flows through Ruaha National Park impacted on wildlife and the tourist industry. In March 2001, Prime Minister, Frederick Sumaye, announced 'that the Government of Tanzania is committing its support for a program to ensure that the Great Ruaha River has a year round flow by 2010' (Kashaigili *et al.* 2009).

The conflict between agricultural production and river flows to downstream users is highlighted in a key tributary of the upper Great Ruaha River. Average flows on the Mbarali River are 16 cu m/s and irrigation users are already permitted to divert 12 cu m/s. The Government has supported the commencement of construction of an off-take canal for the proposed Mwendamtitu irrigation scheme, which would divert 6 cu m/s to irrigate 3 000 ha. Yet the Rufiji River Basin Office confirmed that it has refused to issue the requested permit for this scheme as it would further dry out the river. There are currently limited ways of measuring water diversions for irrigation in the Great Ruaha River Basin and no effective incentives for farmers to use water more productively.

Source: Field research by J Pittock, The Australian National University.

Contributions to this volume

To address the question of what are the measures that will increase food production to reduce poverty while sustainably managing water and the environment in southern Africa, this book is organised into chapters that examine:

- the nature of the challenges at the multinational and national scales, then
- potential solutions in governance and in the field at more local scales, before considering
- potential solutions.

The initial chapters in this text assess the nature of the challenge of reducing poverty through sustainable agricultural development and water management as a basis for identifying solutions at large scales. Food security in southern Africa is summarised in Chapter 2 by Professor Ayalneh Bogale and colleagues at the African Centre for Food Security at the University of KwaZulu-Natal. They consider whether the challenges of high population growth and low agricultural productivity can be overcome to meet development goals for reducing hunger and poverty. Measures they assess for facilitating sustainable livelihoods among the people and nations of sub-Saharan Africa include increased investment in agriculture, sustainable land and water management processes, and drought-resistant crop varieties.

An institutional analysis in Chapter 3 is presented in two parts by Dr Amy Sullivan, an expert in agriculture, water, gender and poverty issues in Africa, and Dr Jamie Pittock, a researcher on climate, water and energy policies at The Australian National University and former Director of WWF's Global Freshwater Program. Sullivan leads the Challenge Program on Water and Food (CPWF) Limpopo Basin Project based at the Food and Natural Resources Policy Advisory Network from South Africa. Presented first are the lessons from two global assessments of solutions for integrating the need to produce more food with the need to also sustain freshwater resources and ecosystems, with particular reference to Africa. These are the Comprehensive Assessment of Water Management in Agriculture and the CPWF, especially the Limpopo Basin case study. The CPWF aims to increase the resilience of social and ecological systems through better water management for food production by focusing on the nexus between water, food and poverty in developing countries. Sullivan & Pittock then go on to review the agricultural policies of African governments, including whether lessons from the assessments are being incorporated. The review focuses on the pan-African 'Comprehensive African Agriculture Development Programme', and, more specifically, on the contributing national policies of nine eastern and southern African states.

A more biophysical analysis of the role of conservation agriculture and rainwater harvesting for poverty reduction is the focus of Chapter 4, by Doctors Mutsa Masiyandima and Jean-Marc Mwenge Kahinda, hydrological and agricultural water management experts with CSIR, South Africa's leading government scientific research organisation. A typology of the different types of rainwater

harvesting and small-scale, decentralised irrigation technologies is provided as a basis for further analysis. By linking physical and socioeconomic data, the opportunities to reduce poverty through these water management and agricultural developments in southern Africa are identified.

Based on this analysis, the next four contributions to this publication consider potential solutions in governance and in the field. The poor record of irrigated agriculture is the basis for an analysis in Chapter 5 of how 'blue water' can be better used in agriculture in southern Africa. Dr Richard Stirzaker is a Principal Research Scientist specialising in agricultural and hydrological sciences at CSIRO, the leading research organisation of the Australian Government. Based on their experience in Africa, Stirzaker and Pittock argue that new thinking is needed to overcome low agricultural productivity, unprofitability and extensive areas of unused irrigated schemes in Africa. He uses the lack of incentives for more productive use of water in agriculture as a way of examining how greater investment in social learning and adaptive management could contribute to solutions.

In Chapter 6, the application of integrated water resources management as a framework for catchment-based water and food security is assessed. Dr Sharon Pollard, Derick du Toit, Donna Hornby and Brian Mandikiana lead this analysis as researchers and leading practitioners of systems thinking, social learning and adaptive management in rural development. They draw on their work at the Association for Water and Rural Development (AWARD), an action-research non-governmental organisation based in rural Limpopo Province in South Africa. Their research considers the reasons behind the lack of local-scale implementation of national policies for better water management and agricultural development. Drawing on on-the-ground research, they detail the types of local institutions, social learning and adaptive management required to achieve pro-poor and sustainable improvements in water use for agriculture.

The focus of Chapter 7 is on rainwater harvesting and conservation agriculture techniques practised in South Africa, Mozambique and Zimbabwe. Dr Hodson Makurira from the University of Zimbabwe is one of southern Africa's leading experts in water for food in rain-fed systems and he presents an assessment based on his field research in the three nations. He reports on a review of rainwater harvesting practices in Mozambique, South Africa and Zimbabwe, and identifies key barriers to broader uptake of decentralised rainwater harvesting systems—namely, knowledge of the opportunities and financing for the initial capital works.

The practical issues facing village communities in improving water harvesting are the subject of the eighth chapter, a case study from rural Mpumalanga Province in South Africa by Professor Jacqui Goldin and Germaine Owen. Professor Goldin is an anthropologist who has applied these skills in the fields of poverty and development, including as the SADC-Waternet Chair for Water and Society at the University of the Western Cape and chairwoman of a non-governmental environmental education and development organisation, Ecolink, in

Mpumalanga. The authors apply the capability approach to youths in four villages participating in an integrated rainwater harvesting project to assess whether improved human capabilities lead to improved food security and management of water resources and a healthier ecosystem.

The final chapter summarises this research by arguing for a new approach to sustainable management of water for agricultural development and poverty reduction in Africa. It is argued that the focus of many African governments and multilateral agencies on expansion of irrigation schemes is misplaced without a major effort to overcome the reasons so many schemes have failed and why agricultural productivity is so low. Instead, they argue for a greater investment in training people and establishing institutions. Agriculture and water departments will need to refocus many of their programs. It requires water, agricultural and environmental agencies, among others, to genuinely work together to manage land and water resources sustainably. This work requires agencies to establish communication, feedback loops, adaptive management systems and new reward structures for public officials. In this volume, the authors point to a number of examples where these approaches are beginning to take hold. The challenge is to build on these modest successes to achieve widespread benefits.

There are no simple solutions for increasing agricultural production and enhancing food security while sustaining freshwater ecosystems and resources. The diverse perspectives included in this text are an opportunity to discuss and decide on better ways to meet the food needs of people while conserving the environment.

References

Australian International Food Security Centre (AIFSC) 2012, *Food Security and Why It Matters*, Australian International Food Security Centre, Canberra.

Committee on World Food Security (CWFS) 2012, *Committee on World Food Security*, Food and Agriculture Organization, Rome.

Comprehensive Assessment of Water Management in Agriculture (CAoWMiA) 2007, *Water for Food, Water for Life. A comprehensive assessment of water management in agriculture*, Earthscan & International Water Management Institute, London & Colombo.

Faurès, J-M & Santini, G (eds) 2008, *Water and the Rural Poor. Interventions for improving livelihoods in sub-Saharan Africa*, Food and Agriculture Organization, Rome.

Food and Agricultural Organization (FAO) 2011, *The State of Food Insecurity in the World, 2011*, Food and Agricultural Organization, Rome.

International Fund for Agricultural Development (IFAD) 2010, *Rural Poverty Report 2011*, International Fund for Agricultural Development, Rome.

Kashaigili, J J, Rajabu, K & Masolwa, P 2009, 'Freshwater management and climate change adaptation: experiences from the Great Ruaha River catchment in Tanzania', *Climate and Development*, 1(3): 220–8.

Rijsberman, FR 2006, 'Water scarcity: fact or fiction?', *Agricultural Water Management*, 80(1–3): 5–22.

Rockstrom, J 2000, 'Water resources management in smallholder farms in eastern and southern Africa: an overview', *Physics and Chemistry of the Earth, Part B: Hydrology, Oceans and Atmosphere*, 25(3): 275–83, doi: 10.1016/S1464-1909(00)00015-0.

Rockstrom, J & Karlberg, L 2010, 'The quadruple squeeze: defining the safe operating space for freshwater use to achieve a triply green revolution in the Anthropocene', *Ambio*, 39: 257–65.

Smakhtin, V 2008, 'Basin closure and environmental flow requirements', *Water Resources Development*, 24(2): 227–33.

Svendsen, M, Ewing, M & Msangi, S 2009, *Measuring irrigation performance in Africa*, IFPRI Discussion Paper 00894, International Food Policy Research Institute, Washington, DC.

United Nations (UN) 2011, *International Human Development Indicators*, United Nations, New York.

You, L, Ringler, C, Wood-Sichra, U, Robertson, R, Wood, S, Zhu, T and Sun, Y 2011, 'What is the irrigation potential for Africa? A combined biophysical and socioeconomic approach', *Food Policy*, 36(6): 770–82, doi: http://dx.doi.org/10.1016/j.foodpol.2011.09.001.

Chapter 2

Assessment of food security in southern Africa

AYALNEH BOGALE, JOYCE CHIJTA, UNATHI KOLANISI AND MAXWELL MUDHARA

Introduction

Southern Africa comprises 15 countries that have constituted themselves into the Southern African Development Community (SADC).[1] The member states are at different stages of development, but are predominantly underdeveloped. Economic growth and development across the region are heterogeneous, with some countries attaining high growth rates while others have very low growth rates.

Maize is the staple food of the region, such that food security at the regional level can be measured by the extent to which the region meets its requirements from aggregate maize production; however, this would not reflect the food situation at the household level. The region faces intermittent maize deficits. For example, in 2011–12 the region experienced a cereal deficit of about 0.95 million tonnes compared with a surplus of 0.73 million tonnes in 2009–10. The deficit is attributed to a reduction in cereal production, especially in South Africa. SADC reported a decreasing trend in the food-insecure population during the seven years between 2004 and 2011; however, it also noted that the number of food-insecure people remains high in spite of improved food production in recent years—probably an indication of chronic food insecurity and high levels of poverty in the region, which undermine access to food.

[1] Southern African countries are Angola, Botswana, Democratic Republic of Congo (DRC), Lesotho, Malawi, Mozambique, Namibia, Seychelles, South Africa, Swaziland, Tanzania, Zambia, Madagascar and Zimbabwe.

Agriculture has varied importance in terms of the contributions to the gross domestic product (GDP) of SADC countries, ranging from four percent up to 27 percent, with up to 70 percent of the population depending on agriculture for income, employment and food security (SADC 2011). Governments in southern African countries have realised the value of agriculture and some have allocated ten percent of their national budget to improve food security and rural development compared with previous investment levels of less than five percent. Through the SADC Regional Indicative Strategic Development Plan (RISDP) and Comprehensive Africa Agriculture Development Programme (CAADP), governments have acknowledged the pivotal role played by agriculture in economic growth, economic stability, food security and poverty reduction. The two strategies aim to enhancing the mobilisation of agricultural resources and achieving a target of six percent agricultural and economic growth by allocating ten percent of the national budgets to agriculture.

The SADC countries collectively regard food security as a priority area and expressed their commitment through the Dar-es-Salaam SADC Declaration. The declaration recognises that inadequate food security compromises the quality of life of the regional population. The region set itself several objectives relevant to the development of agriculture and achievement of food security, which include, among others, the promotion of sustainable and equitable economic growth and socioeconomic development to ensure poverty alleviation, with the ultimate objective of its eradication. This suggests that the region recognises the centrality of poverty reduction as a strategy to eradicate food insecurity. The Dar es Salaam Declaration points out that the regional leaders were aware of the underlying reasons for food insecurity, such as inappropriate national agricultural and food policies, and inadequate farmer access to key agricultural inputs and markets.

The agricultural performance of the region is strongly intertwined with the attainment of food security. The performance of agriculture in the region and hence the attainment of food security are linked to the availability of labour, as most operations are manually executed. As a result, this performance is also greatly influenced by, among others, HIV/AIDS, which has severely affected the region.

This chapter examines the dimensions of food security in the southern African region in the context of its most common definition. Of course, various definitions of food security have been proposed in the literature, to the extent that the Food and Agriculture Organization (FAO) indicates that there are more than 200 definitions in publications. Countries at the World Food summits held in 1996 and then in 2001 endorsed the definition of food security, which was refined further in the State of Food Insecurity in the World 2001 (FAO 2001) to include an aspect of social access. The social aspect was brought in following Amartya Sen's assertion that focused on the entitlements of individuals and households (Sen 1981). The full definition says food security exists 'when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences, for an active and healthy lifestyle' (FAO 2001). The FAO illustrates that there has been a transformation in the

definition of food security to reflect the progression in the official thinking on the matter. This definition includes four components of food security—namely availability, access, utilisation and stability.

For operational purposes, however, agencies make propositions to effect a reduction of poverty as a way of addressing food insecurity. Indeed, the SADC member states noted that they have achieved sustained annual GDP growth rates close to the seven to eight percent mark, which they noted to be critical for meeting the target of halving poverty by 2015 and thereby reducing food insecurity.

On the other hand, food insecurity has been said to exist when people do not have adequate physical, social or economic access to food. This insecurity has been noted to have three levels at which it can be measured—that is, transitory, chronic and acute. Where populations have access to 'adequate' amounts of food, the new question being raised is whether the food has all the qualities to allow for improvement of human nutrition and health. The International Food Policy Research Institute (IFPRI) has noted that poor diet quality and related micronutrient deficiencies are now the most pressing nutritional problems affecting the poor (Fan & Pandya-Lorch 2012).

This chapter starts off by presenting a brief implication of food price volatility in the region with respect to food security. It then looks at poverty and standards of living in the region, followed by an assessment of long-term trends in the availability and stability of food. Last, the chapter looks at the factors impacting on the achievement of food security such as access to agricultural support including marketing, land reform and social protection mechanisms. The chapter then wraps up with a concluding section.

Major crops and implications of food price volatility

While, in general, the recent food security situation across most of the SADC region has been progressively improving, there remain localised areas of food insecurity and undernutrition as exemplified by the fact that stunting is reported to be predominant in countries such as Malawi, Mozambique, Swaziland, Tanzania and Zambia. Various factors such as the high prevalence of HIV/AIDS, low incomes, drought spells, flood and cessation of rainfall led to limited agricultural production and, consequently, inadequate food/nutrient consumption. Moreover, the agricultural system and food in most of the region were severely affected by the increase in food prices in 2008. This was a significant period for the region as well as for the global food price index. Wheat prices doubled and rice prices increased from about US$370 a tonne to more than US$1,000/t, causing, for the first time in history, the number of people suffering from chronic hunger to reach one billion globally. The food price hike exacerbated the poverty and food insecurity of many poor households in the region. The food insecurity situation in the region worsened—since most of the countries were suffering chronic hunger and malnutrition even before the advent of the high food prices. Even though the crisis is slowly passing, hunger and malnutrition remain

problematic as access to food by the poor is a key challenge. One of the possible measures commendable to mitigate the current food price spike for the SADC countries is producing food domestically to meet local demand by concentring on local food crops that are more resilient to the global crisis. Table 2.1 presents important crops per SADC country.

Domestic production can reduce the need for food imports and buffer the impact of global food price trends. If domestic crop harvests are satisfactory for meeting domestic consumption demands with reasonable surplus to be carried over to the next season, this would transcend to household food security, as staple food is readily available from own production and local markets, reducing food prices.

A recent study by the African Postharvest Losses Information System (APHLIS) estimates that most countries in southern Africa lose up to 40 percent of their produce after harvest because of poor storage facilities (APHLIS 2012). One of the achievements reported recently is the establishment of silos in most SADC countries. The surplus of each year is stored for future use. The current problem is the surplus that is stored for more than two years as there is a risk of stock spoilage during storage. It is commendable that currently food sufficiency through food availability for most countries is not much of a problem, but food insecurity, especially through food access, utilisation and stability, still poses a great threat to food security. This is particularly a problem for households that are facing food-entitlement deficits or are experiencing shocks to livelihoods.

Table 2.1 Important food crops in the SADC region

Country	Major/staple food crops	Relevant/minor crops
Angola	Maize, cassava	Wheat, rice, sorghum & millet
Botswana	Maize, wheat, sorghum & millet	Rice
Lesotho	Maize, wheat, sorghum & millet	
Malawi	Maize	Rice, wheat, sorghum, cassava
Mozambique	Maize, cassava	Rice, wheat, sorghum
Namibia	Maize, wheat, sorghum & millet	
South Africa	Maize, wheat	Rice
Swaziland	Maize, wheat	Rice
Tanzania	Maize, cassava	Rice, wheat, sorghum, pulses, bananas, sweet potatoes
Zambia	Maize, wheat, sorghum & millet	
Zimbabwe	Maize, wheat, sorghum & millet	

Apart from requiring adequacy, ensuring sustainable access also requires that food be physically accessible to all households at all times. Common obstacles to such stability of physical access and adequacy in SADC countries include the high dependence of agricultural production on weather, highly fragmented smallholder farmers based on low input production technology and poor infrastructure. Moreover, the ineffectiveness of government policies in some

countries has also eroded smallholders' ability to buy seed and fertiliser to enhance productivity (Panos 2007).

Prevalence of poverty in the SADC region

It is now just more than one decade since all 189 UN member states established goals and targets to free humanity from extreme poverty, hunger, illiteracy and disease (United Nations 2011). Goal number one is generally to eradicate extreme poverty and hunger, and its main target is to halve, between 1990 and 2015, the proportion of people who are extremely poor. The most-accepted measures of global poverty are $1 per day income for extreme poverty and $2 per day for moderate poverty. Recently the World Bank readjusted the $1 per day to $1.25 per day (Ravallion *et al.* 2009). For international comparison, the prevalence of poverty is expressed as the proportion of the population below the minimum level of income. The minimum level of income refers to the monetary value of the average daily dietary energy requirement (2100 kilocalories) of the population provided by a normative food basket using food prices of low-income population groups. Inspired by the Millennium Development Goals (MDGs), many countries have set national priorities and subsequent actions aimed at attaining these targets.

Currently the world may have some cause to celebrate because poverty has declined significantly at the global level, particularly because of the rapid and sustained economic growth in East Asia, which managed to reduce the proportion of poor from 60 percent in 1990 to 16 percent in 2005. But with the 2015 deadline looming, the question of how much progress has been made in Africa to achieve the goal of reducing the proportion of people whose income is less than $1 a day has a mixed response. It should not be surprising that many sub-Saharan African countries will miss several of the global MDGs because these targets were not set specifically for individual countries; they were based on aggregate global trends (Vandemoortele 2007). In sub-Saharan Africa, poverty has declined a modest eight percent, from 59 percent in 1996 to 51 percent in 2005. In Malawi, the proportion of poor people declined from 83 percent in 1998 to 74 percent in 2004. Mozambique managed to reduce the proportion of the poor by about 24 percent between 1996 and 2008, whereas Tanzania reduced its proportion of poor from 88 percent in 2000 to 67 percent in 2007. These intermediate results clearly indicate that most countries are off track to reach the target of reducing the proportion of the extremely poor by 50 percent.

Many countries in the SADC region experienced negative annual growth in real GDP per capita between 1990 and 1999. Angola and Zambia had the worst-performing economies, with about -1.99 and -1.84 percent annual growth. After Angola achieved political stability, its economy made remarkable improvement during the 2000–10 period, attaining annual per capita income growth of about 10.7 percent.

Table 2.2 Trend in GDP per capita in selected SADC countries

Country	GDP per capita (current price)			Annual growth rate (current price)		Annual growth rate (constant 2000 US $)	
	1990	2000	2010	1990-99	2000-10	1990-99	2000-10
SSA	588	512	1286	-1.29	15.05	-0.47	2.37
AGO	993	455	4423	-5.41	57.46	-1.99	10.71
BWA	2743	3395	7403	2.38	13.11	3.18	3.07
MWI	200	163	343	-1.89	12.07	1.86	1.86
MOZ	182	251	410	3.79	7.56	2.85	6.70
NAM	1661	1829	5330	1.01	15.85	1.14	2.94
ZAF	3182	3103	7275	-0.25	14.09	-0.57	2.40
TZA	172	300	527	7.42	7.16	-0.16	4.85
ZMB	418	315	1253	-2.47	29.47	-1.84	3.62
ZWE	839	546	595	-3.49	1.26	0.07	-3.85

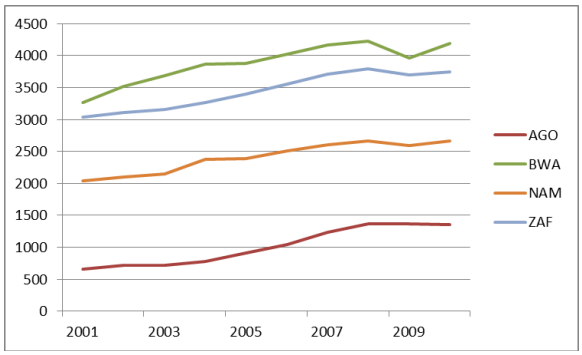
Source: Based on World Bank 2011, WDI Data Catalogue, The World Bank, Washington, DC, http://data.worldbank.org/data-catalog/world-development-indicators/ [accessed 12 January 2011].

NB: SSA = sub-Saharan Africa; AGO = Angola; BWA = Botswana; MWI = Malawi; MOZ = Mozambique; NAM = Namibia; ZAF = South Africa; TZA = Tanzania; ZMB = Zambia; ZWE = Zimbabwe.

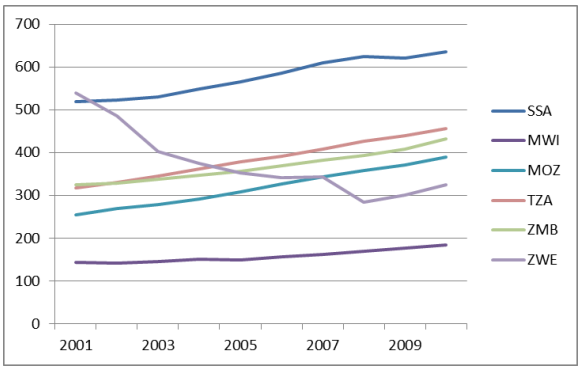
A relatively better economic performance has been attained during the past decade (2000 to 2010) in most SADC countries, particularly in South Africa, Angola, Botswana and Namibia (Figure 2.1). There is, however, increasing concern that the achievements have, in most cases, failed to lift the majority of citizens from grinding poverty, thus renewing calls for governments and stakeholders in economic development to rethink their poverty-eradication strategies. Deep-rooted poverty has also resulted in a widening gap between the poor and the rich. Countries such as Namibia, for instance, are said to have the highest income disparity in the world, with a Gini Index of greater than 0.70. Ironically industrialisation and commercialisation have contributed to more joblessness.

The SADC countries are richly endowed with natural resources, yet their governments are failing to come up with policies that ensure that returns from mineral wealth trickle down to the citizens. Rather, the adoption of free-market economy models has resulted in governments shrinking their responsibilities to their citizens. Most SADC governments are failing to ensure that the majority of citizens in the region have adequate food on their tables, running water and other utilities.

Figure 2.1 GDP per capita at constant price (constant 2000 US$)



Panel 2.1a Better performing economies



Panel 2.1b Least performing economies

NB: SSA = sub-Saharan Africa; AGO = Angola; BWA = Botswana; MWI = Malawi; MOZ = Mozambique; NAM = Namibia; ZAF = South Africa; TZA = Tanzania; ZMB = Zambia; ZWE = Zimbabwe.

A closer look at food security in the SADC region, 1990–2010

The concept of food security is closely linked with the poverty in a country. The two concepts are interrelated and to some extent have an influence on one another. In order to ensure food security, not only does a country need to have an adequate supply of food, either through own production or through imports, an adequate amount of food must be within the physical reach of vulnerable households. Furthermore, even if the country's food supply is adequate based on the normal food requirements of its citizens, the food needs of every person in the country may not be satisfied as food must be continuously accessible to all household members. National adequacy of food availability can be assessed based on the total supply relative to total requirements. Ideally food availability per person would be a good indicator of adequacy, but food insecurity may still prevail even where a food supply is available due to unemployment, rising food prices and flawed distribution systems, all of which affect people's access to available food (Sen 1981).

As depicted in Table 2.3, in lieu of per capita availability and adequacy in SADC countries, only three countries—Malawi, South Africa and Zambia—produced adequate cereal in 2010. Botswana had the largest deficiency (88 percent) followed by Angola, Zimbabwe and Namibia, with about 66, 65 and 61 percent, respectively. It needs to be noted, however, that although domestic production is the major component of food supply in most countries, the level of imports is a key determinant of adequacy at the aggregate level for many food-deficit countries. The ability of these countries to secure sufficient amounts of food is largely dependent upon their commercial import capacity. Some economic and financial indicators including total export earnings and foreign exchange reserves confirm that Botswana, Angola and Namibia have managed to improve their commercial import capacity in recent years.

Table 2.3 Food availability and stability for selected SADC countries, 1990–2010

Country code	Annual cereal production and adequacy			Cereal yield			Food production index
	Mean (1990-2010)	CV	Adequacy (2010)	Mean	Std dev.	CV	
AGO	564 921	0.3706	-66.27	525.75	136.96	0.261	198
BWA	39 240	0.4614	-87.60	409.07	231.45	0.566	113
MWI	2 002 323	0.3424	19.37	1291.64	422.80	0.327	129
MOZ	1 271 732	0.3440	-57.23	718.74	203.63	0.283	102
NAM	107 020	0.3262	-60.86	374.00	106.05	0.284	101
ZAF	11 831 927	0.2301	82.36	2552.98	792.21	0.310	122
TZA	4 730 979	0.2439	-13.21	1350.29	295.68	0.219	134
ZMB	1 253 541	0.3092	6.25	1626.06	369.26	0.227	135
ZWE	1 786 902	0.4457	-65.22	976.57	433.34	0.444	82

Notes: Requirements are calculated based on the following assumptions. First, a person requires annually about 230 kg of cereal equivalent to be food secure. In typical African households, cereal contributes about 70 percent of the daily calorie intake of individuals. Therefore a person requires about 160 kg. Total requirement is therefore a product of 160 and population size. CV = coefficient of variation; Std dev. = standard deviation.

NB: AGO = Angola; BWA = Botswana; MWI = Malawi; MOZ = Mozambique; NAM = Namibia; ZAF = South Africa; TZA = Tanzania; ZMB = Zambia; ZWE = Zimbabwe.

Results in Table 2.3 also show that not only is agricultural productivity very low in SADC countries, but there also is a higher degree of production instability. The observed variability in annual cereal production and cereal yield per hectare ranges between 23 percent and 46 percent for annual cereal production and between 22 percent and 57 percent for yield per hectare. Botswana had the highest variability in both cereal production and yield between 1990 and 2010. Zambia,

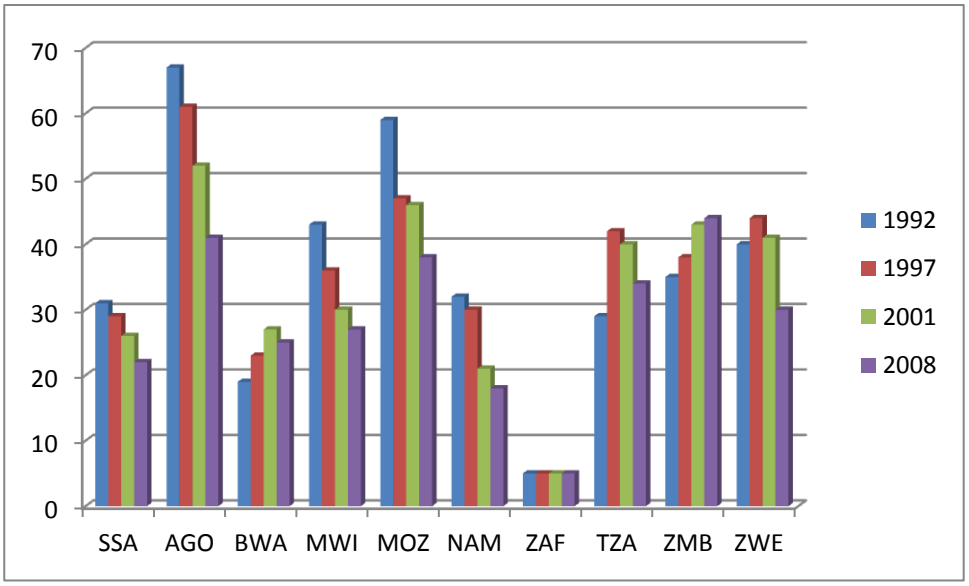
which obtained the highest yield per hectare for cereals, next to South Africa, has also relatively the lowest variability. Although food production includes both cereal and non-cereal staples, it is the higher variability in cereal production that explains most of the observed variance in total food production (Salih 1994).

Even though some remarkable increases in production and productivity have been observed, particularly in South-East Asia during the past decades, low productivity remained among the major challenges in sub-Saharan Africa, including most SADC countries. Increasing agricultural productivity not only can increase food availability and access, it also can improve the welfare of the population of these countries, the majority of whom live in rural areas; however, plagued with problems of limited knowledge of improved practices, low use of improved seeds, low fertiliser use, inadequate irrigation, absence of strong institutions and ineffective policies, food production has not significantly improved in most of these countries. Among the countries under consideration, Angola almost doubled its food production by 2010 compared with the level in 1990, whereas Zimbabwe has experienced a decline in food production by 18 percent compared with the 1990 level.

A number of different indicators can be used to measure food insecurity. To reflect the multidimensional nature of food insecurity and hunger, IFPRI *et al.* (2011) combines three equally weighted indicators—nutrition, child underweight and child mortality—to construct the Global Hunger Index (GHI). The GHI ranks countries on a 100-point scale. Zero is the best score (no hunger), and 100 is the worst, although neither of these extremes is reached in practice. This composite index takes into account the nutrition situation not only of the population as a whole, but also of a physiologically vulnerable group—children—for whom a lack of nutrients creates a high risk of illness, poor physical and cognitive development and death. Based on the GHI 2011 results, the situation of hunger in eight SADC countries is considered to be alarming or serious. Angola, Zambia, Mozambique and Tanzania, with an index of 20–29.9 percent, are considered to have alarming levels of hunger. The hunger situation in Malawi, Mozambique, Namibia and Zimbabwe is classified as serious, with a GHI value of 10–19.9 percent.

Besides this composite index, the prevalence of food insecurity can be captured by assessing undernourishment. Undernourishment in a given country can be measured by the proportion of those undernourished as a percentage of the population (reflecting the share of the population with insufficient calorie intake). Undernutrition declined in most SADC countries between 1992 and 2008 except for Botswana, Tanzania and Zambia (Figure 2.2). The percentage of undernourished people in South Africa remained essentially unchanged between 1992 and 2008, while the percentage of undernourished people declined in Angola, Malawi, Mozambique, Zimbabwe and Namibia. From the 1992 undernutrition prevalence rate, two countries—Angola and Namibia—were able to reduce their rates by 40 percent or more. Malawi and Mozambique have also made modest progress by reducing the proportion of undernourished people by about 36 percent in the same period. Zimbabwe managed to reduce the prevalence of undernutrition by 25 percent for the period under consideration.

Figure 2.2 Prevalence of undernourishment (percent of population)



Source: Compiled from World Bank 2011, WDI Data Catalogue, The World Bank, Washington, DC, http://data.worldbank.org/data-catalog/world-development-indicators/ [accessed 12 January 2011].

Food-insecure households in the region had difficulty providing enough food for all their members due to a lack of resources. In these households, the food intake of some household members can be reduced and normal eating patterns disrupted due to limited resources. Households with children, female-headed households and households without jobs are particularly highly vulnerable to food insecurity.

Agricultural support and markets for food security

The importance of agricultural support services is recognised in a SADC policy framework that seeks to increase agricultural production, improve earnings and increase foreign currency. There are varied views on what agricultural support refers to and how it is measured. Agricultural support descriptions are often used interchangeably to refer to subsidy, support and aid to producers. Developed countries such as those in the Organisation for Economic Cooperation and Development (OECD) have agreed indicators and measures of agricultural support. The SADC region has, however, invested its efforts in developing a Regional Agricultural Policy (RAP) (SADC 2010), which sets its main functions as the promotion and support of regional and national agricultural sectors and regional integration. One of the RAP's specific objectives includes promoting support for production, productivity and competitiveness in the agricultural sector. Furthermore, the SADC RAP (2010) aims to support income growth for small-scale farmers.

The continued low economic productivity of SADC countries prompted the 1999 Declaration of Productivity. In 2003 the picture remained the same and the SADC RISDP put forward a road-map that included the implementation of frameworks such as the CAADP, which encourages governments to invest up to ten percent of their national budgets in supporting agriculture.

According to the SADC (2010), general problems that need to be addressed in SADC countries through an agricultural support policy framework are related to:

- lack of institutional coordination,
- unsustainable use and poor management of natural resources,
- technological constraints,
- unsupportive policy environment,
- non-conducive macroeconomic environment,
- inadequate land tenure security and lack of land policy,
- poor agricultural input and output markets,
- climate constraints, and
- high HIV and AIDS infection rates.

These problems can be effectively addressed by employing various intervention measures, the outcome of which also depends on the actual country circumstances. Some of these intervention options are briefly discussed below.

Agricultural extension support

It is undisputable that agricultural extension is essential for agricultural development, with the aim of accelerating the contribution to economic, social and political change (Shinn *et al.* 2009). Extension has a wide range of functions and now encompasses a wider range of learning and communication activities planned by extension officers in partnership and in response to, mostly, rural people's needs.

The role of extension is indispensable in promoting increased agricultural production and contributing towards food security, poverty alleviation and regional economic growth. Extension policies in SADC should aim to increase the level of agricultural skills that aim to meet the needs of all sectors of the agricultural value chain especially those aimed at improving farmers' productivity for market access. This will require improving the number and quality of agricultural graduates who are appropriately trained to meet the needs of producers and the rest of the agricultural value chain.

Currently policy direction in developing countries is indicative of a new dimension because of a global movement for reforming the extension systems (Qamar 2005). As the world becomes more globalised, emerging needs for extension are evident. The renewed commitment related to the first MDG of fighting hunger and poverty directly demands stronger support from extension services regardless of whether these are housed in the private or the governmental sectors. In this regard, serious attention by policymakers is required

for improving extension in the SADC region. The FAO's research advocates action-oriented and practical guidelines to afford policymakers solutions for extension reforms.

Enhancing investment in agriculture

Food security and agriculture have been given very high priority in the African Union's New Partnership for Africa's Development (NEPAD) vision and the CAADP. NEPAD has put forward the CAADP to realise improved food security and agricultural production. Investment in agriculture has been in decline worldwide, with most governments noting a decline over the past 10 years in donor aid flows and government allocations towards agriculture while food imports and populations have increased (SADC 2011). From the SADC region countries, Zambia has recorded one of the fastest population growth rates in the world. Sectors such as agricultural research and development have had declining investment for years. The need for macroeconomic and sectoral policy integration was recognised first in 1992 (SADC 2011) but has become more urgent in recent times, and the renewed commitment brought on by the NEPAD CAADP is encouraging. The fulfilment of the CAADP process among SADC member states is key to achieving sustained agricultural-led economic growth. This process has been progressing steadily. Table 2.4 indicates the progress made by 2011. Most of the SADC countries, with the exception of Angola, have made progress towards implementation of the CAADP; however, only six countries have signed the CAADP compact, which leads to an agricultural investment plan for the country. According to the NEPAD Planning and Coordinating Agency (2011), emerging results on the CAADP process point towards reform of how the investment plans are arrived at, showing comprehensive planning, local financing and more cooperation between government departments. These efforts could, in the long term, enable the countries to achieve national and household-level food security.

Marketing and market access

There is acknowledgment that agricultural development and economic growth in SADC depend on improving the competitiveness of the smallholder farmer through technology improvement, access to local and international markets and price incentives. Markets are the link to a much required commercial exchange in order to derive an income for national food security and incomes for farming households to derive sustainable livelihoods. SADC's agricultural markets can be best described as undergoing erratic reform, where transformation of food value chains is characterised by the rapid transformation of traditional markets. This is resulting in new entrants in the form of supermarkets in urban centres (Louw *et al.* 2008).

The SADC RAP encompasses the marketing and trade policy framework and focuses its Pillar II on Trade and Markets Strategies issues. With the exception of South Africa, in SADC market infrastructure including lack of good roads and market information remain key constraints on market access (SADC 2011). Calls for support for small-scale farmers, and for their market access, are gaining some

Table 2.4 Progress made on CAADP process

Country	Milestones
Angola	▪ Engagement on CAADP processes yet to be started
DRC	▪ Compact signed ▪ Developing investment plan
Botswana	▪ Initial discussions on CAADP process initiated
Lesotho	▪ Launched CAADP implementation ▪ Developing National Strategic Development Plan
Malawi	▪ Signed compact ▪ Developed investment plan and held technical review ▪ Submitted funding proposal to GAFSP Global Agricultural and Food Security Programme ▪ Held business meeting
Madagascar	▪ Initial discussions on CAADP engagement held
Mozambique	▪ CAADP launched ▪ Preparations for CAADP signing are under way ▪ Refinement of the investment plan ongoing
Mauritius	▪ Stocktaking work started ▪ Engagement with government under way
Namibia	▪ A road-map on implementing CAADP in place
Seychelles	▪ Stocktaking exercise undertaken ▪ Identification of priority areas undertaken ▪ Compact signed
South Africa	▪ Development of CAADP road-map implementation under way
Swaziland	▪ Signed the CAADP compact ▪ Drafting the investment plan
Tanzania	▪ Signed the compact ▪ Developed the investment plan ▪ Independent technical review conducted ▪ Business meeting to be held in November 2011
Zambia	▪ Signed the compact ▪ In the process of developing the investment plan

Source: New Partnership for Africa's Development (NEPAD) Planning and Coordinating Agency 2011, Progress on CAADP implementation, CAADP Stakeholder Seminar, Pretoria, South Africa, www.nda.agric.za/.../CAADP/.../Stakeholders%20Seminar%20SA%20-%20%20October%202011.ppt [accessed 31 January 2012].

momentum, and they are being seen as important contributors to national food security in the future (Wegner & Zwart 2011).

Smallholder farmers in the SADC have an important role to play in food security and may benefit from the supermarket growth into the SADC region; however, according to Louw *et al.* (2008), smallholder farmers face several challenges, including high transaction costs, scattered farms in remote areas, low education levels affecting negotiation skills and poor or lack of market information. Van Tilburg and Van Schalkwyk (2012) further illustrates that smallholders experience poverty due to 'limited access and exclusion [from] formal' markets.

Land reform

Land is a critical resource and a precondition for food security, and agricultural and economic development. Land reform can be defined narrowly to mean a redistribution of rights in land for the benefit of the landless, tenants and farm labourers (Warriner 1969). The SADC region continues to experience the impact of the colonial land system, post-colonial reform and traditional and customary land systems. Compared with other regions in the world, the SADC region is confronted with settlers' large dispossession of land, with indigenous populations left with much less and inferior land (SARPN & World Bank 2007). This situation is further exacerbated by the fact that the SADC economies are facing widespread unemployment and other constraints resulting in complex and often unclear and insecure land rights. Due to this dire state of land reform, most SADC states have prioritised land reform as an urgent national priority. The SADC Summit of August 2001 mandated the SADC ministers of agriculture to develop a regional strategy for land reform that will provide technical support to member states in developing pro-poor land reform and agrarian development (SADC 2003).

The SADC region has had mixed success and failures with land reform. The South African and Zimbabwean cases show different approaches to land reform with different results. The following cases provide examples of the different approaches, varying from market based to non-market approaches.

Case 1: Zimbabwe

At the country's independence, the Zimbabwean Land Reform Programme started with a target to resettle 162 000 families on 9 million ha of land with only 3.3 million ha redistributed to some 54 000 families along with 0.5 million ha of commercial-sector land using the willing seller–willing buyer model, which slowed when the Government ran out of funds (Adams 1995). With the introduction of the 1992 Land Acquisition Act, the Government's hand at acquiring land more speedily was strengthened by introducing non-market land-acquisition measures. New studies tracking the progress of people's livelihoods and food security are emerging. According to Scoones (2010), nearly 8 million ha has been transferred to more than 160 000 households, driven by two main models aimed at

smallholder production and one aimed at commercial production since the fast tracking began in the year 2000. Scoones explains that the fast track has resulted in many small-scale farms focused on mixed farming, but more than 4 million ha remain for commercial farming—still largely operated by 200–300 white-owned commercial farmers. The result of this fast track is a complex mix of successes and failures, which has resulted in a large knock-on effect on the rest of the economy with exports suffering the most. Contradictorily some commodities have grown since the 1990s—for example, small grains (163 percent), drybeans (282 percent) and cotton (13 percent) (Scoones 2010). In terms of livelihoods, of the 400 household samples for the study, more than half were accumulating assets, producing regularly for income and coping despite challenges, while others were not coping and were dropping out of the production cycle due to poverty and ill health. The study shows that new farmers require start-up assistance and much support to make a sustained livelihood from the land.

Case 2: South Africa

The legalised apartheid land policies of South Africa engineered extreme inequality of landownership, with 83 percent of land in white hands and only 13 percent owned by blacks despite the fact that the Africans are the majority population in South Africa. Post-apartheid, the three-pronged land-reform program (restitution, land tenure and redistribution) had multiple objectives aimed at redistribution of wealth, historical redress and economic growth (DLA 1997). Renowned land-reform scholar Lahiff (2008), in the report on the status of the South African Land Reform Programme, pointed to the fact that South Africa's land reform is in difficulty. There is consensus that land reform in South Africa is not reaching its intended objective. It is emerging that transferred land has not yielded desired transformed livelihoods more than 14 years since the transition to democratic rule (Lahiff 2008). As elicited by Lahiff (2008), concern has been raised about the Government's persistence in continuing with a policy approach that has clearly not yielded the desired outcome. This emerging picture of inefficiency in the land-reform program—failing to produce transformed livelihoods and economic growth—exists in parallel with questions about the state's ability to deliver on the objectives amidst little post-settlement support. Despite the strong constitutional rights women supposedly enjoy in South Africa, the gender sensitivity of the country's land-reform program has been found wanting (Thamaga-Chitja *et al.* 2010) due to the complexity and dichotomy of customary land law practices and statutory laws, illuminated by the lived experiences of women in rural South Africa.

These cases have captured two countries that began land reform in similar circumstances, with set objectives and indicators. South Africa can be described as

being at the crossroads—that is, faced with the reality of slow-moving reform that is struggling to meet its objectives. Both cases paint inefficiency in land reform on several fronts including policy, implementation, legislation and resources, and contention with statutory and customary laws, which have side-lined the main users of the land: women.

Land and gender

Women form more than 50 percent of the SADC's population. Still, the majority of women lack access to and ownership of land, and most land laws do not explicitly state women's right to land. Estimates suggest that women own only one percent of the land (ActionAid 2010). Women in SADC and in the rest of the African continent are faced with poorer prospects than men in accessing land. Most often women have to navigate the systems that sideline them, ranging from the colonial and apartheid (in South Africa) to traditional customary laws and practices (Tripp 2004). The result is that women have poor prospects for reasonable livelihoods and attainment of food security. Improving women's access to and control over land is seen by many as crucial to enhancing food and nutrition security, and reducing poverty. Having control over land would also strengthen the position of women within the household and promote other social and economic rights.

Social protection

Social protection is the set of policies and programs designed to reduce poverty and vulnerability. This can be achieved in a variety of ways such as promoting efficient labour markets, diminishing people's exposure to risks and enhancing their capacity to protect themselves against hazards and interruption/loss of income. The policies and procedures involve five major kinds of activities: labour market policies and programs, social insurance programs, social assistance, micro and area-based schemes, and child protection. Social protection entails dealing with issues such as vulnerability, hazards and targeting. Some instruments in social protection address food security. Social protection has an important role to play in addressing acute food issues.

The member states in SADC have recognised the need for social protection programs, which, among other things, ensure that people are not exposed to acute food insecurity. The SADC countries developed a Charter of Fundamental Social Rights, which, through Article 10, undertakes to provide sufficient resources and social assistance to people who are unable to either enter or re-enter the labour market and have no means of subsistence. They put in place measures to ensure social safety nets such as social security systems consisting mainly of child support grants, disability grants and old age pensions, school feeding schemes and access to health care.

Interventions in southern Africa have largely aimed at restoration of assets, and protection and strengthening of entitlements for the destitute or those unable to work. Social protection mechanisms that address food insecurity include transfers to support entitlements, including cash transfers, school feeding and public works

programs. Programs of various nature are implemented across the region by the private sector, non-governmental organisations or governments.

Vulnerability assessments and the monitoring of coping strategies are used for development of social protection interventions. These instruments are also mainstreamed in food security. For example, in Malawi, the starter pack program provided free, small packs of improved seed of maize and other crops and the appropriate fertilisers. Levy *et al.* (2004) argued that the starter pack is a tool for combating chronic food security and also synergistically dealing with social protection.

Public works programs are used in the SADC region, usually in times of drought. They can be a means of generating temporary employment for households experiencing food insecurity due to drought-induced income shortfalls. Teklu (n.d.) further pointed out that the food security outcomes of public works are dependent on factors such as employment and wage policies, the labour market and the manner in which the program is implemented—for example, the technologies used and decisions taken at the household level. Decisions at the household level relate to the willingness to participate in the programs, income effects and consumption decisions. Indeed, the key issues with public works programs are whether they target the desired segment of the population, and whether the necessary monitoring and evaluation mechanisms are put in place.

Other challenges facing food security in southern Africa

Factors such as HIV and AIDS, and climate change impact on attainment of food security in the southern African region.

HIV and AIDS

The southern African region has been devastated by the HIV/AIDS pandemic. Since the mid 1980s there has been a rapid increase in the prevalence of HIV and AIDS, with some countries in the region such as South Africa and Botswana now having amongst the highest levels of infection in the world. Most countries in the region have prevalence rates of around 20 percent for the entire adult population between the ages of fifteen and forty-nine. Factors contributing to the spread of the disease include poverty, gender inequality, intergenerational sex, illiteracy, stigma and discrimination, alcohol abuse and lack of communication about the disease due to cultural barriers. The pandemic has had a negative impact on society such as increases in the number of orphans, high infection rates amongst women and the loss of an economically active age group; the last has significant repercussions for food security in the region. The pandemic is undermining socioeconomic development efforts and gains in SADC countries.

Recent studies have shown that very poor households are more susceptible to the impact of HIV/AIDS on their human, social, financial, natural and physical resources. It reduces labour accompanied by the loss of knowledge and skills. Financially income that could have been used for food is lost as money is spent on medicines, transport, funeral expenses and increased costs of caring for orphans.

Losses of social resources result from increased demands on the household and family, emotional trauma and social isolation related to (fear of) stigma and discrimination, child adoption, new support networks via Home-Based Care (HBC) workers and weakening of organisational structures. Farming might be neglected and widows and orphans may lose rights to land. The impact of this loss of resources could be a vulnerability to food insecurity.

In general, HIV/AIDS perpetuates the poverty cycle of poorer households, and undermines their resilience. In addition, the impact of HIV/AIDS is gender differentiated. Women in rural areas bear the responsibility of looking after household welfare, and undertaking production functions and household maintenance. Their socioeconomic status makes them more vulnerable to the effects of the HIV/AIDS pandemic because their responsibilities require that they are subservient to males.

Climate change

Africa is the continent that is one of the most vulnerable with the least capacity to cope with the impacts of climate change, even though it contributes nearly nothing to the problem (less than four percent of greenhouse gas emissions). Africa's high vulnerability arises from the natural fragility of its ecosystems (degradation and desertification in 67 percent of its surface area), exposure to frequent natural disasters (droughts and floods), and dependence of livelihoods and economic activities on highly climate-sensitive natural resources and rain-fed agriculture (70 percent population, 30 percent GDP from agriculture), and so on.

Extreme events of drought, flood and sea-level rises caused by climate variability and climate change constitute important variables determining agricultural productivity, food security and livelihoods in Africa. Natural disasters triggered by extreme weather events, such as droughts and floods, have devastating impacts on human lives and livelihoods (millions of people are affected); they have resulted in substantial declines in productivity of economic activities, and could even threaten and erode developmental gains, hampering progress in achievement of development goals (including MDGs).

The Intergovernmental Panel on Climate Change (IPCC) report (2007) predicts that up to 250 million people in Africa will experience problems in accessing sufficient water by 2020 because of climate change, and that agricultural production could be halved in certain instances during the same period. IFPRI predicts that, without adaptation, the impact of climate change on agriculture and food security will be high, with the number of malnourished children possibly increasing an extra 10 million to a total of 52 million by 2050.

Agricultural productivity and food security in the African context should therefore be linked with resilience of livelihoods and adaptation of production systems to climate variability and climate change. The extent to which African agriculture sufficiently adapts to climate change and climate variability determines the options for successful agricultural growth and economic transformation in Africa. In African agricultural systems, which are primarily rain

fed, adaptive capacity is inherently related to the ability to maintain or to buffer ecosystem productivity under climatic stress.

Conclusions

In conclusion, coupled with a high population growth rate, the trend of food output in SADC countries provides a grim prospect for reaching the MDGs if we continue with business as usual. More alarming is the higher than normal degree of production instability in the region using the coefficient of variation as an indicator of variability. One important implication of this assessment is that even though current problems of food insecurity in southern African countries are strongly associated with low agricultural productivity, remedial action must not just take the form of reversing the trend. Other complementary and possibly alternative actions deserve attention as well.

This includes putting in place incentives, policies and institutional mechanisms, including adequate support in terms of financing, technology and capacity building, to enable the agricultural sector to become a significant part of the solution to the interdependent challenges of food security in the context of continuing economic development, increased investments in sustainable land and water management practices including water storage, drainage and flood control, and development of drought-resistant crop varieties. It also necessitates a judicious addressing of the historical legacies associated with the policy neglect and disinvestment in agriculture, as well as an appreciation that climate change impact is an additional burden on Africa's efforts to reduce poverty and achieve food security.

References

ActionAid 2010, *Her mile: women's rights and accesses to land. The last stretch of road to* eradicate hunger, [Web document], www.actionaid.it/filemanager/cms_actionaid/...pdf/HerMile_AAItaly.pdf [accessed 23 January 2011].

Adams, M 1995, *Land reform: new seeds on old ground?*, [Web document], www.odi.org.uk/resources/docs/2979.pdf [accessed 30 January 2012].

APHLIS (African Postharvest Losses Information System) 2012, Improving qualitative and quantitative postharvest losses estimates in Sub-Saharan Africa. www.erails.net/FARA/aphlis/aphlis/Home [accessed on 27 January 2012].

Department of Land Affairs (DLA) 1997, *South Africa Land Policy White Paper*, Government of South Africa, Pretoria, www.pmg.org.za/files/docs/090617whitepaper.doc [accessed 25 June 2010].

Fan, S., Pandya_lorch, R. (2012) (eds). Reshaping Agriculture for Nutrition and Health. International Food Policy Research Institute, Washington, DC.

FOA (2001). The State of Food Insecurity in the World 2001. Food and Agriculture Organization, Rome. International Food Policy Research Institute (IFPRI), Welthungerhilfe & Concern Worldwide 2011, *Global Hunger Index 2011. The challenge of hunger: Taming price spikes and excessive food price volatility*, International Food Policy Research Institute, Washington, DC.

Intergovernmental Panel on Climate Change (IPCC) 2007, *Climate Change 2007: Impacts, adaptation and vulnerability: Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)*, Cambridge University Press, Cambridge.

Lahiff, E 2008, *Land reform in South Africa: a status report*, [Web document], Research Report 38, Programme for Land and Agrarian Studies (PLAAS), University of Western Cape, www.plaas.org.za/pubs/rr/PLAAS_RR38_Lahiff.pdf [assessed 31 January 2012].

Land Development and Governance Institute (LDGI) 2011, *The fourth score card report on the implementation of land reforms in Kenya*, [Web document], www.ldgi.org/index.php?option=com_k2&view=item&task...id [accessed 30 January 2012].

Levy, S, Babalona, C & Chinsinga, B 2004, *Food security, social protection, growth and poverty reduction synergies: the Starter Pack Programme in Malawi*, ODI Natural Resources Perspectives No. 95, www.idu.org.uk [accessed 1 February 2012].

Louw, A, Nhemachena, C & van Zyl, S 2008, *Agribusiness linkages in southern African region: small farmer participation*, [Web document], Recovering Markets Policy Brief 2, http://web.up.ac.za/sitefiles/file/48/2052/3_%20Agribusiness%20Linkages%20in%20SADC.pdf [accessed 31 January 2012].

New Partnership for Africa's Development (NEPAD) Planning and Coordinating Agency 2011, Progress on CAADP implementation, CAADP Stakeholder Seminar, Pretoria, www.nda.agric.za/.../CAADP/.../Stakeholders%20Seminar%20SA%20-%20%20October%202011.ppt [accessed 31 January 2012].

Nthia Njeru, EH 1991, The socio-economic and political dimensions in the management of land in Kenya, National Conference on Land Reform and the Land Question, Windhoek, Namibia.

Panos, 2007, *Ensuring a food secure future: ingredients for change*, Panos Media Toolkit on Communicating Research No. 3, London.

Qamar, KM 2005, *Modernizing Agricultural Extension Systems: A practical guide for policy makers of developing countries*, [Web document], Food and Agriculture Organization, Rome, ftp://ftp.fao.org/docrep/fao/008/a0219e/a0219e00.pdf [accessed 31 January 2012].

Ravallion, M, Chen, S & Sangraula, P 2009, 'Dollar a day revisited', *World Bank Economic Review*, 23(2): 163–84.

Salih, S 1994, 'Food security in East and southern Africa', *Nordic Journal of African Studies*, 13 (1): 3–27.

Scoones, I 2010, *Zimbabwe's Land Reform: Myths and realities*, Royal African Society, London.

Sen, A 1981, *Poverty and Famines: An essay on entitlement and deprivation*, Clarendon, Oxford.

Shinn, GC, Wingenbach, GJ, Lindner, JR, Briers, GE & Baker, M 2009, 'Redefining agricultural extension as a field of study: a consensus of fifteen engaged international scholars', *Journal of International Agricultural & Extension Education*, 16(1): 2–16.

Southern African Development Community (SADC) 2003, *Proposal for the Establishment of a Regional Land Reform Technical Support Facility (RLRTSF)*, Southern African Development Community, Gaborone, Botswana.

Southern African Development Community (SADC) 2010, *Regional Agricultural Policy. Country summary agricultural reviews policy*, Southern African Development Community, Gaborone, Botswana.

Southern African Regional Poverty Network (SARPN) & World Bank 2007, Land Redistribution: Towards a common vision. A Regional Course—Southern Africa, 9–13 July, Hatfield, South Africa.

Thamaga-Chitja JM, Kolanisi U & Murugani V (2010). 'Is the South African Land Reform Programme, gender sensitive to women's food security and livelihoods effort?' Agenda, 86: 122-134.

Teklu, T [n.d.], *Labour-intensive public works: the experience of Botswana and Tanzania*, citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.139 [accessed 1 February 2012].

Tripp, AM 2004, 'Women's movements, customary law and land rights in Africa: the case of Uganda', *African Studies Quarterly*, 7(4), http://web.africa.ufl.edu/asq/v7/v7i4a1.htm [accessed 20 June 2011].

United Nations 2011, *The Millennium Development Goals Report 2011*, United Nations, New York.

van Tilburg A & Van Schalkwyk HD (2012). Strategies to improve Smallholders Market Access. In: Van Schalkwyk HD ; Groenewald JA; Fraser GCG; Obi A & van Tilburg A (2012). Unlocking Markets for Smallholder in South Africa Mansholt publication series - Volume 10. PP: 35-48. Wageningen Academic Publishers.

Vandemoortele, J 2007, *MDGs: Misunderstood targets?*, International Poverty Centre, United Nations Development Programme, Geneva.

Warriner, D 1969, *Land Reform in Principle and Practice*, Clarendon Press, Oxford.

Wegner, L & Zwart, G 2011, *Who Will Feed the World: The production challenge*, Oxfam Research Projects, London, www.oxfam.org.

World Bank 2011, *WDI Data Catalogue*, The World Bank, Washington, DC, http://data.worldbank.org/data-catalog/world-development-indicators/ [accessed 12 January 2011].

Chapter 3

Agricultural policies and irrigation in Africa

Expert advice and government priorities

AMY SULLIVAN AND JAMIE PITTOCK

Introduction

Earth's land and water face increasing pressure. At 7 billion today, global population is expected to approach 9 billion in less than 40 years. The additional 2 billion people will require 70 percent more food than is presently consumed (Fisher & Cook 2012). With agriculture already using 70 percent of the world's freshwater resources, increasing food production by a further 70 percent will require major investment in new technologies, techniques and approaches to growing more food with less water (Fisher & Cook 2012). Increases are necessary in water productivity and water-use efficiency.

In this chapter, we first review the relevant outcomes for irrigated agriculture in Africa from two major global assessments of water and agriculture—namely, the Challenge Program on Water and Food and the Comprehensive Assessment of Water Management in Agriculture. The second part of this chapter then examines the agricultural policies of African governments, in particular, the Comprehensive Africa Agriculture Development Programme, in order to draw conclusions as to progress in securing food supplies through more sustainable irrigated agriculture in Africa.

Lessons from water and agricultural assessments

Challenge Program on Water and Food

The Challenge Program on Water and Food (CPWF) of the Consultative Group on International Agricultural Research (CGIAR) was designed to investigate the water and food nexus in river basins around the world. Launched in 2002, the CPWF seeks to understand issues around development, poverty and water productivity. Phase I of the CPWF (2002–07) consisted of 68 research projects, undertaken across ten river basins in Africa, Asia and Latin America. Among the African river basins studied were the Limpopo, Niger, Nile and Volta. These projects explored an extensive set of water and food issues, from a variety of disciplinary perspectives and partnerships. The goal of this phase was to identify successful strategies for improving food security and reducing poverty. This work generated creative ways to define water and food problems and began developing new kinds of partnerships for addressing them.

Two key lessons emerge from the work of the CPWF Phase I that are relevant to Africa—namely, that:

1. improved water productivity coupled with empowerment, equity, market access and ecosystem conservation enables food-producing communities and ecosystems to become more resilient to biophysical and socioeconomic changes; and
2. development and adoption of rainwater management systems based on multiple uses of small reservoirs can result in improved livelihoods for smallholder farmers in sub-Saharan Africa.

Phase I context was provided by a series of nine basin focal projects (BFPs), which analysed water availability, water access, water productivity, water–poverty linkages and water governance. The BFPs were analysed and summarised (Fisher & Cook 2012), with the take-home message that, despite similarities, each basin presents different underlying problems that must be addressed systematically and contextually to improve food security and reduce poverty. The key findings from the BFP include:

1. Large-scale irrigation investments should be reconsidered as the intended benefits rarely accrue as anticipated to the intended audiences.
2. Increased investment should be made to help the poor cope with all nature of water crises, including drought, flood and water-quality issues.
3. Institutional development, capacity building and integration are critical to improving access to and the productivity of water resources in the basin for poor rural communities (a finding from the Limpopo BFP).

Phase II of the CPWF (2009–13) takes a different approach and organises research around a context-specific basin development challenge. Each of the six Phase II basin development challenges (BDCs) was developed in a consultative process that included review of previous research, meetings and consultative workshops with basin stakeholders. BDC development included articulating theories of

change, including impact pathways, by which research in partnerships was expected to lead to outcomes.

The process by which each BDC laid out a theory of change, impact pathways and outcome logic models (OLMs) allowed each to link their activities to outputs, intended outcomes and impact with likely audiences. The first step in the process was for each project team to imagine a point in the future when their project work had been successfully completed. This step articulated the change each team envisioned from their work in the longer term. From the overall vision, each project derived a limited number of outcome pathways, corresponding with their major research activities. Each outcome pathway was then described in detail, including:

1. actor(s) who will change;
2. change in actor practice and behaviour;
3. change in knowledge, attitude or skills (KAS) in actor(s) required to achieve practice change;
4. project strategies for achieving these changes in KAS and practice;
5. process output(s) involved in change; and
6. risks and assumptions.

A narrative that spelled out the total of the vision accompanied each of these pathways. While these OLMs are not sufficiently detailed for monitoring, they serve as clear guideposts for regular reflection and learning by project teams. The OLMs are useful for linking outputs to specific audiences for outcomes, including targeted output packaging and communications—a step frequently left out of research efforts.

The Limpopo, Nile and Volta river basins in Africa have been engaged in the CPWF for a decade. The three basin programs have evolved over that time and are building significant bodies of outputs and evidence about the relationships between water and food, and poverty and food insecurity.[2] Taken together with accumulated evidence from the Andes in Latin America, and the Ganges and Mekong in Asia, the CPWF has generated a series of program-level messages of relevance going forward.

The overall message currently emerging from the CPWF suggests that despite areas and instances of physical scarcity, the planet has enough water to meet the full range of human and ecosystem needs for the foreseeable future, with a number of caveats. The challenge is going to be equitable access, requiring judicious and creative management; trade-offs must be made and ecosystems must be maintained. More specific messages from CPWF Phase II include:

1. Sustainable intensification (and diversification) of smallholder systems may be available through more efficient use of scarce dry-season water in order to access high-value market chains.

[2] See: www.fanrpan.org/projects/lbdc/; http://nilebdc.org/; http://volta.waterandfood.org/.

2. Policy processes based upon collaboration and dialogue should encourage more equitable benefit and risk sharing.
3. Trans-boundary and multi-sectoral institutional arrangements are needed to foster more equitable development, improve governance and support innovative technical solutions.
4. Innovative partnerships are critical to converting science-based evidence into outcomes and impacts on the ground. Theories of change and outcome mapping can help pave this pathway to achieving impact in the short term.
5. Emerging findings from the Limpopo Basin suggest that basin water levels can support further resource development, but that catchment-level analysis must be matched to proposed technologies.
6. Further experience from the Limpopo illustrates the value of diverse partnerships and networks to move from research for publication to evidence for outcomes and impact.

The Comprehensive Assessment of Water Management in Agriculture

The International Water Management Institute (IWMI) undertook a second global assessment: the Comprehensive Assessment (CA) of Water Management in Agriculture (IWMI 2007). The CA was published in 2007 and reviewed decades of development investment and efforts and assessed opportunities going forward. The CA suggests, like the CPWF and others, that great potential lies in addressing the yield gap between high and low-efficiency farmers. This will require better water management, better and more equitable policies and implementation, and improved production techniques.

The CA recommends changes in techniques, technologies and policies, grounded in reality, and responsive to different situations as both humans and socio-ecological systems are changing all the time. The CA recommends eight policy actions, summarised here:

1. Change thinking about water and agriculture: In order to ensure food security, reduce poverty and conserve ecosystems, rainwater must be governed and managed to support multiple-use agro-ecosystems.
2. Improve access to agricultural water: Secure water access for smallholder farmers via legal and physical means (rights, storage and delivery) is needed so that they can more fully engage in growing market opportunities.
3. Agriculture and ecosystems: Ecosystem thinking needs to be integrated into agricultural planning, development and implementation.
4. Increase water productivity: Investment is needed in technologies and systems that will deliver greater yields from less water, reducing future demand, ecosystem damage and competition.

5. Upgrade rain-fed production systems: Rain-fed agriculture supports the majority of Africa's smallholder farmers and has the greatest potential for production and productivity increases.
6. Adapt yesterday's irrigation to tomorrow's needs: Modernisation of traditional irrigation for multiple services and diverse livelihoods can generate higher value agricultural production and profits.
7. Target state institutions for reform: State water institutions must engage with coalitions to reform water governance in general, and as it pertains to agriculture in particular. Linking idiosyncratic water, food and environment policies is a time-consuming and frustrating process.
8. Trade-offs and difficult choices: Water allocation and use are driven by competing demands and the need for trade-offs. This negotiation process must be transparent and include all stakeholders in meaningful and relevant ways.

Consequently, new investment in irrigated agriculture could specifically address increasing water productivity, delivering higher yield from less water, reducing water demand, ecosystem damage and competition. It may also begin to adapt yesterday's irrigation to tomorrow's needs. By focusing on learning and adaptive management, today's farmers can build their livelihoods for tomorrow, based upon more efficient water use, greater productivity and more profitable agriculture. It is expected that individual gains will be buttressed by stronger local and catchment-level institutions and governance structures—helping ensure sustainability of the learning.

In summary, food security and poverty reduction require additional investments in agricultural water management in sub-Saharan Africa. History has shown that there are no silver bullets for achieving food security and poverty reduction. Rather, agricultural water management investments should be tailored to the specific needs and situations in different countries, such as the following examples:

- Where irrigation infrastructure has been developed and fully utilised: With limited scope for expansion to increase food security and reduce poverty, the goal should be to improve the efficiency and management of existing systems, increasing the productivity of land and water resources through strengthening institutions and related software.
- Where water resources are available but less developed: Where water is considered economically rather than physically scarce, investment should be made in both large and small-scale irrigation. Of primary importance is prioritised investment in capacity and institutional development for scheme staff, entrepreneurs and farmers in collective management of water resources.
- Where water resources are scarce: Areas of physical water scarcity require pro-poor investments in land and water conservation technologies and practices, use of marginal-quality water, and integration of crops, fisheries and aquaculture, and tree/livestock

systems to increase the economic value and livelihoods per drop of water.

- Policy and market integration: Agricultural water development must take place within an enabling policy environment, linked to input and output markets. Critical to the success of any commercial venture is the necessary incentive structure for engaging smallholder farmers, and keeping them engaged in commercially viable enterprises. This includes secure tenure, access to finance, and input and output markets to sustain the initial investment and enthusiasm.

Two common themes emerging from these recommendations for enhanced irrigated agricultural production are the need to enhance institutions and to enhance water productivity. It is in this context that we now consider the agricultural policies of African governments, with a particular focus on nine countries selected for assessment as part of an Australian aid project.

Agricultural policies in Africa

Introduction

The picture of agriculture in sub-Saharan African agriculture may appear dynamic locally and regionally, yet seems to remain static and low producing in the aggregate. This reflects an ever increasing population and high-risk reliance on rain-fed agriculture with pockets of highly productive commercial irrigation and a disappointing history with small-scale irrigation.

Agriculture supports the livelihoods of more than 415 million people in sub-Saharan Africa—some 55 percent of the total population (Development Support Monitor 2012). The majority of these farmers are engaged in mixed crop–livestock, rain-fed smallholder farming characterised by low productivity. In fact, per capita food production in Africa has stagnated for more than 20 years. This stunted growth and resulting rural poverty can be linked directly to a lack of rural infrastructure, agricultural inputs and technology (IFAD 2010). The majority of these farmers face unreliable rainfall, reduced soil fertility, and unfavourable land, water and trade policies. They have little to invest in infrastructure development or maintenance and have limited access to context-specific technologies and knowledge.

While the United Nations reports reduced poverty levels globally from 1990 to 2000, the number of poor living on US$1 a day in sub-Saharan Africa increased from 227 million to more than 300 million in that decade. Sub-Saharan Africa remains the world's poorest region, with 34 of the world's 50 poorest countries. This can be partially attributed to low and unpredictable rainfall, recurrent weather events and widespread reliance on a poor-performing smallholder agricultural sector (Hanjra & Gichuki 2008).

Successful large-scale commercial farming in sub-Saharan Africa can be competitive with global production standards. Yet smallholders living next-door

are vulnerable to sporadic or failed rains, long-term droughts, natural hazards, disease and even death. Chronic exposure to overlapping or simultaneous risk traps smallholder farmers in a cycle of poverty and food insecurity. It is therefore thought that significant investment in agricultural water management for smallholder farmers can help pave pathways to food security and away from poverty. Hanjra and Gichuki (2008) suggest that investment in agricultural water management (including irrigation) can positively change the opportunity structure for rural populations, particularly when made in concert with secure tenure rights, basic education and health care, supporting infrastructure, and markets.

Donor-funded irrigation in sub-Saharan Africa has struggled to be sustainable and to maintain peak production levels over time, but there have been successes and lessons learned. Among such programs implemented between the late 1960s and the early 2000s, researchers identified a number of factors behind poor performance:

- inadequate design and planning that led to high costs, delays and cost over-runs;
- hardware before software: emphasis on large-scale, high-technology irrigation systems rather than small-scale appropriate technology, as well as inadequate investment in the software (people) component;
- design and planning based upon inadequate hydrological, soil, topographical and environmental data, leading to fundamentally unsound irrigation planning, operation and management;
- insecure land tenure, unexplored institutional issues and non-existent governance structures;
- planning and investment weighted towards design and building with insufficient planning and investment in operations, maintenance, upgrades and depreciation;
- lack of local community, traditional authority or farmer involvement and contribution to project activities; and
- poorly understood sociopolitical and cultural factors (Hanjra & Gichuki 2008, p. 190).

An estimated 39 million ha of agricultural land in Africa is physically suited for irrigation. Yet only 6 million ha, around five percent of that total, is actually under irrigation (You 2008). Of that 6 million ha, Madagascar, South Africa and Sudan together account for nearly 4 million ha, leaving the rest of sub-Saharan Africa with just 2 million ha of irrigation. Irrigated agriculture outputs in sub-Saharan Africa account for one-quarter of the total value of agricultural outputs, demonstrating that irrigation increases the economic productivity of land. In comparison, South America, East and South-East Asia and South Asia claim ten percent, 29 percent and 41 percent of arable land under irrigation respectively (Development Support Monitor 2012).

Table 3.1 Population & GDP of the 9 African countries (www.tradingeconomics.com)

Country	Population (million) 2011	Population density (people per sq km) 2010	Rural population (%)	GDP per capita (US$) 2011	Agriculture's contribution to GDP (%)
Botswana	2.03	3.54	31	16,200	2
Ethiopia	84.73	82.95	82	1,100	41
Kenya	41.62	71.18	79	1,800	19
Malawi	15.38	158.05	82	900	30
Mozambique	23.93	29.74	71	1,100	32
Tanzania	46.22	50.62	75	1,500	28
Uganda	34.51	167.28	87	1,300	22
Zambia	13. 47	17.39	61	1,715	22
Zimbabwe	12.75	32.20	66	500	20

Table 3.2 Water resources in the nine African countries

Country	Total renewable water resources	Total water withdrawals as percentage of total annual renewable water resources (TARWAR)**	Total agricultural water withdrawals as percentage of (TARWAR)**	Per capita water use (cu m/yr) 2000*
Botswana	14.7 (2001)	1.6	0.7	107
Ethiopia	110 (1987)	5.1	4.7	72
Kenya	30.2 (1990)	9.0	7.2	46
Malawi	17.3 (2001)	5.8	4.7	78
Mozambique	216 (1992)	0.3	0.3	32
Tanzania	91 (2001)	5.7	5.1	135
Uganda	66 (1970)	0.5	0.2	10 ('02)
Zambia	105.2 (2001)	1.7	1.3	149
Zimbabwe	20 (1987)	21.0	16.6	324 ('02)

*Sources: * = CIA (online) The World Factbook, Central Intelligence Agency, Washington DC, www.cia.gov/library/publications/the-world-factbook/ [accessed 22 February 2013]; ** = International Food Policy Research Institute (IFPRI) 2011, Global Hunger Index. The challenge of hunger: Taming price spikes and excessive food price volatility, International Food Policy Research Institute, Washington, DC, www.ifpri.org/sites/default/files/publications/ghi11.pdf [accessed 12 November 2012].*

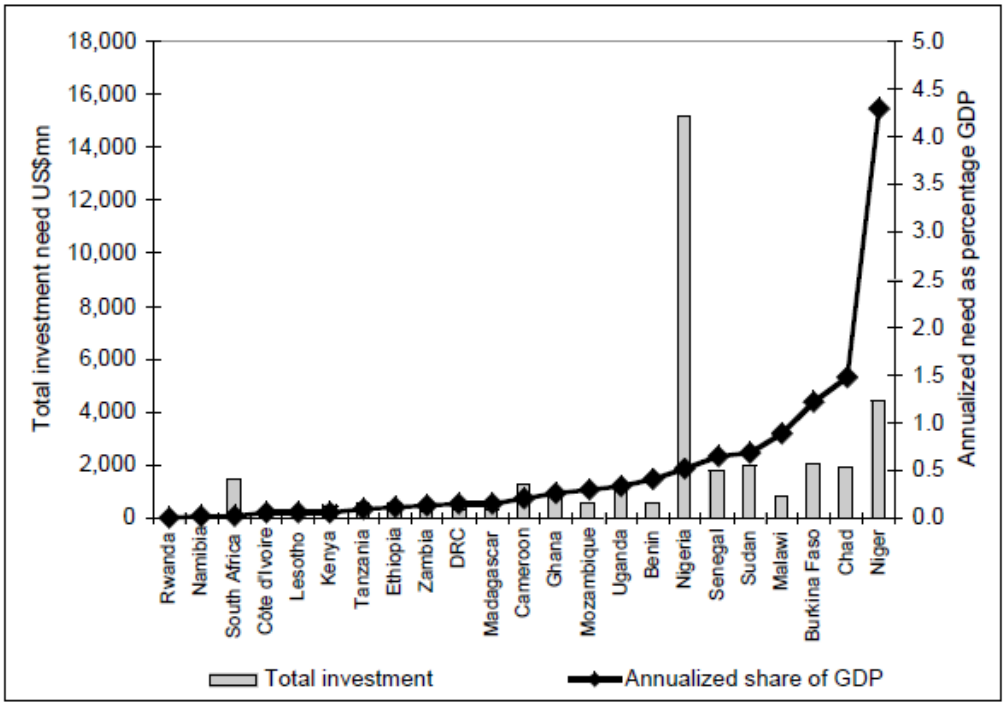
Table 3.3 Irrigation and agricultural productivity in nine African countries

Country	Area under irrigation (ha)	National targeted area	Total % of irrigation-equipped area/ cultivated area*	Percentage irrigation-equipped area actually irrigated/ total equipped area*	Value of irrigated output as share of total agricultural output (%)*	Share of irrigation potential (%)*	Average rate of growth of irrigated area (2000–03)
Botswana	1,439 of which only 620 is functional	Irrigation potential is estimated at about 13,000 ha. Target of rehabilitation of 1,000 ha (Government of Botswana 2008).	0.4	96.0	16.6	11	0.0
Ethiopia	289,530	510 603 ha of new irrigation under construction or planned.	2.7	-	-	11	0.0
Kenya	103,203	Increase area under irrigation by 140,000 ha by 2012.**	2.0	94.2	9.5	29	5.8
Malawi	56,390	Malawi plans to double its area under irrigation, adding a further 50 000 ha (unpublished data, this study).	2.3	47.7	8.7	35	0.6
Mozambique	118,120	3.3 million ha potentially irrigable, about 120,000 ha with irrigation infrastructure of which only 50,000 ha is currently used.	2.7	33.9	4.8	4	0.0

Tanzania	184,330	2.3 million ha classified as high potential, 4.8 million ha as medium potential, and 22.3 million ha as low potential.*** 2002 National Master Irrigation Plan set target at 25,000 ha of new irrigation development per year (Therkildsen 2011).	3.6	-	10.0	9	2.3
Uganda	14,418, formal	253,250 ha (Republic of Uganda 2011).	0.1	64.5	0.5	10	0.0
Zambia	155,912	200,000 ha by 2010 (Kodamaya 2009).	2.9	100.0	28.2	30	3.7
Zimbabwe	175,513	Zimbabwe has 366,000 ha of irrigation potential; 175,000 ha of land is developed. Currently, 102 000 ha is operational, remaining 73,000 ha is equipped but requires rehabilitation.	5.2	71.4	25.9	47	0.0

*Sorces: * = Svendsen, M, Ewing, M & Msangi, S 2009, Measuring irrigation performance in Africa, IFPRI Discussion Paper 00894, International Food Policy Research Institute, Washington, DC; ** = Government of Kenya 2008, Water for agriculture and energy in Africa: the challenges of climate change, National Investment Brief prepared for High-Level Conference on Water for Agriculture and Energy in Africa: The Challenges of Climate Change, 15–17 December, Sirte, Libyan Arab Jamahiriya; *** = United Republic of Tanzania 2011, Tanzania Agriculture and Food Security Investment Plan (TAFSIP), URT, Dar es Salaam www.gafspfund.org/sites/gafspfund.org/files/Documents/TAFSIP_FINAL_FOR_PRINTING_AND_CIRCULATION.pdf [accessed 22 February 2013].*

Figure 3.1 Irrigation investment needs required to realise irrigation potential in Sub-Saharan Africa by country



Source: You, LZ 2008, Irrigation investment needs in sub-Saharan Africa. Africa infrastructure country diagnostic (AICD), Background Paper 9, International Food Policy Research Institute, Washington, DC, p. 9.

The total investment needed for each country to meet their irrigation potential, in millions of US dollars and as a share of annual GDP, is shown in Figure 3.1. This may help prioritise donor support, for example, to the countries on the right-hand side, where modest investments could help nations who will struggle most to fund such capital expenditure on food security from domestic resources.

Across sub-Saharan Africa agricultural, water and environmental policies are not harmonised to any meaningful degree within countries or across river basins; planning and development of each sector remain isolated from the others. Basin, national, provincial and local development of agriculture is often conceptualised and planned in isolation from corresponding water interests. Irrigation water user associations are one of few instances where agricultural and water interests are represented at the same table, albeit at a very local level.

The risks of continued isolation of water and agricultural planning and management are becoming clearer as competition for available resources increases. The global shift towards integrated water resources management (IWRM) since its appearance in 1993 has reached water resources planning and management in Africa. In 2010, Global Water Partnership published an evaluation of progress towards a number of milestones in IWRM planning across southern

and eastern Africa (GWP 2010). The results for nine African countries are presented in Tables 3.4 and 3.5, assessed according to progress towards an enabling environment and IWRM planning.

Table 3.4 Progress on enabling environment and institutional arrangements to improve Africa's water security

Key

Little progress achieved

Some progress, limited achievements

Substantial achievements

Country	Policy and legislation	Infrastructure platform	Sustainable financing	Institutional arrangements	Institutional capacity
Botswana					
Ethiopia					
Kenya					
Malawi					
Mozambique					
Tanzania					
Uganda					
Zambia					
Zimbabwe					

Source: Global Water Partnership (GWP) 2010, Improving Africa's Water Security: Progress in integrated water resources management in eastern and southern Africa, Global Water Partnership Eastern Africa & Global Water Partnership Southern Africa, Pretoria.

Table 3.4 summarises national progress towards answering the following questions that reflect establishment of an enabling environment for implementing IWRM.

1. Are appropriate policy and legislation in place to support IWRM?
2. Is an adequate water resources infrastructure platform in place?
3. Is there sufficient sustainable financing for the implementation of IWRM?
4. Is the institutional capacity, particularly in relation to human resource capacity, sufficient to implement IWRM?

Table 3.5 Progress on the Implementation of Management Instruments for IWRM

Key

Little progress achieved

Some progress, limited achievements

Substantial achievements

Country	IWRM planning	Water use efficiency	Stakeholder engagement	Allocation mechanisms	Monitoring and information	Environmental sustainability
Botswana						
Ethiopia						
Kenya						
Malawi						
Mozambique						
Tanzania						
Uganda						
Zambia						
Zimbabwe						

Source: Global Water Partnership (GWP) 2010, Improving Africa's Water Security: Progress in integrated water resources management in eastern and southern Africa, Global Water Partnership Eastern Africa & Global Water Partnership Southern Africa, Pretoria.

The nine African countries' progress in establishing the management instruments for effective IWRM is assessed in Table 3.5. For instance, there is substantial achievement towards water-use efficiency by Tanzania compared with Zimbabwe's lack of progress. Table 3.5 also offers an assessment of the monitoring and information management capacity of the countries, with Zimbabwe having substantial achievements in this field. If their IWRM experiences to date were facilitated strategically, different countries could share and learn a great deal from them.

While the water sector is working towards IWRM planning, the agricultural sector has engaged in a continent-wide planning process and framework. Within the past 10 years investment in African agriculture has been increasingly informed and guided by a planning process and framework known as the Comprehensive African Agriculture Development Programme (CAADP).

Comprehensive African Agriculture Development Programme

The Comprehensive African Agriculture Development Programme (CAADP) is a planning and development framework for the African agricultural sector. It was designed to advance agriculture as a driver of economic growth, and to help raise agricultural productivity thereby reducing hunger and poverty on the continent. CAADP was formulated by the African Union Commission (AUC) under the New Partnership for Africa's Development (NEPAD), and was endorsed by the African Heads of State and Government at the African Union Summit in Maputo in July 2003.

CAADP encourages strategic and organised investment in agricultural sector support and development in Africa. The CAADP framework seeks to guide country strategies and investment programs; stimulate and support policy dialogue, organisational and capacity development, and peer learning; prompt multi-stakeholder engagement (government, civil society and private sector); and support alignment and harmonisation between local and international institutions and development partners. Through CAADP, African governments committed to increasing public investment in agriculture to a minimum ten percent of national budgets, and to achieve a minimum six percent annual growth in agriculture by 2015.

While CAADP planning and implementation are done mainly at the national level, those processes are meant to be aligned with regional policies and groupings. Regional economic communities (RECs) are developing regional CAADP processes in an effort to better integrate agricultural growth and trade across borders, share lessons, strategies and experiences, and assist with implementation. RECs work in support of the CAADP agenda by guiding country activities, coordinating regional implementation, monitoring and evaluating progress towards implementation, building partnerships and directing investment to facilitate national processes. At the continent level, the African Union and NEPAD facilitate broad partnerships and technical support for the RECs and country processes.

At the national level, CAADP compacts are high-level agreements between governments, regional representatives and development partners for coherent implementation within countries. National CAADP compacts reflect national investment and development priorities and lay out entry points for various stakeholders to engage with development processes; they identify actions, commitments and partnerships. Ideally compacts guide country policy and investment responses, planning for development assistance, and public–private partnerships to support investment.

CAADP is organised into four pillars—or entry points—described below (NEPAD 2012).

Pillar 1—extending the area under sustainable land management—promotes technologies and approaches related to water and irrigation, and conservation-agriculture investment in sustainable land management. Under this pillar,

NEPAD coordinates, aligns and manages knowledge initiatives across Africa, encouraging investment in CAADP-aligned priorities and minimising constraints to such investment. Unpublished data (2012) summarising 20 national CAADP implementation plans suggest that six percent of the agricultural investment of these countries is devoted to sustainable land and water management.

Pillar 2—rural infrastructure and trade-related capacities for market access—targets improved market access by improving rural infrastructure and other market and trade-related interventions, include policy and regulatory frameworks. This pillar focuses on what it takes to get better-quality outputs to markets, and better information up and down value and supply chains. This pillar promotes sound trade policies across all levels; strengthens capacity to negotiate trade; facilitates partnerships with the private sector; and encourages domestic and foreign direct investment in agriculture.

Pillar 3—food and nutrition security—is aligned with the first Millennium Development Goal (MDG) of halving extreme poverty and hunger by 2015. This pillar seeks to increase food security and reduce hunger by raising smallholder productivity and improving responses to food emergencies. It specifically targets vulnerable populations and the chronically food insecure. Pillar 3 combines the CAADP vision of increased productivity, integrated markets and greater food and income security for vulnerable groups.

Pillar 4—research and training for technology dissemination and adoption—recognises the role of research in reducing poverty and hunger. It aims to improve agricultural research and strengthen dissemination systems, while promoting the uptake of appropriate technologies. Pillar 4 aims to increase the support available to help farmers adopt improved options for scaling up and scaling out.

CAADP formulation and implementation are undertaken through strategic functions by a broad range of actors grounded within the four pillars identified above. As this is an Africa-wide framework, the African Union (through the NEPAD Planning and Coordinating Agency) is tasked with overall coordination. RECs develop regional compacts and agricultural investment plans for implementation while linking and supporting their member states with national-level activities. At the country level, governments lead the formulation and implementation of national compacts and investment plan development. The broader international community provides technical and financial support to CAADP processes. Strategic functions for the CAADP agenda are led by NEPAD and include:

1. promoting CAADP principles in country development and implementation activities by leveraging technical expertise and supporting RECs;
2. managing communication and information in support of CAADP implementation and partnerships, which includes awareness campaigns and knowledge sharing;
3. facilitating and coordinating monitoring and evaluation with an eye to impact assessment and peer review of processes and outcomes;

4. linking resources with programs—directing potential investors to well-suited opportunities; and
5. harnessing key thinking and experience—knowledge management to help strengthen the CAADP agenda by sharing the best available information (NEPAD 2012).

The formulation of national and regional investment plans is one of the most important activities to implement CAADP after the definition and signature of the compact. As of September 2012, some 30 African countries have signed national CAADP compacts and are at various milestones recognised in the CAADP process, including:

1. CAADP process launch,
2. development of the compact,
3. signing of the compact,
4. investment plan development, and
5. business meeting.

Progress towards CAADP implementation since 2003, illustrating different stages of implementation, is shown in Table 3.6.

Table 3.6 Progress towards CAADP Implementation (as of September 2012)

Countries still to launch CAADP (12)	Countries working towards signing CAADP compacts (6)	Countries with signed CAADP compacts (30)		
		Countries only signed CAADP compact (7)	Countries with investment plans (4)	Countries that have held business meetings (10)
Algeria	Comoros	Central African Republic	Burkina Faso	Benin
Angola	Congo-Brazzaville	Democratic Republic of Congo	Guinea	Burundi
Botswana	Lesotho	Djibouti	Guinea Bissau	Cape Verde
Cameroon	South Africa	Mozambique	Ivory Coast	Ethiopia
Chad	Sudan	Seychelles		Gambia
Egypt	Zimbabwe	Swaziland		Ghana
Gabon		Zambia		Kenya
Madagascar				Liberia
Mauritius				Malawi
Namibia				Mali
Sao Tome & Principe				Mauritania

Countries still to launch CAADP (12)	Countries working towards signing CAADP compacts (6)	Countries with signed CAADP compacts (30)		
		Countries only signed CAADP compact (7)	Countries with investment plans (4)	Countries that have held business meetings (10)
South Sudan				Niger
				Nigeria
				Rwanda
				Senegal
				Sierra Leone
				Tanzania
				Togo
				Uganda

Source: New Partnership for Africa's Development (NEPAD) (n.d.), The Comprehensive Africa Agriculture Development Programme (CAADP). Countries with investment plans, New Partnership for Africa's Development, Midrand, South Africa, www.caadp.net/pdf/Table 1 Countries with Investment Plans ver15 (2).pdf.

Lessons learned

CAADP development and implementation focus on national-level processes to accommodate the specific needs of each African country. National round-table processes were designed as an initial step in the process responsible for: aligning state policies with regional priorities; identifying and strategising around economic bottlenecks; identifying funding gaps; and initiating monitoring and evaluation of CAADP progress. Having learned through experience, the CAADP process has changed since early implementation. Specific aspects of this shift are shown in Table 3.7.

Table 3.7 Shifts in CAADP Implementation by 2009

From: initial CAADP process design	To: adapted CAADP process design
One administratively appointed focal-point person to drive CAADP within each country.	A country implementation team to manage the process strategically and professionally: ▪ facilitation of dialogue and consultations for informed decision making on government and stakeholder buy-in; ▪ internalised CAADP functions including aligning relevant decision-making bodies.
Facilitation through RECs.	Facilitation, support and capacity development of country teams through a CAADP resource group and, within that,

From: initial CAADP process design	To: adapted CAADP process design
	country support teams composed of RECs, the African Union, NEPAD and pillar institutions taking joint responsibility with clear performance criteria. The CAADP resource group acts as a fast-learning group where lessons and experiences can be rapidly shared and performance enhanced.
The compact agreement as a major focus of the CAADP process.	Focusing on the impact and outcomes of the process, negotiated with countries and leading to improved performance and capacities to reach the six percent growth target.
The primary implementation focus on government.	Government leadership but including ownership and responsibilities across a wider network of players such as parliamentarians, civil society and other actors. A focus on collective responsibility for implementation and delivery from all major stakeholders. Capacity and institutional arrangements and implementation modalities are part of planning.
Instruction to implement CAADP from the higher level; resistance from middle levels.	Exploring CAADP's value addition with countries and using a flexible implementation design accordingly, building on the buy-in of technocrats and their institutions.
A mechanical and static 'round-table' process.	Flexible mainstreaming and alignment of CAADP into national development strategies (reviewing the value of CAADP against existing strategies and plans/programs). Focusing on organisational development and the quality of a strategic process for design and management, as well as building competence and engaging in continuous learning.
Use of 'isolated consultants' for an initial stocktaking exercise.	Use of the existing knowledge system and institutions to build fundamental relationships, arrangements and capacities that link planning to knowledge, information and networks ('building functioning systems'). Expanded stocktaking, diagnosis and an analysis base linked to an ongoing analysis of and support for information needs. A focus on building and nurturing local/systemic capacity for analysis and knowledge generation.
Analytical work in early process heavily based on econometric modelling.	Analytical work based on a wide range of perspectives: policy, institutions/capacity, finance/economics, ecosystems, technology.
Isolated donor support for implementation.	Work on plan-based funding from the Multi Donor Trust Fund, building on donor alignment in individual countries.

Source: www.caadp.net/pdf/CAADP_imp_guide_WEB.pdf.

The changes in CAADP processes and approaches indicate structured sharing and learning from experience has taken place. Initially designed with a CAADP focal person for each country, the process has shifted to country implementation teams with wider reach, greater expertise and broader networks within and across agriculture. Early CAADP activities focused on generation of the CAADP country compact as an end in and of itself. While the compact signals consensus and willingness to engage in a shared way forward, it gives little in the way of guidance, structure or implementation plans for achieving six percent growth. The CAADP round-table process was seen as mechanical and static, at the risk of resting outside mainstream government planning and activities. The current approach focuses on mainstreaming and aligning CAADP processes with national development plans and strategies. Other shifts in the CAADP process seem to reflect 'whose knowledge counts' as more emphasis is being put on enhanced consultation, locally relevant situation analysis and developing the local capacity to lead these processes. While CAADP has focused on planning and investment processes, what is not yet evident is debate over technical and policy outcomes and shared learning of best practices on the issues debated elsewhere in this volume—for instance, on how best to reduce poverty through agriculture and how to sustainably develop agriculture.

The next big hurdle for country CAADP processes will be getting broad-based buy-in to implementing the agreed upon investment plans. In addition to government, other key role-players are critical to the success of CAADP including civil society, the private sector and farmers' groups. Successfully engaging these partners will be another significant step away from business as usual and less integrated development planning and implementation. Yet optimism is called for considering the evolution and progress of CAADP in the past five years.

Pathways from irrigation to food security in Africa

Scientists from the Challenge Program on Water and Food and the International Water Management Institute have published research suggesting that we can meet our growing population's needs, but in order to do so we must improve water use in agriculture (Fisher & Cook 2012; IWMI 2007). Food and agricultural production currently take 70 percent of freshwater withdrawals from rivers and groundwater. Therefore, mounting population pressure and corresponding consumption patterns will increase competing demands on the natural resource base and serve as an incentive for more efficient water use.

Pathways to food security vary across time and space and implicate scales from household to catchment and country, region and continent. Therefore, the emerging agenda must be based upon the recognition of the existing diversity and dynamism of smallholder socio-ecological systems. While our analysis identifies progress with Africa-wide and national-level policy development (through CAADP and IWRM planning), less progress is evident on integration of water and agricultural policies, and on the types of agricultural programs that global assessments suggest would make the most difference for reducing poverty with irrigated agriculture.

Better water management, changes in the enabling and policy environments and improved production techniques will be required to close productivity gaps. Increasing water-use efficiency on existing and planned irrigated land alone would significantly reduce the gap. Linking improved plot-level water-use efficiency to scheme, watershed and basin levels is the next big challenge for research, investment and implementation. This challenge will be met by establishing appropriate and necessary incentive structures such that all decision-makers share risks, responsibilities and benefits (Chilonda *et al.* 2012).

Hanjra and Gichuki (2008) suggest that investment in irrigation water management contributes primarily to poverty reduction (with implications for food security) through a number of pathways, including the following:

- Increased wage labour opportunities: Greater local labour demand due to construction needs and ongoing system maintenance, linked to intensified economic activity due to an extended growing season.
- Higher income and consumption: Based on the assumption that higher income leads to increased consumption, more foodstuffs become available; this may improve nutrition security as well by supporting more meals per day and improved intra-household allocation.
- Improved income and nutrition set the stage for improved access to and benefits from education for all children, with particular attention to girls.
- Investment in irrigation infrastructure lowers the risk of production loss to climate variability, mainly drought and flood. It also reduces susceptibility to seasonal income troughs.
- Greater equity: Investment in irrigation development generates economic activity in proximity to the scheme. In addition to increased money in the area, increased food, information and services become more readily available to the poor.

The next generation of national agricultural policies and programs must focus on achieving these socioeconomic benefits sustainably through increased emphasis on greater water productivity, poverty reduction and implementation at the local scale.

References

Athukorala, K & Fernando, J 2012, 'Investing in women's participation for enhanced water security: a practitioner's view from Sri Lanka', in H Bigas (ed.), *The Global Water Crisis: Addressing an urgent security issue*, Papers for the InterAction Council, 2011–2012, UNU-INWEH, Hamilton.

Australian Agency for International Development (AusAID) 2010, *Looking West: Australia's strategic approach to aid in Africa 2011–2015*, AusAID, Canberra.

Backeberg, GR and Sanewe, AJ 2010, Towards productive water use and household food security in South Africa, Sixth Asian Regional Conference of ICID, 10–16 October, Yogyakarta, Indonesia.

Biggs, HC & Rogers, KH 2003, 'An adaptive system to link science, monitoring and management in practice', in JT du Toit, KH Rogers & HC Biggs (eds), *The Kruger Experience. Ecology and management of savanna heterogeneity*, Island Press, Washington, DC, pp. 59−80.

Boserup, E 1970, *Woman's Role in Economic Development*, St Martin's Press, New York.

Byerlee, D 1998, 'The search for a new paradigm for the development of national agricultural research systems', *World Development*, 26: 1049–55.

Chilonda, P, Musaba, E & Zikhali, P 2012, *2011 Annual Trends and Outlook Report. Agricultural growth trends and outlook for southern Africa: Enhancing regional food security through increased regional productivity*, The Regional Strategic Analysis and Knowledge Support System for Southern Africa (ReSAKSS-SA).

Chilundo, M, Brito, R & Munguambe, P 2004, *Mozambique Country Report on Land and Water Management*, University of Eduardo Mondlane, Maputo.

CIA (online) The World Factbook, Central Intelligence Agency, Washington DC, https://www.cia.gov/library/publications/the-world-factbook/ > [accessed 22 February 2013]

Clark, NG 2002, 'Innovations systems, institutional change and the new knowledge market: implications for third world agricultural development', *Journal of the Economics of Innovation and New Technologies*, 11: 353–68.

Development Support Monitor 2012, *Unlocking the African moment – rural infrastructure in Africa*, DSM Paper Series, Development Support Monitor, Cape Town, South Africa.

Falkenmark, M & Rockstrom, J 2006, 'The new blue and green water paradigm: breaking new ground for water resources planning and management', *Journal of Water Resources Planning and Management*, 132(3): 129–32.

Fisher, M & Cook, S (eds) 2012, *Water, Food and Poverty in River Basins: Defining the limits*, Routledge, London & New York.

Food and Agriculture Organization (FAO) 2012, *Coping with water scarcity. An action framework for agriculture and food security*, FAO Water Reports 38, Food and Agriculture Organization, Rome.

Forum for Agricultural Research in Africa (FARA) 2006, *Agricultural research delivery in Africa: an assessment of the requirements for efficient, effective and productive national agricultural research systems in Africa*, NARS Assessment, Forum for Agricultural Research in Africa, Accra.

Gemo, H 2011, *Moving Towards the Implementation of the CAADP Framework in the Agriculture Sector: The case of Mozambique*, NEPAD Planning and Coordinating Agency, Midrand, South Africa, www.caadp.net/pdf/Moving%20Towards%20the%20Implementation%20of%20the%20CAADP%20Framework%20in%20the%20Agriculture%20Sector%20-%20WEB.pdf [accessed 12 November 2012].

Gillard, J 2011, Australian [sic] strengthens food security in Africa, Media release, 28 October, Office of the Prime Minister, Canberra.

Giordano, M, de Fraiture, C, Weight, E & van der Bliek, J (eds) 2012, *Water for wealth and food security: supporting farmer-driven investments in agricultural water management*, Synthesis report of the AgWater Solutions Project, International Water Management Institute, Colombo.

Global Water Partnership (GWP) 2010, *Improving Africa's Water Security: Progress in integrated water resources management in eastern and southern Africa*, Global Water Partnership Eastern Africa & Global Water Partnership Southern Africa, Pretoria.

Government of Botswana 2008, *National investment brief, Botswana*, Prepared for the High-Level Conference on Water for Agriculture and Energy in Africa: The Challenges of Climate Change, 15–17 December, Sirte, Libyan Arab Jamahiriya, www.sirtewaterandenergy.org/docs/reports/Botswana-Draft2.pdf [accessed 12 November 2012].

Government of Kenya 2008, *Water for agriculture and energy in Africa: the challenges of climate change*, National Investment Brief prepared for the High-Level Conference on Water for Agriculture and Energy in Africa: The Challenges of Climate Change, 15–17 December, Sirte, Libyan Arab Jamahiriya.

Government of Mozambique 2011, *Compact for Development of the Agriculture Sector in Mozambique in the Context of CAADP*, Government of Mozambique, Maputo, www.aec.msu.edu/fs2/mozambique/caadp/PACTO_Novembro-24-2011_Draft_finalEnglish.pdf [accessed 12 November 2012].

Government of Zimbabwe 2011, *Zimbabwe Medium Term Plan, 2011–2015*, Government of Zimbabwe, Harare, www.agbiz.co.za/LinkClick.aspx?fileticket=GbVmM2kyaeg%3D&tabid=337 [accessed 12 November 2012].

Government of Zimbabwe 2012, *Draft Zimbabwe agriculture investment plan 2012–2016 (ZAIP), A comprehensive framework for the development of Zimbabwe's agriculture sector*, Government of Zimbabwe, Harare.

Hanjra, M & Gichuki, F 2008, 'Investment in agricultural water management for poverty reduction in Africa: case studies of Limpopo, Nile and Volta river basins', *Natural Resources Forum*, 32: 185–202.

Holling, CS 1978, *Adaptive Environmental Assessment and Management*, John Wiley, London.

Hsiao, TC, Steduto, P & Fereres, E 2007, 'A systematic and quantitative approach to improve water use efficiency in agriculture', *Irrigation Science*, 25(3): 209–31.

INAG [Water Institute] 2011, *Estratégia Nacional de Irrigação*, Ministério de Agricultura, Maputo.

Inocencio, A, Kikuchi, M, Tonosaki, M, Maruyama, A, Merrey, D, Sally, H & de Jong, I 2007, *Costs and performance of irrigation projects: a comparison of SSA and other developing regions*, IWMI Research Report 109, International Water Management Institute, Colombo.

International Food Policy Research Institute (IFPRI) 2011, *Global Hunger Index. The challenge of hunger: Taming price spikes and excessive food price volatility*, International Food Policy Research Institute, Washington, DC, www.ifpri.org/sites/default/files/publications/ghi11.pdf [accessed 12 November 2012].

International Fund for Agricultural Development (IFAD) 2010, *Rural Poverty Report 2011. New realities, new challenges: New opportunities for tomorrow's generation*, International Fund for Agricultural Development, Rome.

International Water Management Institute (IWMI) 2007, *Water for Food, Water for Life: A comprehensive assessment of water management in agriculture*, Earthscan & International Water Management Institute, London & Colombo.

Jones, WI 1995, *The World Bank and Irrigation*, The World Bank, Washington, DC.

Kashaigili, JJ, Rajabu, K & Masolwa, P 2009, 'Freshwater management and climate change adaptation: experiences from the Great Ruaha River catchment in Tanzania', *Climate and Development*, 1(3): 220–8.

Khan, S, Rana, T & Hanjra, M 2008, 'A cross disciplinary framework for linking farms with regional groundwater and salinity management targets', *Agricultural Water Management*, 95: 35–47.

Kijne, JW 2006, 'Abiotic stress and water scarcity: identifying and resolving conflicts from plant level to global level', *Field Crops Research*, 97: 3–18.

Kodamaya, S 2009, Recent changes in small-scale irrigation in Zambia: the case of a village in Chibombo District, Unpublished project report, Graduate School of Social Sciences, Hitotsubashi University, Tokyo, https://docs.google.com/viewer?a=v&q=cache:HnJ5oRvwrkEJ:www.chikyu.ac.jp/resilience/files/ReportFY2008/ResilienceProject_Report2009_10.pdf+&hl=en&gl=za&pid=bl&srcid=ADGEESiTywcb7aEpQcYITvzXXOnoRxyIpBz1MPjwFwftedKyVnspQav_laowmHAeY144VQ9diHScxYeSZUhSiwMKtLkGQKRJyZfIVgCC4Cf3x9UJZLQ6Ps4cOh38f0jgdn3KHPhfpbsL&sig=AHIEtbRDUISdJAILX6_nFqQ8qBMOPcE60g [accessed 11 November 2012].

Lankford, BA 2005, *Rural infrastructure to contribute to African agricultural development: the case of irrigation*, Report for the Commission for Africa, University of East Anglia, Norwich.

Lankford, BA 2009, 'Viewpoint—the right irrigation? Policy directions for agricultural water management in sub-Saharan Africa', *Water Alternatives*, 2(3): 476–80.

Lee, K 1993, *Compass and Gyroscope: Integrating science and politics for the environment*, Island Press, Washington, DC.

MacDonald, AM, Bonsor, HC, Dochartaigh, BEO & Taylor, RG 2012, 'Quantitative maps of groundwater resources in Africa', *Environmental Research Letters*, 7: 024009.

Makurira, H 2012, *Rainwater harvesting and conservation agriculture in the southern African region. Potential incentives for sustainable farming for food and water security and poverty reduction in southern Africa*, Component report prepared for the project: Assessing Potential Incentives for Sustainable Farming for Food Security, Water and Poverty Reduction in Southern Africa, The Australian National University, Canberra.

Meffe, GK, Nielsen, LA, Knight, RL & Schenborn, DA 2002, *Ecosystem Management: Adaptive community-based conservation*, Island Press, Washington, DC.

Ministério de Agricultura (MINAG) 2011, *Plano Estratégico para o Desenvolvimento do Sector Agrário – PEDSA (2010–2019)*, Ministério de Agricultura, Maputo.

Ministério de Agricultura (MINAG) 2012, *Programa Nacional de Investimento do Sector Agrário (PNISA) 2012–2017*, Documento draft em discussão, Ministério de Agricultura, Maputo.

Munguambe, P, Chilundo, M & Massingue, F 2009, *The IWRM Planning Process in Mozambique – Achievements, lessons and challenges*, Partnership for Africa's Water Development Programme II and Global Water Partnership—SA, Maputo.

Newman, B, Adams, T, Biswas, T, Meissner, T & Smith, K 2012, Irrigation recharge to saline aquifers in the Australian Murray mallee region, Irrigation Australia Limited Conference, 24–29 June, Adelaide.

New Partnership for Africa's Development (NEPAD) (n.d.), *The Comprehensive African Agriculture Development Programme (CAADP). Countries with investment plans*, New Partnership for Africa's Development, Midrand, South Africa, www.caadp.net/pdf/Table 1 Countries with Investment Plans ver15 (2).pdf.

New Partnership for Africa's Development (NEPAD) 2012, *The Comprehensive African Agriculture Development Programme (CAADP). How CAADP works*, New Partnership for Africa's Development, Midrand, South Africa, www.caadp.net/how-caadp-works.php [accessed 26 November 2012].

Ostrom, E, Burger, J, Field, CB, Norgaard, RB & Policansky, D 1999, 'Revisiting the commons: local lessons, global challenges', *Science*, 284: 278–82.

Pahl-Wostl, C & Hare, M 2004, 'Processes of social learning in integrated resources management', *Journal of Community and Applied Social Psychology*, 14: 193–206.

Perry, C, Steduto, P, Allen, RG & Burt, CM 2009, 'Increasing productivity in irrigated agriculture: agronomic constraints and hydrological realities', *Agricultural Water Management*, 96(11): 1517–24.

Pittock, J 2011, *Enhancing collaboration between Africa and Australia on the use of water in sustainable agriculture*, Component report prepared for the project: Assessing Potential Incentives for Sustainable Farming for Food Security, Water and Poverty Reduction in Southern Africa, The Australian National University, Canberra.

Pretty, J, Toulmin, C & Williams, S 2011, 'Sustainable intensification in African agriculture', *International Journal of Agricultural Sustainability*, 9: 5–24.

Republic of Uganda 2011, *A National Irrigation Master Plan for Uganda (2010–2035)*, Ministry of Water and Environment, Kampala, www.google.co.za/url?sa=t&rct=j&q=&esrc=s&frm=1&source=web&cd=5&ved=0CEIQFjAE&url=http%3A%2F%2Fwww.mwe.go.ug%2Findex.php%3Foption%3Dcom_docman%26task%3Ddoc_download%26gid%3D167%26Itemid%3D223&ei=eS-uUPucEeyp0AWnlICgAg&usg=AFQjCNFPZvZ6V-7RAQmOYvwWSC29a3sidw [accessed 11 November 2012].

Rijsberman, FR 2006, 'Water scarcity: fact or fiction?', *Agricultural Water Management*, 80(1–3): 5–22.

Roux, DJ & Foxcroft, LC 2011, 'The development and application of strategic adaptive management within South African national parks', *Koedoe*, 53(2): #1049.

Shah, T, van Koppen, B, Merrey, D, de Lange, M & Samad, M 2002, *Institutional alternatives in African smallholder irrigation: lessons from international experience with irrigation management transfer*, IWMI Research Report 60, International Water Management Institute, Colombo.

Smakhtin, V 2008, 'Basin closure and environmental flow requirements', *Water Resources Development*, 24(2): 227–33.

Stankey, GH, Clark, RN & Bormann, BT 2005, *Adaptive Management of Natural Resources: Theory, concepts, and management institutions*, Forest Service, Department of Agriculture, Portland, Ore.

Stirzaker, RJ, Biggs, HC, Roux, DJ & Cilliers, P 2010, 'Requisite simplicities to help negotiate complex problems', *Ambio*, 39: 600–7.

Svendsen, M, Ewing, M & Msangi, S 2009, *Measuring irrigation performance in Africa*, IFPRI Discussion Paper 00894, International Food Policy Research Institute, Washington, DC.

Therkildsen, O. 2011, *Policy making and implementation in agriculture: Tanzania's push for irrigated rice*, DIIS Working Paper 2011:26, Danish Institute for International Studies, Copenhagen.

United Republic of Tanzania 2011, *Tanzania Agriculture and Food Security Investment Plan (TAFSIP)*, Second draft summary report, 22 May 2011, United Republic of Tanzania, Dar es Salaam, http://agrilinks.org/library/tanzania-agriculture-and-food-security-investment-plan-tafsip-second-draft-summary-report or http://agrilinks.org/sites/default/files/resource/files/Tanzania%20Second%20Draft%20Summary%20TAFSIP.PDF [accessed 11 November 2012].

van Averbeke, W, Denison, J & Mnkeni, PNS 2011, 'Smallholder irrigation schemes in South Africa: a review of knowledge generated by the Water Research Commission', *Water SA*, 37: 797–808.

van Koppen, B, Smits, S, Moriarty, P, Penning de Vries, F, Mikhail, M & Boelee, E 2009, *Climbing the Water Ladder: Multiple-use water services for poverty reduction*, IRC International Water and Sanitation Centre and International Water Management Institute, the Hague.

Woodhill, J 2010, 'Capacities for institutional innovation: a complexity perspective', *IDS Bulletin*, 41: 47–59.

World Bank (n.d.), *Investment in agricultural water for poverty reduction and economic growth in sub-Saharan Africa*, Synthesis report, A collaborative program of AFDB, FAO, IFAD, IWMI & The World Bank, The World Bank, Washington, DC.

World Bank 2009, *Gender in Agriculture Sourcebook*, Agriculture and Rural Development Series, The World Bank, Washington, DC.

You, L, Ringler, C, Nelson, G, Wood-Sichra, U, Robertson, R, Wood, S, Guo, Z, Zhu, T & Sun Y 2010, *What is the irrigation potential for Africa? A combined biophysical and socioeconomic approach*, IFPRI Discussion Paper 00993, International Food Policy Research Institute, Washington, DC.

You, LZ 2008, *Irrigation investment needs in sub-Saharan Africa. Africa infrastructure country diagnostic (AICD)*, Background Paper 9, International Food Policy Research Institute, Washington, DC.

Chapter 4

The role of better water management in agriculture for poverty reduction

JEAN-MARC MWENGE KAHINDA AND MUTSA MASIYANDIMA

Introduction

Increased food security is needed in southern Africa to reduce poverty. Food production is constrained by water scarcity, climatic variability, poor soils and agronomic practices, educational needs of emerging farmers, and institutional barriers. Assessments by international and national authorities (such as the Food and Agricultural Organization and the International Water Management Institute) identify increased agricultural production from rainwater and more efficient use of surface and groundwater as priorities. While it is commonly accepted that better management of water and increased agricultural production can significantly contribute to poverty reduction, these benefits are often poorly quantified. Further, the decentralised and small-scale technologies involved in improving agricultural and water management in this way are often less attractive to national leaders, in part because of the difficulties in communicating their benefits.

This chapter reports on the potential for improving incentives for better water use in agriculture at the meso scale in Mozambique, South Africa and Zimbabwe.[3] It is an assessment of current practices and promising options for research and implementation in: a) rainwater harvesting and conservation agriculture; b) adaptive, local-scale water resource management for agriculture; and c) the role of better water management in agriculture for poverty reduction. Therefore, this chapter assesses current knowledge of the contribution to poverty reduction and

[3] This scoping study was supported by the UNESCO Chair in Water Economics and Transboundary Water Governance at the Australian National University.

food security of better management of water and increased agricultural production from conservation agriculture in southern Africa, and reviews indicators that could be used to assess the performance of future conservation agriculture and rainwater harvesting programs.

Water management in agriculture for poverty reduction: Background

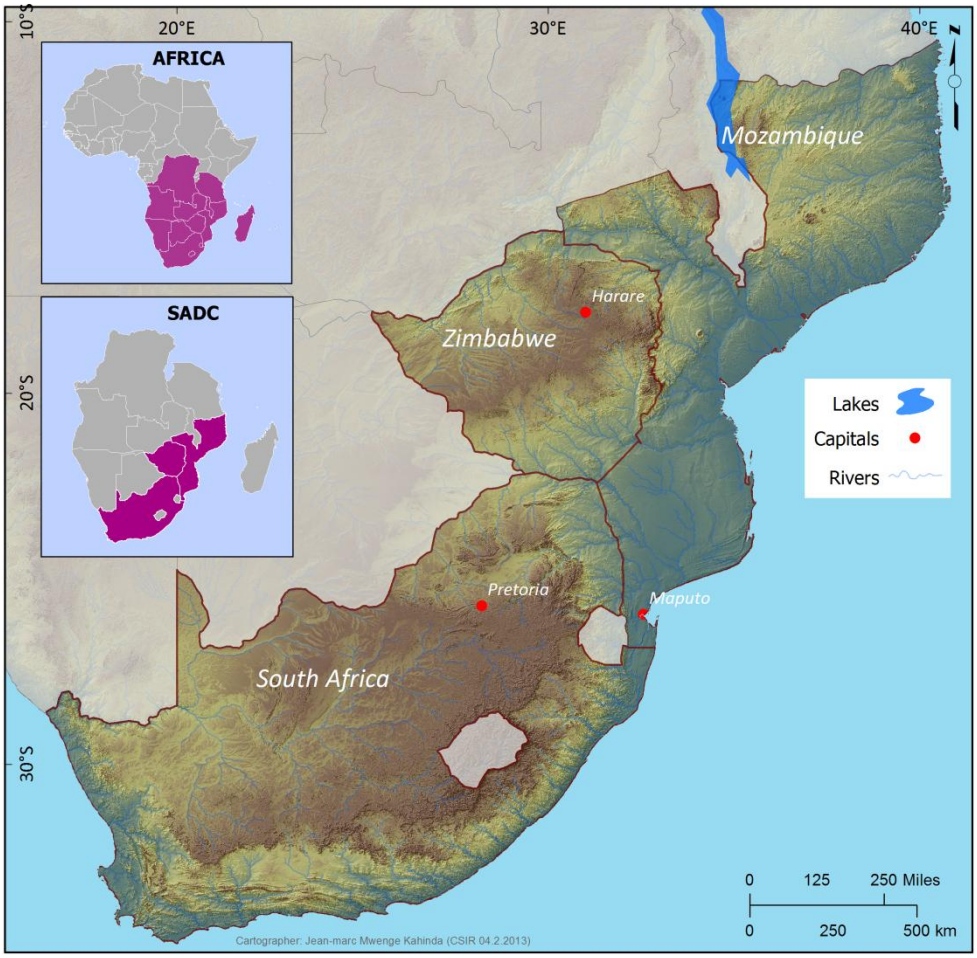
Poverty in southern Africa is invariably linked to lack of access to resources, be they financial or natural resources. Poverty is a lack of access to different livelihood capitals such as water (Sullivan *et al.* 2006). Water is a fundamental input required for livelihoods, health, food production and economic development. Inadequate access to water for consumption and productive uses is a major constraint on poverty alleviation because it deprives communities of the opportunity to sustain their livelihoods (Faurès & Santini 2008). It negatively influences communities' capacity to access food and attain good health. Hanjra *et al.* (2009) highlighted several cases showing the positive effect of access to irrigation water and poverty reduction from 120 empirical studies across Africa and Asia. Yet despite the understanding of the role that access to water for irrigation plays in poverty alleviation, little progress has been made in providing irrigation water to poor farmers across southern Africa. Smallholder farmers in Mozambique, South Africa and Zimbabwe still struggle to produce enough food to meet their daily caloric requirement despite the fact that they have sound water legislation (Jasper 2001; Schreiner & Van Koppen 2002) and agricultural policies (Jeje *et al.* 1998; OECD 2006; Reardon *et al.* 1999). Given the prevalence of rain-fed farming systems in these countries, significant resources have been channelled to enhancing the use of water in the forms accessible to farmers through conservation agriculture and rainwater harvesting.

This component of the project is on the role of better water management in agriculture for poverty reduction, with a specific focus on rainwater harvesting and conservation agriculture.

Study area

The focus of this study is on Mozambique, South Africa and Zimbabwe (Figure 4.1). Nevertheless, various examples from the Southern African Development Community (SADC) region and elsewhere in sub-Saharan Africa are considered. Currently SADC has a membership of 15 states sharing the common vision to ensure economic wellbeing, improvement of standards of living and quality of life, freedom and social justice and peace and security for the people of southern Africa.

Figure 4.1 Location map of Mozambique, South Africa and Zimbabwe



Water and poverty

Water is a necessary condition for growth and development, but not sufficient on its own to reduce poverty. Poverty and water are closely intertwined (Schreiner & Van Koppen 2002) because poor communities rely heavily on natural resources. Consequently the water goods and services provided by ecosystems form a vital lifeline for poverty alleviation. According to Soussan (2004), sustained agricultural development is critical to economic growth and development of developing countries. While water does not directly enhance livelihood, extending the provision of water supply and investing in agriculture, especially for poor communities, lead to significant improvements in livelihood opportunities (PEP 2006; Soussan 2004). Water makes a major contribution to economic growth and development, as a critical factor of production in many crucial sectors and through enhancing health, reducing vulnerability and ensuring greater livelihoods security that in turn create a climate more conducive to investments and enhanced labour productivity (PEP 2006). According to Kemper and Sadoff

(2006), poverty-reducing water strategies should involve broad and targeted actions in water resources and water services. Water is not the only limiting factor to agricultural production (Mwenge Kahinda *et al.* 2007a; Rockström *et al.* 2003), but it is a key input for enhancing agricultural production and other water-related livelihood activities especially in water-stressed countries like South Africa and Zimbabwe.

Smallholder farmers in rural sub-Saharan Africa require, among other interventions, investments in rain-fed water management and supplementary irrigation where feasible. Faurès and Santini (2008) assessed that potential for poverty reduction through water interventions is high in Mozambique and Zimbabwe and moderate in South Africa (Figure 4.2).

Figure 4.2 Potential for poverty reduction in sub-Saharan Africa through water interventions

It is difficult to estimate the portion of the southern African population living below the poverty line, and relying solely on smallholder rain-fed agriculture for

their subsistence has proven to be a challenge. While in South Africa the social transfers from the state distort this assessment, in Botswana and Zimbabwe, the lack of recent population censuses prevents reliable assessment. It is therefore not surprising that international programs such as the Comprehensive Assessment of Water Management in Agriculture (Molden *et al.* 2007) and the Challenge Programme on Water and Food failed to assess the exact number of smallholder farmers with an acceptable level of accuracy. Nevertheless, it can be assumed, especially for Botswana and Zimbabwe, that populaces living below the poverty line and located in rural areas depend on rain-fed agriculture for their livelihood.

Definitions: Conservation agriculture and rainwater harvesting

Conservation agriculture

Conservation agriculture (CA) is a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment (Kassim *et al.* 2009). It was defined by Hobbs (2007) as minimal soil disturbance (no till) and permanent soil cover (mulch) combined with rotations, as a more sustainable cultivation system for the future. The three characteristics of CA are thus:

- continuous minimum mechanical soil disturbance;
- permanent organic soil cover; and
- crop rotations.

The term CA is also used to refer to a suite of technologies aimed at achieving sustainable and profitable agriculture. Depending on technology type, CA achieves the purposes of improving agricultural productivity, reducing the water used for agricultural productivity, improving water efficiency in agriculture or increasing agricultural water productivity, and reducing soil erosion. CA is thus seen as a way of improving water use efficiency in agriculture or increasing water productivity. Although used by some scholars (Rockström *et al.* 2008) as an equivalent to conservation tillage, the two terms define two different concepts, as the latter term involves more soil disturbance. The three CA principles are minimal soil disturbance, permanent soil cover and crop rotations. Practitioners perceive it as a valid tool for sustainable land management (SLM). Water conservation is a key attribute of CA (Giller *et al.* 2011). The water-related benefits of conservation agriculture are enhanced infiltration and increased soil water retention, which are results of improved soil structure. With increasing competition for water among various sectors, irrigated agriculture is facing increasing competition for low-cost, high-quality water (Howell 2001). CA approaches include water conservation measures that lead to increasing the proportion of water that is beneficially used by plants. It also reduces evapotranspiration losses as a result of soil cover and reduced bare-soil evaporation. CA results in increased agricultural output per unit of water. CA can

be used as a way to reduce water allocation to irrigated agriculture and reduce water degradation through reduced erosion. It provides opportunities for reallocating water to other sectors. Other positive benefits of CA include reduced soil erosion, nutrient availability for crops and increased soil organic matter accumulation.

Rainwater harvesting

Rainwater harvesting (RWH) is a general term that describes the concentration, collection, storage and use of rainwater run-off for agriculture, human consumption, other domestic activities, environmental purposes and a number of small-scale productive activities (Gould 1999; Oweis *et al.* 2001). Hence, RWH consists of a wide range of technologies used to collect, store and provide water with the particular aim of meeting demand for water by humans and/or human activities (Barron 2009).

When classified according to the catchment area used, we distinguish:

1. in-situ RWH (iRWH, also called micro-catchment or in-field RWH), where the system uses part of the target area as the catchment area;
2. ex-situ RWH (xRWH, also called macro-catchment or ex-field RWH), where the system uses an uncultivated area as its catchment area; and
3. domestic RWH (dRWH), where the system collects water from rooftops, courtyards, compacted or treated surfaces, and stores it in RWH tanks (above and/or underground) for domestic uses.

A RWH system has three major physical components (Table 4.1):

- a catchment area: where water is harvested;
- a storage facility and/or conveyance system: where water is stored (a reservoir, a cistern, the soil profile, and so on); and
- a target area: where water is used (by human beings, crops, plants, animals, enterprises, and so on).

The management of RWH is a non-physical component and is key to its success.

Table 4.1 Components of the different RWH categories

RWH category	Catchment area	Storage facility	Target use/users
dRWH	Rooftop, path, road, rock, marginal land	Aboveground or underground tank	Human beings, animals, crops and small businesses
iRWH	Arable land	Soil surface, mini-pond or basin	Crops
xRWH	Marginal land, arable land	Dam, reservoir, pond, soil, tanks	Animals, enterprises, crops

Source: Mwenge Kahinda, J 2010, Decision support system for sustainable rainwater harvesting in South Africa, [Unpublished PhD thesis], University of the Witwatersrand, Johannesburg.

CA and RWH in South Africa, Mozambique and Zimbabwe

Conservation agriculture

CA adoption in southern Africa has been a result of donor, Food and Agriculture Organization (FAO) and International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) activities that encourage CA as a way of improving agricultural productivity. CA projects are on the increase; however, CA adoption rates vary widely between the three countries (Table 4.2). The governments take CA activities seriously. As such, South Africa, Mozambique and Zimbabwe have identified CA focal points to promote and coordinate CA activities (FAO 2010a). Estimates of the scale of CA activity in Africa, and the number of households practising CA, vary substantially from one scholar to another (Midler *et al.* 2011). In 2009 the area under CA in Mozambique, South Africa and Zimbabwe was less than five percent of the cropped area in 2008 (Table 4.2). Smallholder farmers often fail to fully implement the CA package and its three core principles (minimal soil disturbance, continuous soil cover and crop rotations). Hence, if we strictly apply the CA definition, agricultural practices that do not exhibit the three components of CA cannot be considered as CA.

Table 4.2 CA adoption in southern Africa, including total area under CA management and numbers of smallholders adopting CA practices

Country	Area under CA (ha)	2008 CA area as % of crop area in 2009
Mozambique	9,000	0.2
South Africa	368,000	2.4
Zimbabwe	15 000	0.4

Sources: Kassam, A, Friedrich, T, Shaxson, F & Pretty, J 2009, 'The spread of conservation agriculture: justification, sustainability, and uptake', International Journal of Agricultural Sustainability*, 7(4): 292–320; Milder et al. 2011.*

Nevertheless, CA techniques have several benefits measured or observed at field/plot scale (Table 4.3).

Rainwater harvesting techniques

There are several RWH techniques; Table 4.4 presents some of these. Rooftop RWH is a major source of drinking water in rural South Africa especially in the Eastern Cape and KwaZulu-Natal (Mwenge Kahinda *et al.* 2007b, 2010), and there is great potential for its implementation in Mozambique and Zimbabwe (Mati *et al.* 2006).

Table 4.3 CA techniques and benefits

CA principle	CA technique	Benefit	Scale*
Continuous minimum mechanical soil disturbance	No till	No till with retained residues improves soil moisture and reduces erosion	Field/plot
	Reduced tillage	Low tillage costs	Field/plot
	Conservation farming—planting basins with mulch and crop residues	▪ Increased soil moisture ▪ Reduced bare-soil evaporation ▪ Reduced erosion	Field/plot
Permanent organic soil cover	Cover crops	▪ Improving soil fertility ▪ Improving soil structure (with the secondary benefit of increasing soil porosity and improving infiltration and soil water retention) ▪ Reducing bare-soil evaporation ▪ Maintaining soil moisture	Field/plot
	Mulch	▪ Increasing infiltration ▪ Reducing bare-soil evaporation ▪ Increasing water use efficiency	Field/plot
Crop rotations	Legume rotations	▪ Improving soil fertility ▪ Improving soil structure—improves soil water retention	Field/plot
	Intercropping		Field/plot

** Scale at which benefit is measured or observed.*

Mozambique

Zai pits are used in the Chokwe District (Ncube *et al.* 2008). Planting pits with a diameter of 20–40 cm and a depth of 10–20 cm are dug and filled with composted organic matter. The excavated earth is ridged around the semicircle to improve the water-retention capacity of the pit.

South Africa

There are iRWH and xRWH systems spread all over South Africa. Denison and Wotshela (2009) documented the following RWH techniques:

- In Gogela (KwaZulu-Natal) they use stone terracing. Specific portions of land are enclosed with boulders and stones that prevent run-off from cascading further down the fields.
- In Thaba Nchu (Free State) and in Tyume Valley (Eastern Cape), hand-dug ponds (*Matamo* in Sotho, or *Ipitsi* in Xhosa) are used to store rainwater.

Table 4.4 RWH techniques per categories

Category	Technique	Use	Storage type
dRWH	Rooftop	Cooking, etc.	(Sub)surface
		Cooking, etc.	(Sub)surface
		Vegetable garden	(Sub)surface
	Tanks	Vegetable garden	Subsurface
iRWH	Contour ridges	Field/crops	Soil profile
		Vegetables	Soil profile
	Semicircular and trapezoidal bunds	Field/crops	Soil profile
		Vegetables	Soil profile
	Small pits	Field	Soil profile
	Small run-off basin	Trees/forestry	Soil profile
	Run-off strips	Field	Soil profile
	Inter-row	Vegetables	Soil profile
		Field	Soil profile
	Meskat	Field	Soil profile
	Contour bench terraces	Field	Soil profile
xRWH	Small reservoirs	All crops	(Sub)surface
	Riverbed	Trees/vegetables	Surface/soil profile
	Water spreading	Field/trees	Soil profile
	Large bunds	Field	Soil profile
	Tanks	All crops	Subsurface
	Cisterns	Drinking/trees/vegetables	Subsurface
	Hillside run-off	Field/trees	Soil profile

Source: After Oweis, T, Prinz, D & Hachum, A 2001, Water Harvesting: Indigenous knowledge for the future of the drier environments, International Centre for Agricultural Research in the Dry Areas, Aleppo.

- Across South Africa, trench-bed gardening is used. The trench system consists of removing soil from the bed, placing organic material at the bottom of the trench, and replacing the soil, taking care to form a terraced bed that will hold water.
- In the Northern Cape areas around Clanwilliam, north-east of the Cedarberg Mountains and north of the Roggeveldberge, planting dams (*Saaidamme* in Afrikaans) are used. The fertile, silt-laden floodwater from the distant mountains (some 100–150 km away in this case) is diverted with structures into a series of large, flat basins that extend between 1 ha and 100 ha in size each. Each basin is ringed by a low earth wall between 1 and 2 m deep and is effectively a flat, shallow dam. The water is kept in the basins between one and three days to saturate the very deep alluvial soils.
- In Stilbaai (Western Cape) the naturally hardened and impermeable surface is cleaned and compacted in order to harvest rainwater that is channelled to an underground tank.
- In Ploegvore (Northern Cape) planting pits are constructed in a variety of circles and ellipses, to depths of 5 cm to 1 m and with spacing of 2–5 m for tree crops and closer for field crops.
- In the Thaba Nchu area (Free State), Kayalethu and Guquka (Eastern Cape) and KwaMncane and Entembeni (KwaZulu-Natal), the micro-basin tillage technique, which consists of 2 m wide sloping run-off strips and 1 m wide basins, is used. The main characteristics of the technique include promoting surface run-off on the run-off strips and storing the run-off water in the basins where it infiltrates.

Zimbabwe

In-situ RWH techniques that are promoted throughout southern Zimbabwe include the following:

- Dead-level contours with or without infiltration pits: dead-level contours are deep trenches, with a cross-sectional dimension of 1.5 m width and 0.5 m depth, dug along the contour ridge to harness run-off and increase infiltration (Mwenge Kahinda 2004). Within the trenches, infiltration pits are built and filled with grass or stover covered with a thin layer of soil (Motsi *et al.* 2004).
- Graded contour ridges: Graded contours are small earthen ridges, 15–20 cm high, constructed across the slopes of cultivated land with a slope of less than five percent (Mupangwa *et al.* 2006).
- Terracing: a ditch is dug on the contour with soil thrown uphill to form a bank that is then seeded with grass (Twomlow *et al.* 1999).
- Small reservoirs: reservoirs generally harnessing water from undefined drainage networks, which is used primarily for supplementary irrigation (Mwenge Kahinda *et al.* 2007a).

- Rock catchments: run-off generated on rocks (protruding granite) located uphill of the field is either diverted to the field or stored in a pond (Mwenge Kahinda 2004).

Upscaling conservation agriculture and rainwater harvesting

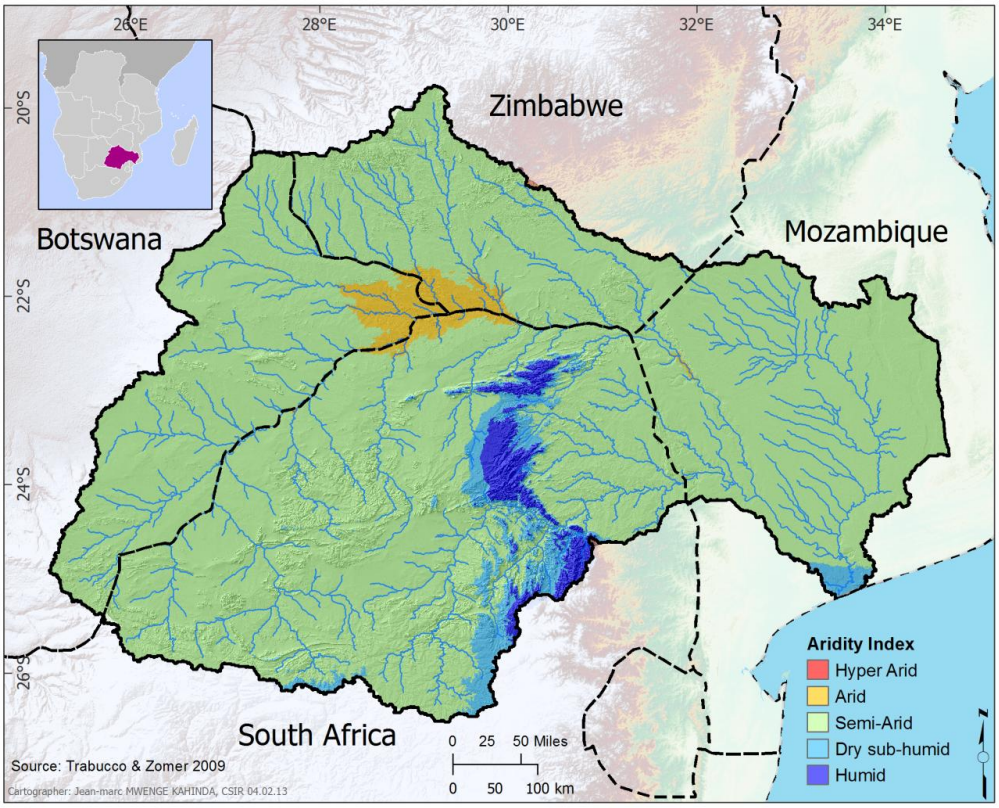
At present, both CA and RWH are implemented below their potential in Africa. A number of scholars have assessed the suitability of RWH in the SADC region. Mbilinyi *et al.* (2006) used physical attributes to produce composite maps that show attributes or 'development domains' that serve as indicators of suitability for targeted RWH interventions in Tanzania. Mwenge Kahinda *et al.* (2009) used biophysical and socioeconomic data sets to assess the RWH footprint of any given area of South Africa. The South African Agricultural Research Council (ARC) has been piloting a RWH program in the Taba Nchu area over the past 15 years but the technique has not extended beyond small plots around homesteads with total adoption of about 0.5 percent of the Upper Middle Modder River Basin. Nevertheless, there are factors such as land tenure, access to capital investment, lack of labour, inappropriate extension services and inappropriate institutions that prevent the upscaling of innovative technologies such as CA and RWH. Makurira (2011) and Mwenge Kahinda and Taigbenu (2011) provide a good account of these factors. In addition, inadequate research and development attention has been paid to the special needs of smallholder farmers, especially on affordable CA equipment (Kassam *et al.* 2009).

Subsistence agriculture in Mozambique, South Africa and Zimbabwe

Regardless of the fact that South Africa is a net food exporter in the region (Table 4.5), its government is faced with a major challenge of feeding and empowering a large segment of its people, most of whom live in rural areas and practise dryland agriculture (Mwenge Kahinda & Taigbenu 2011). Mozambique, South Africa and Zimbabwe receive highly variable rainfall—in both space and time—which generally occurs as storms of high rainfall intensity and short duration. They often experience agricultural droughts and dry spells that reduce harvests or cause total crop failure. With more than 60 percent of water being used for agricultural purposes (Table 4.5), there is little prospect to expand irrigation unless more efficient types of irrigation technologies are utilised.

Smallholder farmers in all three countries have limited access to irrigation. Their agricultural production is primarily rain fed. Incidences of crop failure are high due to high rainfall variability and high incidences of drought. The Limpopo River Basin, which is shared by the three countries and Botswana, is home to more than one million people who depend partly on subsistence agriculture for their livelihoods. The basin area—characterised by an aridity index ranging from 0.05 to 0.65—is mainly arid and semi-arid (Figure 4.3); therefore to enhance yields smallholder farmers need to manage rainfall through interventions such as CA that are said to increase soil moisture.

Figure 4.3 Aridity Index—Limpopo River Basin



RWH is also recommended as a way of redistributing the rainfall that sometimes occurs in a few high-intensity events. Thus, the challenge faced by smallholder farmers is to enhance water productivity of rain-fed agriculture by mitigating intra-seasonal dry spells (ISDS) through the adoption of 'innovative' water management technologies (Mwenge Kahinda *et al.* 2007a).

Mozambique and Zimbabwe have a Global Hunger Index (GHI) of about 20—indicating a high proportion of people who cannot meet their daily calorie requirements.

Significant resources have gone into increasing water productivity aimed at increasing food security in the basin (for example, research funded by the Challenge Program on Water and Food of the Consultative Group on International Agricultural Research, CGIAR). There are still no tangible results linking increased water productivity and poverty alleviation; however, anecdotal data from studies elsewhere in Africa and Asia (Table 4.6) show that improving water availability for crops through irrigation improves food security. Similar to irrigation, conservation agriculture and RWH are intended to improve soil moisture in the root zone and facilitate optimum plant growth.

Table 4.5 Agricultural land utilisation in Mozambique, South Africa and Zimbabwe

Country	Land area (1000 ha)	Arable land (1000 ha)	Irrigated land (1000 ha)	Water use by agriculture (%)	Population (millions)	Global Hunger Index	Cereal production (1000 t)	% of GDP
Mozambique	78,638	4,500	118	87.3	23.4	23.7	1,601	20.9
South Africa	121,447	14,500	1,498	62.7	50.5	7.3	14,586	2.5
Zimbabwe	38,685	3,730	174	78.9	12.6	20.9	700	19

Source: Food and Agriculture Organization Statistical Database (FAOSTAT) 2010, FAOSTAT Database, Food and Agricultural Organization of the United Nations, Rome, www.faostat.fao.org [accessed 18 August 2011].

Significant resources have gone into increasing water productivity aimed at increasing food security in the basin (for example, research funded by the Challenge Program on Water and Food of the Consultative Group on International Agricultural Research, CGIAR). There are still no tangible results linking increased water productivity and poverty alleviation; however, anecdotal data from studies elsewhere in Africa and Asia (Table 4.6) show that improving water availability for crops through irrigation improves food security. Similar to irrigation, conservation agriculture and RWH are intended to improve soil moisture in the root zone and facilitate optimum plant growth.

Table 4.6 Poverty-alleviation benefits of increased moisture availability through irrigation

Immigration benefit	Country/region	Reference
Increased crop output through higher yields and higher cropping intensities	India	Evenson & Gollin (2003)
	China	Huang *et al.* (2006)
Higher production and higher incomes make food available and affordable for the poor, due to a steady supply of food, lower prices and increased purchasing power	Ethiopia	van den Berg & Ruben (2006)
	Gambia	von Braun *et al.* (1989)
Irrigation enables farmers to switch from subsistence to market-oriented production and thus supports crop diversification and specialisation, which generate demand for rain-fed crops, leading to second-round effects on poverty reduction within and outside command areas		Binswanger & von Braun (1991)

Immigration benefit	Country/region	Reference
Reduction of inter-temporal and seasonal variance in output, employment and prices, thus reducing vulnerability and poverty via output and income stabilisation effects	Pakistan	Kurosaki (2006)
		Lipton *et al.* (2003)
Improved nutrition and health due to greater availability and larger amounts of staple food supplies, cleaner water, adequate nutrient intake, more diversified and balanced diets, and improved intra-household allocation of food	West Africa	von Braun (1988)
Irrigation improves equity in favour of the poor	South Africa	Prasad *et al.* (2006)

Mozambique

Smallholder farmers who cultivate about 97 percent of cultivated arable land dominate Mozambique's agricultural sector (FAO 2011a). The sector employs about 81 percent of the country's population (FAO & WFP 2007). Agriculture in Mozambique, as in most countries of the SADC region, provides a precarious livelihood to smallholder farmers who experience crop failure and low productivity with their average crop yields about one-half of the regional average (FAO & WFP 2007). Crop failure and low productivity are in part due to highly variable rainfall. Nevertheless, substantial quantities of maize are exported both formally and informally to neighbouring countries, mainly Malawi.

South Africa

South Africa has a dual agricultural economy, comprising a well-developed commercial sector and a predominantly subsistence-oriented sector in the rural areas. Unlike most other SADC countries, in South Africa the bulk of agricultural production comes from the commercial sector. The agricultural sector is the primary source of income for about 8.5 million people (Burger 2011). While the sector contributes about 2.5 percent to South Africa's GDP (FAOSTAT 2010) and about seven percent to formal employment, the agro-industrial sector is estimated to contribute about 12 percent to GDP (Burger 2011).

Zimbabwe

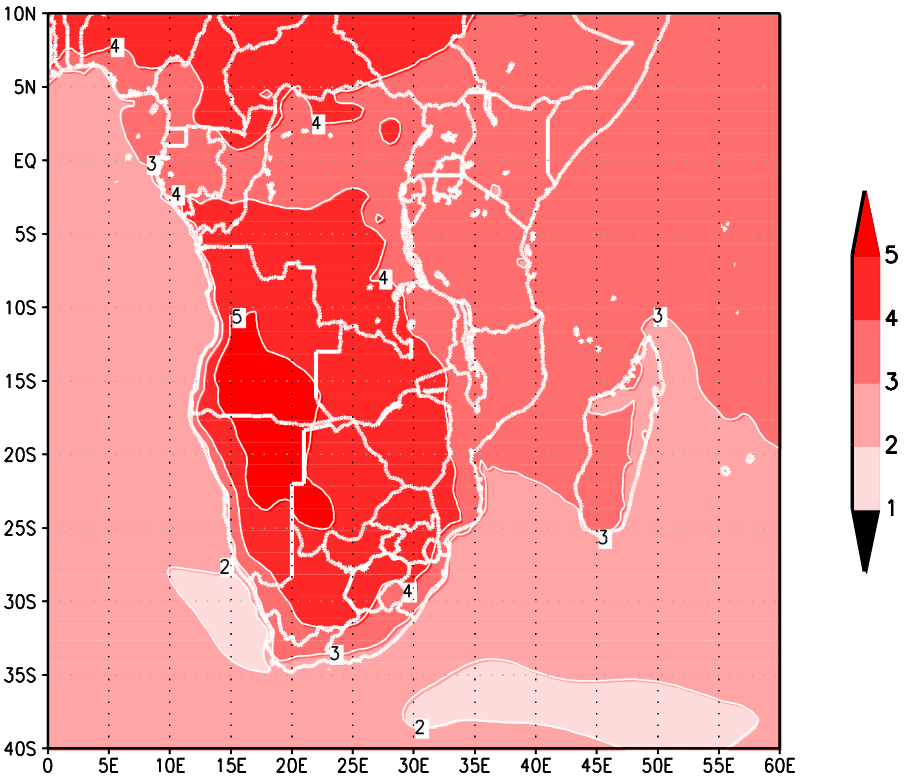
The agricultural sector is the backbone of Zimbabwe's economy, providing livelihood for approximately 70 percent of the population, contributing about 19 percent of GDP (FAOSTAT 2010) and 40–50 percent of exports (FAO & WFP 2007). Until recently, the sector was also characterised by a dualistic structure: low-input and low-productivity smallholder agricultural systems in communal areas and high-input–high-productivity commercial agriculture utilising

predominantly the most fertile areas of the country (FAO 2011b). The sector has now shifted towards basic subsistence farming methods that rely on weather patterns and, as a result, there has been a steady decline in crop yield and an increased exposure to recurrent food insecurity for smallholder farmers (FAO & WFP 2007).

Climate variability and change

Global temperatures over the SADC region have increased by about 0.8°C over the past century, largely in response to the enhanced greenhouse effect (Engelbrecht *et al.* 2009). Over the central interior regions of southern Africa, however, temperatures have been increasing at about twice the global rate (Figure 4.4). This rapid rise in temperature over southern Africa may be attributed to the region's location in the subtropics, in combination with hemispheric changes in circulation systems—primarily the strengthening of the subtropical high-pressure belt over the region (Engelbrecht *et al.* 2009).

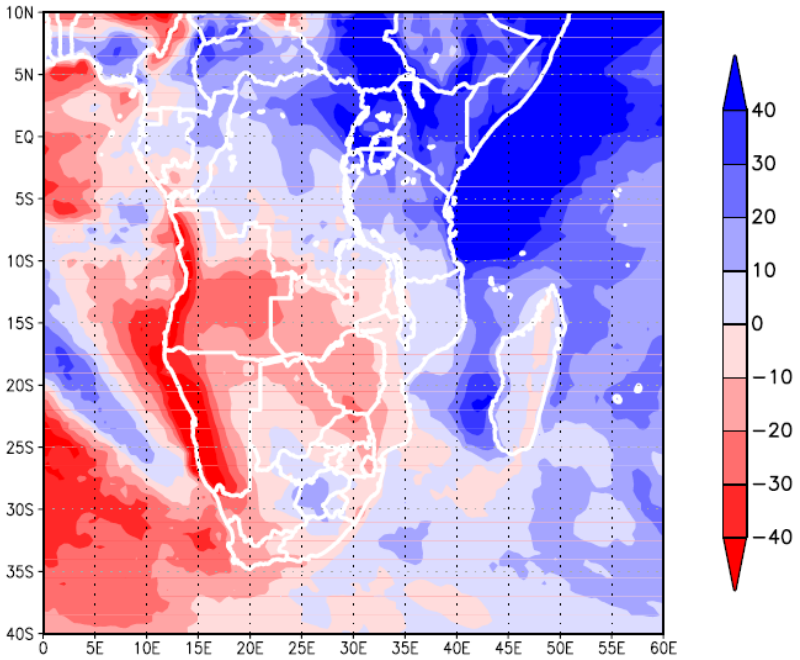
Figure 4.4 Projected percentage changes in summer half-year (ONDJFM) average maximum temperature over Southern and tropical Africa from the CCAM downscalings of 6 CGCMs, for the period 2071–2100



Source: Engelbrecht, FA, 2012. Projected climate futures for southern Africa. Presentation to the Dept of Water Affairs. www.dwaf.gov.za/masibambane/documents/structures/wsslg/Nov17-18-2011/CCAM_DWA_20111117_001.ppt [accessed 4 February 2013].

One of the projected impacts of climate change is reduced precipitation over large areas of the SADC region (Figure 4.5). Reductions in annual rainfall are expected to range between 10 and 40 percent of the mean annual rainfall.

Figure 4.5 Projected percentage changes in average summer (DJF) rainfall over Southern and tropical Africa from the CCAM downscalings of 6 CGCMs, for the period 2071–2100 compared with 1961–1990 under the A2 SRES scenario



Source: Engelbrecht FA, Landman WA, Engelbrecht CJ, Landman S, BOPAPE MM, Roux B, McGregor JL and Thatcher M 2011, 'Multi-scale climate modelling over Southern Africa using a variable-resolution global model'. Water SA 37 (5): 647–658.

In addition to changes in the long-term averages of variables such as rainfall and temperature, climate change may manifest itself over specific regions through increases or decreases in the frequency of occurrence and magnitude of severe weather events such as floods and droughts. Climate change is predicted to intensify the region's struggles with strained water resources and food security (Shewmake 2008). Rising global temperatures are expected to cause declines in agricultural production, threaten biodiversity and the productivity of natural resources, increase the range of vector-borne and waterborne diseases, and exacerbate desertification; thus, they have a disproportionately adverse impact on Africa's agriculture-based economy (Mendelsohn *et al.* 2000). The adverse impacts of climate variability/change on agricultural production could be most negative in areas where the change increases temperature but reduces precipitation at the same rate and simultaneously (Akpalu *et al.* 2008).

While it is possible to account for projected climatic conditions when prioritising areas or catchments for investments in CA and RWH, one has to remember that several sources of uncertainty are associated with the atmospheric global

circulation model. These sources include but are not limited to climate forcing (greenhouse emissions).

Performance indicators

Broadly defined in the context of agricultural water management, a performance indicator is a quantitative or qualitative measurement by which the effectiveness, efficiency, success, and so on, of an innovative agricultural technology are assessed in comparison with set standards or targets. The vast array of performance indicators includes single indicators, composite indicators and aggregated indexes (Walker 2002). A performance indicator should be (USAID 1998) direct—measuring as closely as possible what it is intended to measure; 2) objective—with no ambiguity about what is measured; 3) adequate—taken as a group, a performance indicator and its companion indicators should assess the output using neither too many nor too few variables; 4) quantitative—numerical indicators are more easily understood and can be more easily analysed, while qualitative indicators can supplement quantitative indicators with richness of information; 5) disaggregated—where appropriate in order to track the impact on specific groups; 6) practical—indicator data that can be obtained in a timely way and at reasonable cost, and are easily replicable; and 7) reliable—indicator data are sufficiently reliable for confident decision making.

Agricultural systems can be analysed at various hierarchical levels: cropping systems, farm systems, sub-regional systems, regional systems and national systems (FAO 1992). Furthermore, agricultural production represents a complex system composed of manifold interacting parameters of environmental conditions and human as well as non-human activities (von Wirén-Lehr 2001). It is critical to recognise that performance indicators do not define all aspects of a system. Thus, different spatial scales require different sets of indicators and/or thresholds (Walker *et al.* 2001).

Agricultural productivity performance indicators

Agricultural productivity performance indicators are mainly concerned with the assessment of the crop productivity component, and in some cases economic performance, of agricultural systems. There are several performance indicators of agricultural productivity. These include harvested crop yield, yield gap, yield variability, and value of crop production per household.

Crop yield

Crop yield (expressed as kg ha^{-1}) is the most commonly used agricultural performance indicator. According to Diskin (1997), assessing the impacts of a given intervention on crop yields over time raises a number of important data-measurement and interpretation concerns such as: 1) the climatic conditions and other exogenous factors; 2) the data-collection methods and biases; 3) mixed (inter-)cropping; 4) multiple or continuous harvesting; and 5) the lack of standard units.

Yield increase

The crop yield (kg ha^{-1}) produced under the farmers' conventional tillage practice is often compared with the crop yield obtained under innovative CA and RWH interventions. The yield benefit is calculated either by subtracting the crop yield obtained under conventional tillage from the crop yield obtained under the intervention or by assessing the percentage increase in crop yield. The actual yield takes into consideration social, technical, environmental and economic constraints on the system.

Net margin or profitability

The net margin (profitability) is calculated by deducting the total production costs (expenditures) involved in the enterprise from the total revenue. The revenue is the product of the crop yield by the market price. The expenditures for inputs include direct costs arising from the acquisition of seed, fences, tools, organic and mineral fertilisers, pesticides, herbicides, labour (hired or not), transport of the produce to market, and marketing services. Because labour is not sourced for most smallholder farms, labour is a product of the minimum wage and the sum of manpower required (man days) for farm activities. These activities include the implementation of CA or RWH, planting, applying fertiliser, weeding (either manual or by application of herbicides), applying pesticides, supplementary irrigation and harvesting. In manual cropping systems, land preparation and weeding are labour intensive (Giller *et al.* 2009) and should be counted as expenditure even when the labour is not hired.

Crop water productivity/water use efficiency

Crop water productivity (kg m^{-3}) is the ratio of the net benefits from crop to the amount of water used to produce those benefits (Molden *et al.* 2010; Oweis & Hachum 2006). This definition is scale dependent and, at field or farm scale, means more crop per drop of water (Kijne *et al.* 2003). Increases in crop water productivity are achieved by partitioning precipitation into less surface run-off and more soil moisture, and more soil moisture into crop transpiration and less soil evaporation (Falkenmark & Rockström 2004). Because transpiration governs crop growth, it is more appropriate to consider the transpirational water productivity (WP_T) given by the ratio of crop yield over the productive crop water flow (transpiration); however, given it is difficult to separate productive and non-productive water flows (evaporation), it is common to assess evapotranspirational water productivity (WP_{ET}) (Mwenge Kahinda *et al.* 2007a) (Equation 4.1).

Equation 4.1

$$WP_{ET} = \frac{Y}{ET}$$

Where:

WP_{ET} = Evapotranspirational water productivity (kg m^{-3}); Y = crop yield (kg ha^{-1}); and ET = Evapotranspiration (m^{-3} ha).

Because water use efficiency is a dimensionless term obtained by dividing figures with the same units, the agricultural scientific community now uses the term 'water productivity' as a substitute of the term 'water use efficiency' (Lamaddalena *et al.* 2005).

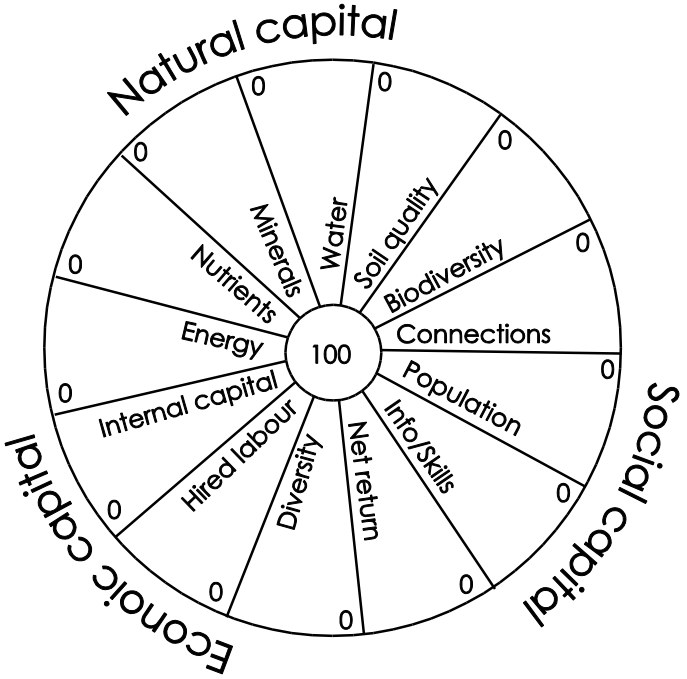
Agricultural crop production index

The FAO uses agricultural production indices that are calculated using the Laspeyres formula. The agricultural crop production indices show agricultural production for each year relative to the base period 1999–2001. The indices are based on price-weighted quantities of commodities produced after deductions of inputs.[4] They include all crops except fodder crops. Regional and income group aggregates for the FAO's production indexes are calculated from the underlying values in international commodity prices, normalised to the base period 1999–2001 (FAO 2011c).

Agricultural sustainability index

Agricultural sustainability indices (ASI) allow the integrated assessments of an agricultural system by combining information provided by different performance indicators (Rao and Rogers 2006). Assessment of agricultural sustainability is thus

Figure 4.6 Sustainability wheel on which the sustainability polygon is constructed



Source: Dumanski, J, Terry, E, Byerlee, D and Pieri, C 1998, Performance indicators for sustainable agriculture, Discussion Note, The World Bank, Washington, DC.

[4] FAO: www.fao.org/waicent/faostat/agricult/indices-e.htm.

complex as it encompasses complex interactions between biophysical and socioeconomic systems (Rao & Rogers 2006). There are different types of agricultural sustainability that can be broadly classified into three groups—those based on: agro-ecosystems, total factor productivity and farm-level assessment frameworks.

For example, the agricultural sustainability index calculated using the Framework for Evaluation of Sustainable Land Management (an on-farm-level framework) combines factors referred to as the five pillars of sustainable land management (productivity, security, protection, viability and acceptability), which aggregate physical, economic and social factors of sustainability. Each factor is rated, positioned on a spoke of the sustainability wheel and then connected to form the sustainability polygon (Figure 4.6).

Water Poverty Index

The Water Poverty Index (WPI) of Sullivan *et al.* (2003) was designed to assist with the challenges of local water management and can be used to track the progress of communities in access to water. The WPI is also used to identify areas of the greatest need for water and therefore facilitates prioritisation of action (Sullivan *et al.* 2006). The component variables of the WPI are:

- resources—how much is available, taking into account seasonal and inter-annual variability and water quality;
- access—how well provisioned the population is, including domestic use and irrigation;
- capacity to manage water resources—based on education, health and access to financing;
- use—captures the use of water and its contribution to the wider economy; and
- environment—attempts to capture the environmental impact of water management to ensure long-term ecological integrity.

The WPI (Equation 4.2) has the structure of the Human Development Index (HDI) (Sullivan *et al.* 2003).

Equation 4.2

$$WPI = \frac{\sum_{i=1}^{N} w_i X_i}{\sum_{i=1}^{N} w_i}$$

Where:

WPI is the Water Poverty Index; X_i is component i of the Water Poverty Index structure for that location; and w_i is the weight applied to the component.

Using the sub-components described above, the WPI can be written as the weighted average of resources (R), access (A), capacity (C), use (U), and

environment (E) (Equation 4.3). Each component is standardised so that it is in the range of 0–100, with 1 as the best condition and 100 the worst.

Equation 4.3

$$WPI = \frac{w_w R + w_a A + w_c C + w_u U + w_e E}{w_r + w_a + w_c + w_u + w_e}$$

A practical application of this methodology is identifying areas where interventions are needed most. These areas with high water poverty are where CA and RWH and other water resource interventions are targeted.

Global Hunger Index

The Global Hunger Index (GHI) is a multidimensional statistical tool developed by Wiesmann *et al.* (2006) and used to describe the state of countries' hunger situation. The index captures three important dimensions of hunger: insufficient availability of food, shortfalls in the nutritional status of children, and child mortality. The GHI is expressed as Equation 4.4.

Equation 4.4

$$GHI = \frac{(PUN + CUW + CM)}{3}$$

Where:

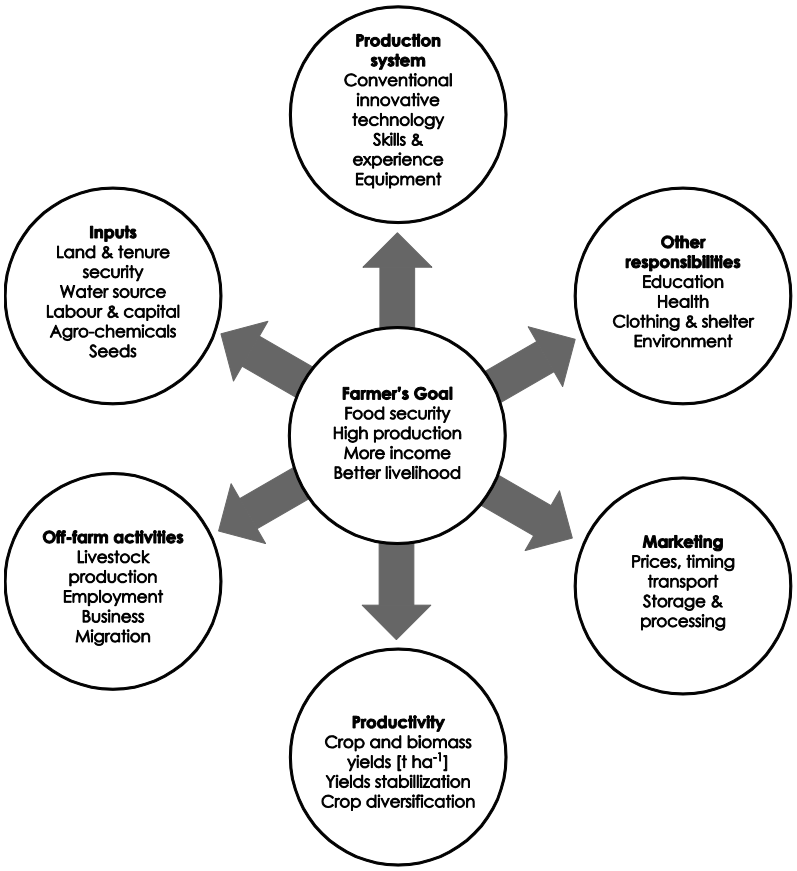
PUN = proportion of the population that is undernourished (%); CUW = the prevalence of underweight children under five (%); and CM = proportion of children dying before the age of five (%).

Effectiveness of performance indicators

To assess the effectiveness of performance indicators, it is critical to define the scale of analysis and to understand the question(s) that need answer(s). Development agents and government departments often have a sectoral approach to impacts and thus concern themselves with a sectoral indication of impact. On the other hand, smallholder farmers have a holistic approach to impacts that goes far beyond the biophysical productivity (Figure 4.7). Ultimately smallholder farmers want to enhance their livelihoods by increasing the profitability of their enterprise or at least enhance their household food security.

Crop yield data are often collected, aggregated and reported at the large scale (basin, river basin, provincial, national and even regional). There is clear evidence from on-farm and on-station research that CA and RWH increase crop yields (Table 4.7) of major cereals in the SADC region. Nevertheless, during the first season of implementation, it is not unusual for the farmer to experience a marginal to severe crop yield decrease (Botha *et al.* 2003; Haggblade & Tembo 2003; Mupangwa *et al.* 2006, 2007; Mutiro *et al.* 2006). In addition, some areas only experience marginal yield increases that do not reward their attempts to adopt innovative technologies (Kosgei 2009; Mupangwa *et al.* 2006; Owenya *et al.* 2011).

Figure 4.7 Smallholder farmers' goal and decision-making dilemma under risks and uncertainties in the SADC region



Source: Derived from Ngigi, SN, Savenije, HHG, Rockström, J & Gachene, CK 2005, 'Hydro-economic evaluation of rainwater harvesting and management technologies: farmers' investment options and risks in semi-arid Laikipia district of Kenya', Physics and Chemistry of the Earth, 30: 772–82.

Such marginal crop increases and decreases have led farmers to conclude that they live in a hydrologically marginal environment where attempts to intensify agricultural activities, by adopting innovative techniques, have no significant agricultural potential. As such, the implementation of innovative technologies (for example, RWH and CA) relies heavily on donor projects (Mwenge Kahinda & Taigbenu 2011) or a combination of 'push' and 'pull' factors to motivate a change from the *status quo* (Baudron *et al.* 2009). Introducing CA and/or RWH may result in yield benefits in the long term, but in the short term yield losses or no yield benefits are just as likely (Giller *et al.* 2009).

For large-scale commercial farmers in the irrigation sector water productivity has value as farmers can relate this to water licences, abstraction and cost of production. Farmers who manage to increase their water productivity tend to expand areas under agriculture using the same amount of water (Molle *et al.* 2004). Water productivity also helps to improve water management of agriculture

by enabling water planners to (re)allocate and co-manage water among users by (re)allocating water from lower-value to higher-value uses within and between sectors (Molden *et al.* 2010).

Table 4.7 Impact of various RWH techniques and CA on maize crop yield in the SADC region compared with the traditional system (t ha^{-1})

Country, location	Intervention	% yield increase	Reference
Lesotho	Planting basin	36–73	FAO (2010b); Silici *et al.* (2011)
Tanzania	Terracing	50.0	GTZ Sustainet (2006)
Rhotia (Karatu District)	Non-ripping plot	6.0	Owenya *et al.* (2011)
Rhotia (Karatu District)	Ripped plot	44.4	Owenya *et al.* (2011)
Rhotia (Karatu District)	CA	82.1	Owenya *et al.* (2011)
Wanging'ombe (Mbeya District)	Tilling + cover crop	50.0	Shetto & Owenya (2007)
Makanya	SI, ripping, Itr	41.0	Mutiro *et al.* (2006)
Makanya	SI, no ripping	(–414.3)	Mutiro *et al.* (2006)
Makanya	Ripping, Itr	80.0	Mutiro *et al.* (2006)
Makanya	Ripping, RD, Ipi	68.9	Makurira *et al.* (2007)
Makanya	Ripping, RD, Ipi, cover crop	70.8	Makurira *et al.* (2007)
Malawi	CA	57.6–71.9	Valencia & Nyirenda (2003)
Zambia	CA (ripping)	6.1	Bwalya (1999)
Mozambique			
Angonia highlands of Tete Province	CA + basin	51.7	Grabowski (2011)
Angonia, Tsangano and Macanga District	CA	57.8	Grabowski (2011)
South Africa			
Glen	Micro-basin tillage	(–0.4)–100	Hensley *et al.* (2000)
Potshini	No till	4.0–54.9	Kosgei (2009)
Zimbabwe	Planting basin	18.9–50.2	Mazvimavi *et al.* (2010)
	CA	42.1	Twomlow *et al.* (2008)
	Planting basin	(–58.0)–47.6	Mupangwa *et al.* (2006)
	Ripper	(–7.9)–30.3	Mupangwa *et al.* (2007)

Ipi = infiltration pits; Itr = infiltration trench; RD = run-off diversion; and SI = supplementary irrigation.

There are different innovative CA and RWH technologies that have been observed to result in marginal increases in water productivity in Tanzania and South Africa (Table 4.8) even when organic or inorganic fertilisers are applied. This is an indication that the level of success of innovative intervention depends on the physiographic and climatic characteristics of the area where they are applied and the crop cultivated. Measured values of water productivity in Tanzania and South Africa (Table 4.8) are low compared with international standards. Nevertheless, they are in line with reported water productivity values of cereals (excluding rice) in sub-Saharan Africa, which range from 0.1 to 0.6 kg m^{-3} (Molden *et al.* 2010; Rosegrant *et al.* 2002). Water productivity does not feature prominently among the many considerations facing resource managers (Molden *et al.* 2010) and it is hardly a major concern for the smallholder farmers (Table 4.7).

Table 4.8: Impact of CA and RWH on water productivity (kg m^{-3}) in the SADC region

Location per country	Crop	Intervention	WP increase	Reference
Tanzania				
Makanva	Maize	SI, ripping, Itr	0.40	Mutiro *et al.* (2006)
Makanva	Maize	SI, no ripping	– 0.40	Mutiro *et al.* (2006)
Makanva	Maize	Ripping, Itr	0.22	Mutiro *et al.* (2006)
Makanva	Maize	Ripping, RD, IPi	0.70	Mutiro *et al.* (2007)
Makanva	Maize	Ripping, RD, IPi, CC	0.70	Mutiro *et al.* (2007)
South Africa				
Thohoyandou	Sunflower	MBT	0.01 – 0.06	Mzezewa *et al.* (2011)
Thohoyandou	Cowpea	MBT	0.01 – 0.12	Mzezewa *et al.* (2011)
Glen	Sunflower	Micro-basin tillage	(–0.09) – 0.16	Hensley *et al.* (2000)
Glen	Maize	Micro-basin tillage	(–0.03) – 0.15	Hensley *et al.* (2000)
Khumo/ Sw-Am	Maize	Micro-basin tillage + OB	0.04	Botha *et al.* (2003)
	Maize	Micro-basin tillage + OB	0.14	Botha *et al.* (2003)

OB = organic mulch in basin; CC = cover crop; IPi = infiltration pits; Itr = infiltration trench; RD = run-off diversion; Bonh = Bonheim-Onrus ecotope, Free State Province; Arc-Lon = Arcadia-Lonehill ecotope, Free State Province; Sw-Am = Swartland-Amandel ecotope, Free State Province.

Water productivity is a performance indicator not commonly assessed because of the difficulty of measuring or evaluating evapotranspiration. Although there are gains to be made in increasing water productivity, these require policies and actions that recognise the complex nature of achieving those gains (Molden *et al.* 2010). The large-scale assessment of water productivity is convoluted by the intersectoral nature of water, competition for water use, resource degradation and issues of equity (Molden *et al.* 2010).

Profitability ($ ha^{-1}) is the difference between the gross income and the input costs incurred to produce a given crop under a selected intervention (CA and/or RWH). Given the high initial capital outlay required (Box 4.1), smallholder farmers who farm on communal land are very reluctant to invest capital and labour on land with uncertain tenure rights (Ashburner *et al.* 2002; Mwenge Kahinda & Taigbenu 2011). The implementation of CA and RWH interventions often requires high initial capital and labour inputs (Monde *et al.* 2006; Mwenge Kahinda & Taigbenu 2011; Ngigi *et al.* 2005; Van Heerden *et al.* 2005). When correctly assessed, the net margin should indicate the profitability of a given field. Unfortunately most smallholder farmers do not incorporate labour as expenditure and thus hide their losses by inflating their net margin figures. The case study presented in Box 4.2 highlights the poor economic performance of RWH/CA and traditional systems. The incorporation of labour cost in the economic analysis (Box 4.2) results in a net loss for all three treatments. Considering that the figures used for the calculations refer to the workload necessary in the early adoption phases, which is expected to decrease over time, the profitability of CA is likely to improve in subsequent seasons.

Box 4.1

Case study 1

Hydro-economic evaluation of farm pond (RWH system) on agricultural production in Kalalu and Matanya areas of Laikipia district in Kenya

Description of cost item	Traditional system	RWH system
Construction of farm pond (20 man-days at US$ 1.5)	–	30
Seepage control UV resistant plastic lining sheet 100 m^2 at US$2.7 per m^2	–	270
Farm pond accessories (fencing and roofing)	–	100
Low-head drip irrigation system (i.e. for two 200-l kits) at US$125	–	250
Total investment cost	–	650
Recurrent cost (labour and inputs) per season	50	200

Expected seasonal returns per ha at US$ 0.25 per kg	250	450
Net benefit on investment per season	100	25

Source: Ngigi et al. *2010.*

Box 4.2

Case study 2

Hydro-economic evaluation of conservation agriculture in Qacha's Nek and Botha Bothe districts in Lesotho

The table below shows profitability with conventional farming (tractor + animal + draft and animal draft) and with the CA method of planting basins. The cost of pesticides and herbicides has not been considered in the analysis because only a negligible share of farmers in both categories reported to be able to afford them.

Profitability in Qacha's Nek and Botha Bothe (kg ha^{-1}) by farming practice:

Description of cost item	Tractor + animal and draught	Animal draught	Planting basin
Fertilizer – 3:2:1 (50 kg)	36.9	36.9	31.4
Maize seeds – hybrid (10 kg)	32.8	32.8	32.8
Ploughing/digging holes	67.5	0.0	0.0
Labour	57.4	57.2	209.5
Total expenditures	**194.5**	**126.9**	**273.7**
Revenue Qacha's Nek	57.4	57.4	209.7
Profit Qacha's Nek	**–137.1**	**–69.5**	**–64.1**
Revenue Botha Bothe	165.3	165.3	258.1
Profit Botha Bothe	**–29.2**	**38.4**	**–15.6**

Time spent to perform different farming activities (person hours ha-1), by farming practice:

Activity	Time (person hr ha^{-1})
Ploughing with tractor, sowing with animals, weeding once by hand	200
Ploughing and sowing with animals, weeding once by hand	295

Digging holes, placing fertilizer and seeds in the holes by hand, weeding 2.5 times	650

Source: FAO 2010.

The sustainability index assesses to what extent management interventions aiming to increase crop productivity in the short term degrade the land resource on which production relies. It therefore assists farmers and water and land resource planners to identify interventions that give the best short-term benefits, but also are sustainable over the long term. There are very few case studies where agricultural sustainability indexes have been used (Dumanski *et al.* 1998).

Indices such as the Water Poverty Index, the Global Hunger Index and the Agricultural Crop Production Index are used at national and regional scales to inform policies and identify 'hot spots' that require immediate attention (Walker 2002). They provide information that is useful to policy and decision makers; they do not provide the information that answers the individual smallholder farmers.

As smallholder farmers have small plots, the scale of analysis of interest to them is field level. For water resource planning and management, however, the suitable scale of analysis is the catchment level. For policymakers, the suitable scale of analysis ranges from provincial to national. The effectiveness of a chosen indicator is dependent on the question(s) asked of the objective for the analysis and scale at which the analysis is made.

Conclusions and recommendations

Access to water of adequate quantity and quality is vital for poverty alleviation in the SADC region. Water is indeed a key input for unlocking the agricultural production of rain-fed agriculture and therefore for the current food crisis in which the rural poor, especially smallholder farmers, of the SADC region are trapped. There is evidence in the literature of positive benefits of CA and RWH for water productivity; however, quantified benefits of agricultural productivity increases are still scarce. Researchers find water productivity and other impact indicators useful tools to compare water use and productivity of different systems. These indicators have little meaning for farmers who are more interested in their livelihoods and making some money from their produce. For a farmer to accurately decide that an innovation is worthy of investment, they should have a realistic understanding of its risks and benefits (Sturdy *et al.* 2008). Thus, while it might be relevant for researchers to investigate the impact of CA and/or RWH on the soil's available water content, organic carbon, water productivity or even crop yield, the impact assessment should be translated to indicators that reflect farmers' concerns. Most performance indicators used by researchers do not indicate whether the smallholder farmer will be able to make a living out of their land by adopting given 'innovative interventions'.

The links between increasing water productivity at the farm scale in smallholder settings and water saving at sub-basin scale are still poorly understood. In fact,

the water saved may be utilised within similar farming systems before it contributes to stream flow or groundwater. Unlike with irrigated agriculture, where the water saved is captured at the source, in rain-fed agriculture the likely benefits of water saving for smallholder farming systems are minimal. Most of the performance indicators widely used by scholars do not capture the farmers' perspectives and are not used by government institutions. Because it is a daunting task to change the performance indicators used by a government—more so when more than one country is involved—scholars might have to rethink and realign the existing performance indicators.

The initial costs associated with CA are often out of reach of the smallholder farmers. As a result, farmers are likely to experience a net loss in the first year of the intervention (see case studies).

There is scope for improving water productivity but this is not everywhere (Molden *et al.* 2010). Some studies indicate marginal increases in WP as a result of CA interventions. The scope for improvement remains in many rain-fed, irrigated, livestock and fisheries systems in many regions of the world. Many farmers in developing countries could raise water productivity by adopting proven agronomic and water management practices. Many promising pathways for raising water productivity are available over the continuum, from fully rain-fed to fully irrigated farming systems.

Conservation agriculture may have several merits. Two main challenges remain: communicating the benefits to farmers, especially small-scale farmers, with the aim of influencing decision-making processes at local and national levels (Ngigi *et al.* 2005) and the lack of realistic and practical options for farmers including knowledge on where and when CA works best, for whom and how it should be configured in the different settings where it may be required (Giller *et al.* 2011).

Over the past decade, a number of methodologies for assessing the RWH suitability of different areas have been developed. Although they now integrate biophysical and socioeconomic attributes, they still do not account for critical attributes such as land tenure that dictate the long-term benefits of near-term investments.

References

Akpalu, W, Hassan, RM & Ringler, C 2008, *Climate variability and maize yield in South Africa: results from GME and MELE methods*, Discussion Paper 00843, International Food Policy Research Institute, Environment and Production Technology Division, Washington, DC.

Ashburner, J, Friedrich, T & Benites J, 2002, 'Opportunities and constraints for Conservation Agriculture in Africa'. LEISA Magazine . October 2002, 13-15.

Barron, J (ed.) 2009, *Rainwater Harvesting: A lifeline for human well-being*, United Nations Environment Programme, Nairobi, Stockholm Environment Institute, Stockholm.

Baudron, F, Corbeels, M, Monicat, F & Giller, KE 2009, 'Cotton expansion and biodiversity loss in African savannahs, opportunities and challenges for

conservation agriculture: a review paper based on two case studies'. *Biodiversity Conservation*, 18: 2625-2644.

Binswanger, HP & von Braun, J 1991, 'Technological change and commercialization in agriculture: the effect on the poor', *The World Bank Research Observer*, 66: 57–80.

Botha, JJ, Van Rensburg, LD, Anderson, JJ, Hensley, M, Macheli, MS, Van Staden, PP, Kundhlande, G, Groenewald, DG & Baiphethi, MN 2003, *Water conservation techniques on small plots in semi-arid areas to enhance rainfall use efficiency, food security, and sustainable food production*, Water Research Commission Report No. 1176/1/03, Pretoria.

Burger, D (ed.) 2011, *South Africa Yearbook 2010/11*, Government Communications and Information Service, Pretoria.

Bwalya, M 1999, 'Conservation farming with animal traction in smallholder farming systems: Palabana experiences', in PG Kaumbutho & TE Simalenga (eds), *Conservation Tillage with Animal Traction. A resource book of the Animal Traction Network for Eastern and Southern Africa (ATNESA)*, Harare, pp. 133–9.

Denison, J & Wotshela, L 2009, *Indigenous water harvesting and conservation practices: historical context, cases and implications*, Water Research Commission Report No. TT 392/09, Pretoria.

Diskin, P 1997, *Agricultural Productivity Indicators Measurement Guide. Food and Nutrition Technical Assistance Project (FANTA)*, US Agency for International Development, Washington, DC.

Dumanski, J, Terry, E, Byerlee, D & Pieri, C 1998, *Performance indicators for sustainable agriculture*, Discussion Note, The World Bank, Washington, DC.

Engelbrecht, FA 2012, Projected climate futures for southern Africa. Presentation to the department of Water Affairs. www.dwaf.gov.za/masibambane/documents/structures/wsslg/Nov17-18-2011/CCAM_DWA_20111117_001.ppt. [accessed 04 February 2013]

Engelbrecht, FA 2010, 'The physical basis for climate change over southern Africa', *Climate Change and Trade: The challenges for southern Africa*, SAIIA, Johannesburg.

Engelbrecht FA, Landman WA, Engelbrecht CJ, Landman S, BOPAPE MM, Roux B, McGregor JL and Thatcher M 2011, 'Multi-scale climate modelling over Southern Africa using a variable-resolution global model'. *Water SA* 37 (5): 647–658.

Engelbrecht, FA, McGregor, JL & Engelbrecht, CJ 2009, 'Dynamics of the conformal-cubic atmospheric model projected climate-change signal over southern Africa', *International Journal of Climatology*, 29: 1013–33.

Evenson, RE & Gollin, D 2003, 'Assessing the impact of the Green Revolution 1960 to 2000', *Science*, 300: 758–62.

Falkenmark, M & Rockström, J 2004, *Balancing Water for Humans and Nature: The new approach in ecohydrology*, Earthscan, London, p. 247.

Faurès, J & Santini, G (eds) 2008, *Water and the Rural Poor. Interventions for improving livelihoods in sub-Saharan Africa*, Food and Agriculture Organization, Rome.

Food and Agriculture Organization (FAO) 1992, *Sustainable Development and the Environment. FAO policies and actions, Stockholm 1972–Rio 1992*, Food and Agriculture Organization, Rome.

Food and Agriculture Organization (FAO) 2010a, *The status of conservation agriculture in southern Africa: challenges and opportunities for expansion*, Technical Brief No. 03, Food and Agriculture Organization Regional Emergency Office for Southern Africa.

Food and Agriculture Organization (FAO), 2010b, *Conservation Agriculture and Sustainable Crop Intensification in Lesotho*, Integrated Crop Management Series Volume 10, Food and Agriculture Organization, Rome.

Food and Agriculture Organisation (FAO) 2011a, *Mozambique*, Food and Agriculture Organization, Rome, www.fao.org/fileadmin/templates/tc/tce/pdf/Mozambique_factsheet.pdf [accessed 18 August 2011].

Food and Agriculture Organisation (FAO) 2011b, *FAO in Zimbabwe*, Food and Agriculture Organization, Rome, www.fao.org/fileadmin/templates/tc/tce/pdf/Zimbabwe_factsheet.pdf [accessed 18 August 2011].

Food and Agriculture Organisation (FAO) 2011c, *FAO Production Yearbook*, Food and Agriculture Organization, Rome, www.fao.org/waicent/faostat/agricult/indices-e.htm [accessed 18 August 2011].

Food and Agriculture Organization Statistical Database (FAOSTAT) 2010, *FAOSTAT* Database, Food and Agricultural Organization, Rome, www.faostat.fao.org [accessed 18 August 2011].

Food and Agriculture Organization (FAO) & World Food Programme (WFP) 2007, *FAO/WFP Crop and Food Supply Assessment Mission to Zimbabwe*, Food and Agriculture Organization and World Food Programme, Rome.

Food and Agriculture Organization (FAO) & World Food Programme (WFP) 2010, *FAO/WFP Crop and Food Supply Assessment Mission to Mozambique*, Food and Agriculture Organization and World Food Programme, Rome.

Giller, KE, Corbeels, M, Nyamangara, J, Triomphe, B, Affholder, F, Scopel, E & Tittonell, P 2011, 'A research agenda to explore the role of conservation agriculture in African smallholder farming systems', *Field Crops Research*, doi: 10.1016/J.Fcr.2011.04.010.

Giller, KE, Witter, E, Corbeels, M & Tittonell, P 2009, 'Conservation agriculture and smallholder farming in Africa: the heretics' view', *Field Crops Research*, 114: 23–34.

Gould, J 1999, 'Contributions relating to rainwater harvesting', in DC Sutherland & CR Fenn 2000, *Assessment of Water Supply Options, Thematic review IV.3 prepared as an input to the World Commission on Dams*, Cape Town.

Grabowski, PP 2011, Constraints to adoption of conservation agriculture in the Angonia highlands of Mozambique: perspectives from smallholder hand-hoe farmers, [Unpublished MSc dissertation], Community, Agriculture, Recreation and Resource Studies, Michigan State University.

GTZ Sustainet 2006, *Sustainable Agriculture: A pathway out of poverty for East Africa's rural poor. Examples from Kenya and Tanzania*, Deutsche Gesellschaft für Technische Zusammenarbeit, Eschborn.

Haggblade, S & Tembo G, 2003, *Conservation farming in Zambia*. EPTD Discussion Paper. Environment and Production Technology Division, International Food Policy Research Institute.

Hanjra, MA, Ferede, T & Gutta, DG 2009, 'Reducing poverty in sub-Saharan Africa through investments in water and other priorities', *Agricultural Water Management Volume*, 96(7): 1062–70.

Hensley, M, Botha, JJ, Anderson, JJ, van Staden, PP & du Toit, A 2000, *Optimizing rainfall use efficiency for developing farmers with limited access to irrigation water*, Water Research Commission Report No. 878/1/00, Pretoria.

Hobbs, PR 2007, 'Conservation agriculture: what is it and why is it important for future sustainable food production?', *Journal of Agricultural Sciences*, 145: 127–37.

Howell, TA 2001, 'Enhancing water use efficiency in irrigated agriculture', *Agronomy Journal*, 93(2): 281–9.

Huang, Q, Rozelle, S, Lohmar, B, Huang, J & Wang, J 2006, 'Irrigation, agricultural performance and poverty reduction in China', *Food Policy*, 31(1): 30–52.

Jaspers, FGW, 2001. 'The New Water Legislation of Zimbabwe and South Africa. Comparison of Legal and Institutional Reform. Compared, International Environmental Agreements'. *Politics, Law and Economics*, 1: 305-325.

Jeje, JJ, Machungo, C, Howard, J, Strasberg, P, Tschirley, D, Crawford, E & Weber, M 1998, *What makes agricultural intensification profitable for Mozambique smallholders? An appraisal of the inputs subsector and the 1996/1997 DNER/SG2000 program: Main report*, Research Report No. 32, Ministry of Agriculture and Fishers, Directorate of Economics.

Kassam, A, Friedrich, T, Shaxson, F & Pretty, J 2009, 'The spread of conservation agriculture: justification, sustainability, and uptake', *International Journal of Agricultural Sustainability*, 7(4): 292–320.

Kemper, K & Sadoff, C 2006, *The Global Water Challenge*, World Bank Global Issues Seminar Series, The World Bank, Washington, DC.

Kijne, JW, Barker, R & Molden, DJ, 2003, *Water Productivity in Agriculture: Limits and opportunities for improvement*, CABI, IWMI, Wallingford, UK.

Kosgei, JR 2009, Rainwater harvesting systems and their influences on field scale soil hydraulic properties, water fluxes and crop production, [Unpublished PhD thesis], School of Bioresources Engineering & Environmental Hydrology, University of KwaZulu-Natal, Pietermaritzburg, South Africa.

Kurosaki, T 2006, 'Consumption vulnerability to risk in rural Pakistan', *Journal of Development Studies*, 42: 70–89.

Lamaddalena, N, Shatanawi, M, Todorovic, M, Bogliotti, C & Albrizio, R 2005, *Water Use Efficiency and Water Productivity. WASAMED Project*, Proceedings of 4th Water Saving in Mediterranean Agriculture Workshop, 30 September – 4 October 2005, Amman, Jordan.

Lipton, M, Litchfield, J & Faures, J 2003, 'The effects of irrigation on poverty: a framework for analysis', *Water Policy*, 5: 413–28.

Makurira, H 2011, *Rainwater harvesting and conservation agriculture in the southern African region. Potential incentives for sustainable farming for food and water security and poverty reduction in southern Africa*, Scoping study report commissioned by the Australian National University, Canberra.

Makurira, H, Savenije, HHG, Uhlenbrook, S, Rockström, J & Senzanje, A 2007, 'Towards a better understanding of water partitioning processes for improved

smallholder rainfed agricultural systems: a case study of Makanya catchment, Tanzania', *Physics and Chemistry of the Earth*, 32: 1082–9.

Mati, B, De Bock, T, Malesu, M, Khaka, E, Oduor, A, Meshack, M & Oduor, V 2006, *Mapping the Potential of Rainwater Harvesting Technologies in Africa. A GIS overview on development domains for the continent and ten selected countries*, Technical Manual No. 6, World Agroforestry Centre, Netherlands Ministry of Foreign Affairs, Nairobi .

Mazvimavi, K, Ndlovu, P & Nyathi, P 2010, *Conservation agriculture practices and adoption by smallholder farmers in Zimbabwe*, Poster presented at 3rd AAAE Conference, 19–23 September 2010, Cape Town.

Mbilinyi, BP, Tumbo, SD, Mahoo, HF & Mkiramwinyi, FO, 2006 'GIS-based decision support system for identifying potential sites for rainwater harvesting'. *Physics and Chemistry of the Earth*, 32, 1074–1081.

Mendelsohn, R, Morrison, W, Schlesinger, M, & Adronova N, 2000, 'Countryspecific market impacts from climate change', *Climatic Change*, 45: 553–569.

Milder, JC, Majanen, T & Scherr, SJ, 2011. Performance and Potential of Conservation Agriculture for Climate Change Adaptation and Mitigation in Sub-Saharan Africa. An assessment of WWF and CARE projects in support of the WWF-CARE Alliance's Rural Futures Initiative. Available from http://ca2africa.cirad.fr. (17 August 2011).

Molden, D (ed.) 2007, *A Comprehensive Assessment of Water Management in Agriculture*, Earthscan, London.

Molden, DJ, Oweis, T, Steduto, P, Bindraban, P, Hanjra, M & Kijne, J 2010, 'Improving agricultural water productivity: between optimism and caution', *Agricultural Water Management*, 97: 528–35.

Molle, F, Mamanpoush, A & Miranzadeh, M 2004, *Robbing Yadullah's water to irrigate Saeid's garden: hydrology and water rights in a village of central Iran*, Research Report 80, International Water Management Institute, Colombo.

Monde, N, Fraser, G, Botha, JJ & Anderson, K 2006, Making home gardening a viable livelihood option in rural areas of South Africa: the case of Guquka and Khayalethu in Central Eastern Cape, Paper presented at the 4th International Conference on Environmental Management for Sustainable Universities, 26–30 June, Steven's Point, Wisconsin.

Motsi, KE, Chuma, E & Mukamuri, BB 2004, 'Rainwater harvesting for sustainable agriculture in communal lands of Zimbabwe', *Physics and Chemistry of the Earth*, 29: 1069–73.

Mupangwa, W, Love, D & Twomlow, S 2006, 'Soil–water conservation and rainwater harvesting strategies in the semi-arid Mzingwane Catchment, Limpopo Basin, Zimbabwe', *Physics and Chemistry of the Earth*, 31: 893–900.

Mupangwa, W, Twomlow, S, Walker, S & Hove, L 2007, 'Effect of minimum tillage and mulching on maize (*Zea mays L.*) yield and water content of clayey and sandy soils', *Physics and Chemistry of the Earth*, 32: 1127–34.

Mutiro, J, Makurira, H, Senzanje, A & Mul, ML 2006, 'Water productivity analysis for smallholder rainfed systems: a case study of Makanya Catchment, Tanzania', *Physics and Chemistry of the Earth*, 31: 901–9.

Mwenge Kahinda, J 2004, Water productivity and yield gap analysis of water harvesting systems in the semi-arid Mzingwane Catchment, Zimbabwe, [Unpublished MSc dissertation], Water Resources Engineering and Management Programme, University of Zimbabwe.

Mwenge Kahinda, J 2010, Decision support system for sustainable rainwater harvesting in South Africa, [Unpublished PhD thesis], University of the Witwatersrand, Johannesburg.

Mwenge Kahinda, J & Taigbenu, AE 2011, 'Rainwater harvesting in South Africa: challenges and opportunities', *Physics and Chemistry of the Earth*, 36: 968–76.

Mwenge Kahinda, J, Lillie, ESB, Taigbenu AE, Taute, M & Boroto, RJ 2008, 'Developing suitability maps for rainwater harvesting in South Africa', *Physics and Chemistry of the Earth*, 33: 788–99.

Mwenge Kahinda, J, Sejamoholo, BPP, Taigbenu, AE, Lillie, ESB & Boroto, RJ 2009, 'A GIS-based decision support system for rainwater harvesting (RHADESS)', *Physics and Chemistry of the Earth*, 34: 767–75.

Mwenge Kahinda, J, Rockström, J, Taigbenu, AE & Dimes, J 2007a, 'Rainwater harvesting to enhance water productivity of rainfed agriculture in the semi-arid Zimbabwe', *Physics and Chemistry of the Earth*, 32: 1068–73.

Mwenge Kahinda, J, Taigbenu, AE and Boroto, RJ 2007b, 'Domestic rainwater harvesting to improve water supply in rural South Africa', *Physics and Chemistry of the Earth*, 32: 1050–7.

Mwenge Kahinda, J, Taigbenu, AE & Boroto, RJ 2010, 'Domestic rainwater harvesting as an adaptation measure to climate change in South Africa', *Physics and Chemistry of the Earth*, 35: 742–51.

Mzezewa, J, Gwata, ET & van Rensburg, LD 2011, 'Yield and seasonal water productivity of sunflower as affected by tillage and cropping systems under dryland conditions in the Limpopo Province of South Africa', *Agricultural Water Management*, 98: 1641–8.

Ncube, B, Magombeyi, M, Munguambe, P, Mupangwa, W & Love, D 2008, Methodologies and case studies for investigating upstream–downstream interactions of rainwater water harvesting in the Limpopo basin', in E Humphreys & RS Bayot (eds), *Increasing the Productivity and Sustainability of Rainfed Cropping Systems of Poor Smallholder Farmers*, Proceedings of the International Workshop on Rainfed Cropping Systems, 22–25 September, Tamale, Ghana.

Ngigi, SN, Savenije, HHG, Rockström, J & Gachene, CK 2005, 'Hydro-economic evaluation of rainwater harvesting and management technologies: farmers' investment options and risks in semi-arid Laikipia district of Kenya', *Physics and Chemistry of the Earth*, 30: 772–82.

Organisation for Economic Cooperation and Development (OECD) 2006, *Agricultural policy reform in South Africa*, Policy Brief, Organisation for Economic Cooperation and Development, Paris.

Oweis, T & Hachum, A 2006, 'Water harvesting and supplemental irrigation for improved water productivity of dry farming systems in West Asia and North Africa', *Agricultural Water Management*, 80: 57–73.

Oweis, T, Prinz, D & Hachum, A 2001, *Water Harvesting: Indigenous knowledge for the future of the drier environments*, International Centre for Agricultural Research in the Dry Areas, Aleppo.

Owenya, MZ, Mariki, WL, Kienzle, J, Friedrich, T & Kassam, A 2011, 'Conservation agriculture (CA) in Tanzania: the case of Mwangaza B CA farmer field school (FFS), Rhotia Village, Karatu District, Arusha', *International Journal of Agricultural Sustainability*, 9(1): 145–52.

Poverty–Environment Partnership (PEP) 2006, *Linking Poverty Reduction and Water Management*, Stockholm Environment Institute, Stockholm, and United Nations Development Programme, Geneva.

Prasad, KC, van Koppen, B & Strzepek, K 2006, 'Equity and productivity assessments in the Olifants River Basin, South Africa', *Natural Resources Forum*, 30: 63–75.

Rao, NH & Rogers, PP 2006, 'Assessment of agricultural sustainability', *Current Science*, 91(4): 25, 439–48.

Reardon, T, Codron, J, Busch, L, Bingen, J & Harris, C 1999, 'Global Change in Agrifood Grades and Standards: Agribusiness Strategic Responses in Developing Countries.' *International Food and Agribusiness Management Review*, 2 (3/4): 421-435.

Rockström, J, Barron, J & Fox, P 2003, 'Water productivity in rainfed agriculture: challenges and opportunities for smallholder farmers in drought prone tropical agro-ecosystems', in JW Kijne, R Barker & D Molden (eds), *Water Productivity in Agriculture: Limits and opportunities for improvements*, CABI, Wallingford, UK, pp. 145–61.

Rockström, J, Kaumbutho, P, Mwalley, J, Nzabi, AW, Temesgen, M, Mawenya, L, Barron, J, Mutua, J & Damgaard-Larsen, S 2008, 'Conservation farming strategies in East and southern Africa: yields and rain water productivity from on-farm action research', *Soil Tillage Research*, 103: 23–32.

Rosegrant, MW, Cai, X & Cline, AS 2002, *World Water and Food to 2025: Dealing with scarcity*, International Food Policy Research Institute, Washington, DC.

Schreiner, B & Van Koppen, B 2002, 'Catchment management agencies for poverty eradication in South Africa', *Physics and Chemistry of the Earth*, 27: 969–76.

Shewmake, S 2008, *Vulnerability and the impact of climate change in South Africa's Limpopo River Basin*, Discussion Paper 00804, International Food Policy Research Institute, Environment and Production Technology Division, Washington, DC.

Shetto, R & Owenya, M (ed.) 2007, *Conservation Agriculture as Practised in Tanzania: Three case studies*, African Conservation Tillage Network, Nairobi, Centre de Coopération Internationale de Recherche Agronomique pour le Développement, Paris, and Food and Agriculture Organization, Rome.

Silici, L, Ndabe, P, Friedrich, T & Kassam, A 2011, 'Harnessing sustainability, resilience and productivity through conservation agriculture: the case of Likoti in Lesotho', *International Journal of Agricultural Sustainability*, 9(1): 137–44.

Soussan, J 2004, *Water and Poverty. Fighting poverty through water management*, Asian Development Bank, Manila.

Sturdy, JD, Jewitt, GPW & Lorentz, SA 2008, 'Building an understanding of water use innovation adoption processes through farmer-driven experimentation', *Physics and Chemistry of the Earth*, 33: 859–72.

Sullivan, CA, Meigh, JR, Giacomello, AM, Fediw, T, Lawrence, P, Samad, M, Mlote, S, Hutton, C, Allan, JA, Schulze, RE, Dlamini, DJM, Cosgrove, WJ, Delli Priscoli, J, Gleick, P, Smout, I, Cobbing, J, Calow, R, Hunt, C, Hussain, A, Acreman, MC, King, J, Malomo, S, Tate, EL, O'Regan, D, Milner, S & Steyl I 2003. The water poverty index: development and application at the community scale. *Natural Resources Forum*, 27: 189–199.

Sullivan C.A., Meigh J.R and Lawrence, P., 2006. Application of the Water Poverty Index at Different Scales: a Cautionary Tale. Water International 31 (3): 412-426.

Trabucco, A., and Zomer, R.J. 2009. Global Aridity Index (Global-Aridity) and Global Potential Evapo-Transpiration (Global-PET) Geospatial Database. CGIAR Consortium for Spatial Information. Available from www.csi.cgiar.org (04 February 2013).

Twomlow, SJ, Riches, C, O'Neill, D, Brookes, P & Ellis-Jones, J 1999, 'Sustainable dryland smallholder farming in sub-Saharan Africa', *Annals of Arid Zone*, 38(2), 93–135.

Twomlow, S, Urolov, JC, Jenrich, M & Oldrieve, B 2008, 'Lessons from the field—Zimbabwe's Conservation Agriculture Task Force', *Journal of SAT Agricultural Research*, 6.

United States Agency for International Development (USAID) 1998, *Guidelines for indicator and data quality*. Performance Monitoring and Evaluation TIPS, USAID Center for Development Information and Evaluation, Washington, DC, www.usaid.gov/policy/ads/200/tips12.pdf [accessed 15 November 2011].

Valencia, JA & Nyirenda, N 2003, 'The impact of conservation agriculture technology on conventional weeding and its direct effect on maize cost production in Malawi', *Conservation Farming for Sustainable Agriculture, Workshop Proceedings*, Proceedings of the 19th Biennial Weed Science Society Conference for Eastern Africa, Lilongwe, Malawi, pp. 35–42.

van den Berg, M & Ruben, R 2006, 'Small-scale irrigation and income distribution in Ethiopia', *The Journal of Development Studies*, 42: 868–80.

Van Heerden, PS, Woyessa, YE & Pretorius, E 2005, 'Assessment of the potential adoption of infield rainwater harvesting technique in the communal farming areas of the upper and middle Modder River Basin, South Africa', *South African Journal of Agricultural Extension*, 34(2): 334–48.

von Braun, J 1988, 'Effects of technological change in agriculture on food consumption and nutrition: rice in a West African setting', *World Development*, 16, 1083–98.

von Braun, J, Puetz, D & Webb, P 1989, *Irrigation technology and the commercialization of rice in the Gambia: effects on income and nutrition*, Research Report 75, International Food Policy Research Institute, Washington, DC.

von Wirén-Lehr, S 2001, 'Sustainability in agriculture—an evaluation of principal goal-oriented concepts to close the gap between theory and practice', *Agriculture, Ecosystems and Environment*, 84: 115–29.

Walker, J 2002, 'Environmental indicators and sustainable agriculture', in TR McVicar, Li Rui, J Walker, RW Fitzpatrick & Liu Changming (eds), *Regional Water and Soil Assessment for Managing Sustainable Agriculture in China and Australia*, ACIAR Monograph No. 84, Australian Centre for International Agricultural Research, Canberra, pp. 323–32.

Walker, J, Veitch, S, Braaten, R, Dowling, T, Guppy, L & Herron, N 2001, *Catchment condition in Australia*, Final Report to the National Land and Water Resources Audit.

Wiesmann, D, Weingärtner, L & Schöninger, I 2006, *The Challenge of Hunger: Global Hunger Index: Facts, determinants, and trends*, Deutsche Welthungerhilfe and International Food Policy Research Institute, Bonn and Washington, DC.

World Bank 2003, *Mozambique agricultural development strategy stimulating smallholder agricultural growth*, Report No. 32416-MZ, The World Bank, Washington, DC.

Chapter 5

The case for a new irrigation research agenda for sub-Saharan Africa

RICHARD STIRZAKER AND JAMIE PITTOCK

Introduction

Over the past 50 years, increases in global food production have been able to outstrip population growth. Asia has been the star performer, with per capita food production doubling over the period. Africa, on the other hand, shows no real progress. Food production per capita today is similar to what it was in 1961 and food imports have steadily risen. Total cereal production has increased more or less in line with population, but this increase is almost entirely due to cropping more land, not increasing yield per unit area. In southern and eastern Africa, per capita yields have even declined substantially over the past few decades (Pretty *et al.* 2011).

The Green Revolution package of improved varieties, agrochemicals and irrigation that has so impacted on the rest of the world has largely bypassed Africa. Even the two simplest ingredients of the package—improved varieties and fertiliser—have yet to have major impact. Irrigation is the hardest part of the package to implement successfully because of the high costs of developing irrigated land and the inability to generate sufficient profit to cover recurrent operation and maintenance expenses. Moreover the investment in irrigation can only be fully reaped once the other elements of the production package are in place. There is little point in adding water to low-fertility soils growing low-yielding varieties.

Irrigation also must support a governance component that is not required for rain-fed farming. Water must be allocated, infrastructure maintained, fees collected and conflicts resolved. Governments worldwide are handing over these responsibilities to farmer groups, and Africa is struggling through this transition

(Shah *et al.* 2002). Typically large numbers of smallholdings make up a scheme, so the transaction costs are large and these cannot be supported by the generally low productivity so common in sub-Saharan Africa. The food crises of the mid 1970s sparked the development of new irrigation schemes around the world, but the rate of new development has steadily declined. Lending to sub-Saharan Africa for irrigation projects from the World Bank dropped significantly due to perceptions of disappointing performance, and the vicious cycle of low cost recovery leading to lack of maintenance resulting in poor water productivity (World Bank n.d.).

The most recent food crisis has revived interest in irrigation in sub-Saharan Africa, especially in the light of Food and Agriculture Organization (FAO) estimates that sub-Saharan Africa has attained just 20 percent of its irrigation potential. It would seem that there is a critical role for irrigation to play in the ongoing food security crisis, yet the costs of irrigation development in sub-Saharan Africa are often reported as higher than anywhere else in the world and the performance of the irrigation schemes worse (Jones 1995). So, can increased investment in irrigated agriculture really form a part of the food security plan for sub-Saharan Africa? What would this investment look like and what should the accompanying research agenda be to get the best food security and environmental outcomes from investment in irrigation?

Increasing supply: Exploiting more surface water

The governments of sub-Saharan Africa face a distressing set of problems. The number of food-insecure people nearly doubled in the 30 years after 1980, to 240 million (IFAD 2010). Many countries fall well short of national food sufficiency, and calorific intake across the region is 20 percent below the world average. The Global Hunger Index (GHI), which combines under-nutrition, low child weight and child mortality rates, reports numerous sub-Saharan African countries in the serious and alarming categories (IFPRI 2011). These statistics not only translate into physical suffering, but also predispose the next generation to learning difficulties and disease.

The yields of rain-fed staple crops are low in sub-Saharan African countries and the national annual production fluctuates widely, reflecting the difficult and highly variable growing environment. The potential role of irrigation to increase and stabilise food supply seems obvious and the comparison with Asia inescapable. For example, South Asia irrigates almost 40 percent of its cultivated land, whereas sub-Saharan Africa irrigates just four percent (Svendsen *et al.* 2009; You *et al.* 2010). This proportion increases to five percent when adding informal irrigation such as flood recession cropping, cultivated wetlands and spate irrigation (diversion of floodwaters over extensive areas of floodplain).

The modest development of irrigation in sub-Saharan Africa does not appear to be rooted in scarcity of resources. The size of the renewable water resource on a per capita basis is slightly above the world average, but the exploitation of this water is much lower. In fact, the average global consumption of water is four to five times greater than consumption by sub-Saharan Africans. The New Partnership

for African Development (NEPAD) argues irrigation area needs to expand by six percent per year with an annual injection of $42 billion (quoted in Lankford 2005). This is six times the current rate of increase and governments of Africa and the donor community are now looking at serious new investments in irrigation infrastructure (Svendsen *et al.* 2009).

The political will to invest must be matched by a robust understanding of the size of the resource to be developed. The FAO AQUASTAT database estimates the total annual renewable water resource (TARWR) for each county, which is the sum of both surface water and groundwater resources. Surface water is made up of inflows to rivers and lakes and includes river flow entering from countries upstream less their obligation to supply a certain minimum flow to downstream countries. Renewable groundwater is estimated as the annual recharge to aquifers. When viewed as a whole, sub-Saharan Africa utilises just 1.5 percent of its total renewable resource, of which almost 90 percent goes to the agricultural sector. This is in stark contrast with northern Africa, which currently consumes more than 250 percent of its TARWR through overexploitation of groundwater reserves.

The TARWR can be a misleading figure. Places where water is abundant require little irrigation, whereas water resources in dry areas are often overexploited. A country such as South Africa consumes 25 percent of its TARWR and is considered severely water stressed. In fact, 25 percent would seem to be an upper limit of consumption, and even this requires major engineering works and inter-basin transfers. Averages are also highly misleading in hydrology, because in flood years the water cannot be used. Conversely, droughts can stretch over many years and overexploited basins will fail to provide the minimum flows needed to sustain ecological functions. Total dam capacity in sub-Saharan Africa is about 80 percent of the world average, equating to about 15 percent of the average annual river discharge (Svendsen *et al.* 2009); however, much of this water is contained in a small number of large dams, which are primarily used for hydro-power generation, not irrigation.

You *et al.* (2010) conducted an extensive modelling exercise to evaluate the NEPAD vision of increasing the irrigated area from 12 to 20 million ha across sub-Saharan Africa. They compiled a ten km grid GIS (geographic information system) map to show the productivity of different crops and combined this with a hydrological model and an economic model. The hydrological model calculated run-off as the maximum potential supply of water. They separately calculated the potential new irrigable areas from dam-based systems and for small-scale systems. For dam-based systems, the irrigable land was limited by the topography and delivery costs around the dam site itself. For small-scale systems, the limit was the amount of available run-off water, and the constraint that irrigated areas had to be within five hours' travel time of a local market.

Assuming a development cost of $3,000/ha for dam-based systems and $2,000/ha for small-scale systems, they calculate that an extra 22 million ha could be irrigated, giving an internal rate of return on investment of at least six percent.

The calculations incorporate a number of conservative assumptions, such as an overall irrigation efficiency of 0.4, attainable yields of 30–80 percent of the potential and that 30 percent of dam capacity was available for irrigation. These investment prices are low compared with other studies and probably only attainable if the cost of the dam was paid for by another sector, such as hydro-power generation. When You *et al.* (2010) doubled the per hectare investment cost, the area that could be profitably irrigated dropped by nearly 50 percent. Nevertheless this area of irrigable land is above the ambitious NEPAD target, so at first cut the land and water resources do not seem to be the limiting factors.

Paying for irrigation infrastructure

Despite the renewed interest of large donors to invest in irrigation infrastructure, development costs in Africa have historically been higher than elsewhere. Jones (1995) reported that the average cost of irrigation development in sub-Saharan Africa was $18,000/ha compared with $4,800/ha in the rest of the world (1991 prices). This alarming statistic stimulated a major review by the International Water Management Institute (IWMI), first to confirm these figures and second to try to explain them (Inocencio *et al.* 2007). They analysed 314 irrigation projects from Africa and around the world to try to tease out the factors that contribute to the cost and performance of irrigation schemes. Inocencio *et al.* (2007) then compare the case studies in sub-Saharan Africa with the case studies from other developing countries, which were drawn from the Middle East, Asia and Latin America.

The study showed that the average cost of new irrigation projects in sub-Saharan Africa was $14,500/ha compared with $6,500/ha in the other developing regions—more or less confirming the common perception. Not only were the development costs higher, but also the probability of a successful project in sub-Saharan Africa was 56 percent compared with an average of 72 percent in the other regions. The condition for 'success' was set at projects that produced an economic internal rate of return (EIRR) greater than ten percent, which is widely accepted by donors as the threshold for public investment.

High costs combined with high failure rates seem to spell doom for irrigation investment in sub-Saharan Africa; however, if the irrigation projects were divided into those considered a success and those considered a failure, it may be possible to diagnose and overcome the problems. The calculation of EIRR takes into account the total cost of the development, operation and maintenance costs and returns due to water provision over the lifetime of a project (assumed to be 30 years) and the gestation period of the investment.

When projects considered a failure on EIRR grounds were eliminated from the case studies in sub-Saharan Africa, the investment costs per hectare were markedly lower. The cost of successful new construction projects dropped from $14,500/ha to $5,700/ha in sub-Saharan Africa and in the rest of the regions from $6,500 to $4,600. This suggests that irrigation projects in sub-Saharan Africa are not intrinsically more expensive than everywhere else. It appears that the costs are

skewed by a group of expensive projects at a development cost of more than $20,000/ha that failed to reach the threshold EIRR. Projects in sub-Saharan Africa were also smaller in size, developed in much drier regions requiring more water per hectare (700 mm versus 1200 mm in the other regions) and in very poor countries with higher costs for doing business. All these factors appear to contribute to higher costs (Inocencio *et al.* 2007).

The cost of all new project studies declined in sub-Saharan Africa from $18,000 in the 1970s to $9,000 in the 1990s (in other regions the change is from just $7,000 to $6,000/ha). At the same time, the EIRR increased in sub-Saharan Africa on new construction projects from six percent in the 1970s to 25 percent in the 1990s, and the success rate in sub-Saharan Africa increased from 42 percent to 86 percent over the same period. What factors have contributed to this success?

First, successful projects had greater effort put into appraisal, implementation and supervision by donors, and this has eliminated some of the more spectacular failures of the early years. Second, the tasks of operation and maintenance shifted from solely the responsibility of government to more fully involving the farmers. Third, successful projects had a greater share of the total costs allocated to the 'software' components. The 'hardware' of irrigation projects represents the engineering infrastructure, whereas the software includes better technical assistance, design and management in the construction phase as well as better agricultural support, institution building, and training agency staff and farmers after construction (Inocencio *et al.* 2007).

Although the greater spending on the software component could almost double the costs of the entire project, the investment was more than rewarded by the improved performance and hence the higher EIRR. Increased farmer contribution to projects was also correlated with success, not because it reduced the costs significantly, but because it improved subsequent project performance. Other factors correlated with success were projects that used both surface water and groundwater, a shift towards horticultural crops and a shift towards development in wetter sites (Inocencio *et al.* 2007).

Managing demand: Using currently available water more efficiently

The supply side of the irrigation equation—that is, providing more water infrastructure—is the easiest option for increasing food supply from irrigation. Politicians favour it because it makes for highly visible new development activities and donors favour it because it is amenable to the usual planning, monitoring and evaluation protocols. Addressing the demand side for water is more difficult. Here the aim is to derive more economic benefit from the same amount of water or the same benefit from a reduced supply by addressing inefficiencies in the existing system.

Consider a typical situation where water is delivered to the farm through open, unlined channels. On reaching the farm, the water may be stored in a small dam

before being moved to individual fields in earthen canals. Then water is applied to the crop by flooding the field. Water is lost at each of these three steps through leakage, evaporation and drainage. For example, it would not be unusual to lose 20 percent of the water in conveyance to the farm and a further 30 percent when storing and moving water around the farm. Since it is difficult to uniformly replenish the rooting zone by flood irrigation, a further 40 percent can be lost through drainage below the root zone and water running off the end of the field. The biggest loss is often through direct soil evaporation, where half the water applied to the field can be lost before it is transpired.

Since each of these losses is in series, the overall efficiency is the product of each of the individual steps in getting water from a dam to a transpiring leaf (Hsiao *et al.* 2007). In the above example, just 17 L would be transpired of the 100 L that were released by the dam; however, not all losses are the same. Perry *et al.* (2009) divide up the gross withdrawal from the dam into beneficial consumption by the crop via transpiration and non-beneficial consumption via weeds and soil evaporation. The proportion of water withdrawn from the dam that is not consumed is divided into water that makes its way back to the river or groundwater and thus can be recovered, and water that is not recoverable because it ends up in salty or inaccessible aquifers.

Modernising the irrigation system by piping water, using a pressurised irrigation system, will dramatically cut non-beneficial consumption and non-recoverable return flows. Improving farming practices can have a similar impact. Planting the right varieties on time, scheduling irrigation, supplying nutrients and protecting crops' completion from weeds and attack from pests and disease can double or even quadruple yields. When putting the engineering and agronomic aspects together, remarkable improvements can be attained. Hsiao *et al.* (2007) calculate that if each of the steps in the chain from dam to final harvest fell into the 'poor' category, we might grow only 24 g of food from every 1,000 L of dam water; however, if each step was elevated into the good-practice category, each 1,000 L could produce 1,220 g of food.

The fiftyfold difference between good and bad practices makes one wonder why there would be such a focus on simply doubling the area of irrigated land—the so-called 'supply' solution. The reason is that addressing many of the inefficiencies is expensive and rarely cost effective when the price of water is low. Furthermore, improving yields through better on-farm water and agronomic management requires an enormous effort in training. The local knowledge and capacity to provide such training are in very short supply.

It seems that irrigation schemes inevitably go through a life cycle, starting with an exploitation phase and only moving into a conservation phase when water becomes a limiting resource. As the supply becomes scarcer still, a scheme moves into the reallocation phase, where water use shifts to more profitable users (FAO 2012). This could mean changing from irrigating staple crops to irrigating horticultural crops or competition from other sectors for water, such as mining,

industry or domestic users. Most sub-Saharan countries are still in the exploitation phase.

Big is beautiful?

One of the main findings of Inocencio *et al.* (2007) was that the success of an irrigation project was strongly dependent on the total cost, which, from the case studies, was strongly correlated with project size. Large projects almost by definition are cheaper on a per hectare basis simply because the infrastructure costs can be divided over a much larger area. Projects in sub-Saharan Africa were on average only one-sixth of the size of those in the other regions, and this flowed through to higher cost and ultimately lower internal rates of return, leading to the suggestion that 'big is beautiful'.

Although there are efficiencies in scale when conducting engineering works, the situation plays out quite differently from a hydrological perspective over the longer term. For example, the Chokwe irrigation area on the Limpopo River in southern Mozambique is one of the largest schemes in southern Africa. It covers an area of 34,000 ha, but 11,000 ha have been abandoned because of waterlogging and salinity. Of the remaining 23,000 ha, only 7,000 ha are actually being used because infrastructure has fallen into disrepair, and was further damaged by the floods in February 2000 and January 2012. Estimates are that Chokwe needs $45 million just to upgrade the existing infrastructure (Chilundo *et al.* 2004).

The Islamic Development Bank is funding the repair work on 7000 ha and the Chinese Government has plans to repair a further 10 000 ha, but no scheme can rely on outsiders to keep bailing it out. It is expected that once 20 000 ha are under cultivation, and farmers pay $108/ha for the water, the scheme could pay its way; however, the farmers will need to lift their current rice yields from 4 to 6 tot/ha to be able to afford such charges (http://allafrica.com/stories/201205290141.html).

But what of the remaining 14,000 ha—mostly affected by salinity and waterlogging? It is one thing to rebuild canals and dig out the surface drains, but dealing with high water tables presents a problem of a different order. The heavy, salt-laden soils along the southern area of the scheme have low hydraulic conductivity and are very difficult to drain. Growing one crop of rice per year using 10 ML/ha across 20,000 ha of Chokwe using Limpopo water at 300 mg/L salt means that 60,000 tonnes of salt are added to the land each year. If all this salt can be flushed back to the river, the system or parts thereof will continue to fail.

This story has been repeated all over the world. For example, the cheapest way to expand irrigated land in the lower Murray of South Australia was to develop along the river. In the Loxton area, irrigation was developed over a naturally saline water table approaching the level of seawater. Within two decades the extra hydraulic loading from irrigation started to push this salty water into the river, increasing the daily discharge from 10 to 100 t of salt per day. Since 1980 the Murray–Darling Basin Commission (MDBC) has spent more than $200 million on salt-interception schemes to counter this (Newman *et al.* 2012). The lesson is clear: over the period that internal economic rates of return are calculated, big schemes

make a lot of sense because they are cheaper to construct. Yet schemes that drown in their own salt either because of bad locations or simply because of their own size have far greater costs down the line.

Whereas Chokwe is by far the largest scheme in Mozambique, the country has developed 159 schemes coving 118 000 ha. Although there is significant potential to increase this area, 66 percent of the land with existing irrigation infrastructure lies unused. About five percent of the area comprises relatively small schemes of less than 50 ha and here the unused portion is just less than 50 percent (Chilundo *et al.* 2004). The trend seems to be: the larger the system, the greater are the problems. In contrast, the small wetland and 'dambo' hydrological settings common in Mozambique are intensively used by smallholder farmers, particularly when located near markets. Although tiny in scale and with huge variations in water availability during the year, these systems are well exploited by farmers.

New opportunities for irrigation development

At this point there is conflict between the high-level assessments that favour big schemes on rivers and empirical evidence that smaller schemes can function better. Attention has recently shifted towards the more widespread groundwater resource. There are several advantages here for small-scale irrigators. Farmers who traditionally grow rain-fed crops can produce under irrigation in the dry season, creating new income opportunities. They could also provide supplementary irrigation to rain-fed crops when rains fail during part of the cropping season. The great benefit of groundwater is that it responds much more slowly than surface waters to drought and is therefore a buffer against climate variability. Groundwater also covers large spatial areas, and, if exploitable, provides opportunities for farmers to diversify their livelihood strategies without the social dislocation and landownership problems that plague new surface-water schemes.

Understanding the size of the groundwater resource and the rate at which groundwater is replenished is the first step in developing a strategy for sustainable utilisation. Surprisingly the first quantitative continent-wide assessment of groundwater resources in Africa was published only recently (MacDonald *et al.* 2012). The average rainfall across the African continent is 660 mm, of which about 130 mm is considered to reach rivers, lakes and groundwater, and thus represents a renewable resource. The groundwater resource is estimated to have an equivalent water depth of 22 m, or 170 times greater than the renewable resource. This groundwater is unequally distributed, with the huge sedimentary aquifers across North Africa holding the equivalent of 75 m depth of water, whereas storage in the widespread Precambrian basement rock aquifers may be less than 0.5 m.

The aquifers across North Africa are recharged at below 5 mm per year and, though a huge resource, are exploited for irrigation much faster than they are replenished; however, many of the aquifers in the rain-fed cropping zone are

replenished at 25–100mm per year and are shallow enough to be exploited by relatively small pumps (MacDonald *et al.* 2012). Away from urban areas, groundwater is usually free of human pathogens because of the natural filtering provided by the soil above; however, quality can be an issue—both excessive salt levels and toxic ions such as fluoride and arsenic. Poor-quality water does not appear to be a major issue across the region, although much testing remains to be done.

Assuming groundwater is of suitable quality and close enough to the surface for economical drilling and pumping then the productivity of the aquifer determines the suitability of the resource for irrigation. Large centre-pivot type irrigation systems may need bores that yield around 50 L per second, and such aquifers are rare in Africa. Bores for household water supplies need only have yields of around 0.3 L/s and such aquifers are widespread across sub-Saharan Africa. Ideally irrigation would need a supply of around 5 L/s, but this is not common; however, large areas fall into a zone where bore yields are between 0.5 and 5 L/s, where correctly sited bores could supply sufficient water for community gardens and supplemental irrigation (MacDonald *et al.* 2012).

Low to moderate-productivity bores will prevent the concentration of irrigation in certain areas and thus help mitigate the ever present threats of salinity and waterlogging. Small pumps servicing irrigation areas widely spread across the landscape mean that expensive and often wasteful reticulation systems are no longer required, and farmers have unprecedented control over their water resource. If they own their own pump, they effectively have water on demand, unlike the schemes where water is available on a rotational basis (often once per week), which can lead to conflicts between users in different parts of the scheme. Although the additional pumping costs cut into profit, it can also guard against excessive water consumption. The groundwater resource is, of course, very vulnerable to the tragedy of the commons, as the users are not necessarily formally linked in such a way as to avoid overexploitation.

Large irrigation schemes based on rivers and dams and widely distributed small areas fed from groundwater are two ends of the spectrum. In between lies various forms of water harvesting and capture ranging from in-field run-off–run-on systems to storage tanks and lined dams. Here there is a trade-off between the upfront investment cost and the reliability of supply. In-field rainwater harvesting is not expensive, but nor is there a guaranteed supply of water. Excavated dams measuring 100 m x 70 m x 7 m holding 50,000 cu m cost around $1 million to construct. The cost of storage is therefore $20/cu m and, assuming the dam is completely filled twice during the year, 20 ha of land could be supplied with 500mm of irrigation water. This equates to a development cost of $50,000 per hectare—10 times higher than the cost of developing larger schemes from rivers. Plastic or ferroconcrete tanks have even higher storage costs, with a capital outlay of $50/cu m or more (Makurira 2012).

Small-scale storage systems make sense in the context of multiple-use systems where water is provided for domestic and productive purposes. The basic

domestic supply of 20 L per person per day is sufficient for drinking and personal hygiene and has a huge impact on disease reduction and releasing women from the time-consuming chore of fetching water. If this is increased to 50 L per person per day then there is sufficient water for laundry, livestock and some fruit trees around the home. Increasing the water supply to 100 or even 200 L per day can supply a vegetable garden or even a small irrigation enterprise. The progression is called climbing the multiple water use ladder (van Koppen *et al.* 2009).

There is a huge cost in providing reticulated water to meet the basic domestic demand at the base of the ladder. The marginal cost of supplying more water to households—especially if directed towards growing fruit and vegetables, which provide the nutritional supplements so often lacking in a cereal-based diet—may well be worthwhile. Backeberg and Sanewe (2010) report on the huge potential of homestead farming for food security in rural South Africa where 65 percent of the land available for small-scale farming is made of plots smaller than 0.5 ha around existing dwellings. Providing treated water for agricultural purposes is an unnecessary expense, but there may soon be economical options for treatment at the home itself. Given that water and sewage-treatment plants in Africa often do not work reliably, it may be possible to do the tertiary treatment using a filter or membrane on one tap in the home. Then the reticulation system provides a much larger quantity of primary treated water, and the drinking water undergoes final treatment at a single tap in the home.

A new water research agenda for sub-Saharan Africa

There is political will to develop irrigation in sub-Saharan Africa through the NEPAD strategy and there appear to be sufficient water and land available. Moreover, sub-Saharan Africa has shown great improvements in irrigation performance in recent decades due to the combination of better planning and better management, such that the performance of larger schemes is catching up with the rest of the world. The current value of irrigated agriculture in sub-Saharan Africa is about 25 percent of the total agricultural output. This contribution comes from just 3.5 percent of the cultivated land area (or 4.5 percent if we add the informal sector), meaning that there is a five–sevenfold increase in value of irrigated agriculture over dryland agriculture because of higher yields and more profitable crops (Svendsen *et al.* 2009). This calculation is in stark contrast with the rest of the world where the comparable ratio is around two.

There are also new opportunities fast approaching. The trend in Asia towards small-scale private irrigation is now starting in sub-Saharan Africa where farmers are using their own initiative and financial resources. The movement started with the use of treadle pumps, which can irrigate around 0.2 ha for a cost of $50–100; however, as occurred in Asia, in Africa motorised pumps costing less than $250 that can irrigate one to two ha are proving the most profitable option (Giordano *et al.* 2012). Whereas groundwater supplies 60–80 percent of irrigation water in India and Bangladesh, it probably accounts for less than ten percent in sub-Saharan Africa. Giordano *et al.* (2012) estimate annual net revenues of $20 billion flowing

from the development of small reservoirs and a further $22 billion from expanding the use of small motorised pumps, benefiting hundreds of millions of small-scale farmers through secure access to water.

If the above opportunities can be realised, they will have a major impact on food security in sub-Saharan Africa; but there are formidable obstacles. First, crop yields still fall well below potential. Smallholder irrigated agriculture cannot be a subsistence activity, because profits are needed for operation and maintenance costs. Low productivity feeds into the second problem, which is the abandonment of irrigated lands when infrastructure fails. Van Averbeke *et al.* (2011) show a stark example of this among smallholder schemes in South Africa. Of the 67 gravity-fed flood systems, 20 percent had fallen into disuse and 56 percent of pressurised systems were no longer operational. Even in a country with relatively good extension support, it seems that only the simplest of systems can be maintained.

Third, salinity and waterlogging remain ever present threats. Somewhere between 20 and 30 percent of the world's irrigated land is currently seriously affected by salinity and/or waterlogging, and between 1.5 and 2.5 million ha are abandoned by irrigators each year (Khan *et al.* 2008; Kijne 2006). The example of Chokwe in Mozambique is a stark reminder that sub-Saharan Africa will not be immune from the hydrological problems facing irrigation across the rest of the world. Fourth, despite the apparent abundance of water resources, the transition to water scarcity occurs quickly as irrigation develops, and it is already acute in some areas. The institutional and governance arrangements that can frame the development needs of the country within the constraints of the resource are weakly developed, as are the water user associations that oversee the operation and maintenance costs of the irrigation systems themselves.

The grand challenge for irrigation is to improve productivity and profitability whilst operating within the sustainable limits of the catchment to supply water and dispose of salt. Historically irrigation has been dominated by an engineering paradigm of pipes and canals and 'look-up' tables that profess to advise farmers how much water to use. In practice, very few components of the water cycle are measured and few schemes would have much idea about how much food is produced for a given quantity of water, what the potential might be and what steps would be needed to get there. Moreover, there remain huge barriers between the world views and expertise of the multiple stakeholders, from small-scale farmers to agricultural advisors, hydrologists, donor agencies and the host of institutional structures trying to manage water and food security from local to national and even international scales.

The dilemma described above lands the irrigation problem in the centre of social–ecological complexity. The social complexity arises from multiple stakeholders who hold different world views, may have different value systems and whose interests cover very different time or spatial scales. The ecological complexity arises from the uncertainties of climate and water availability and the fate of excess water and solutes in the landscape. Under these circumstances there is no

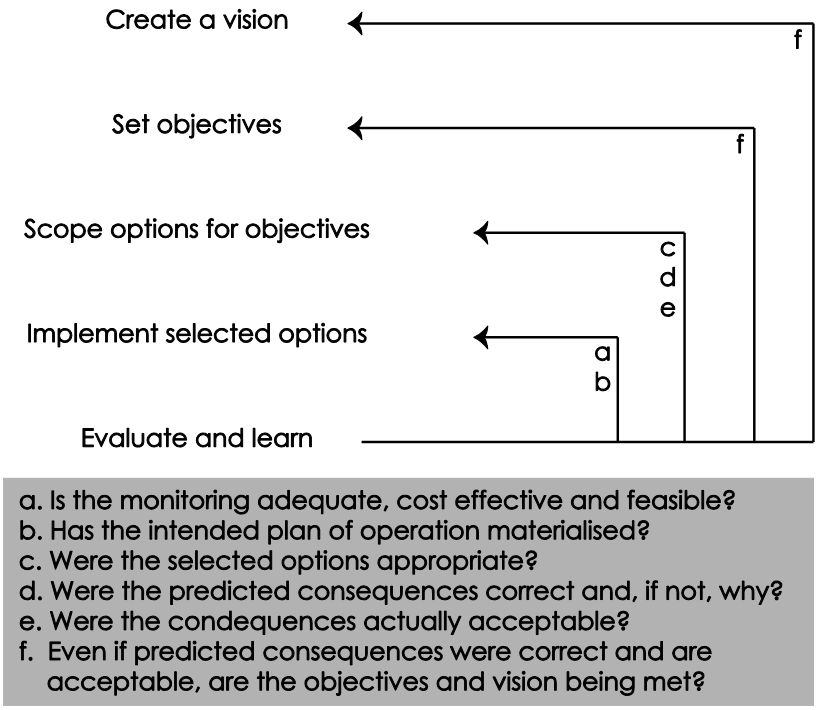
optimal solution, but instead a need for ongoing learning and adaptation (Pahl-Wostl & Hare 2004). This realisation led to the development of the field of adaptive management, which is built on the premise that we have to use real-life management of the system as a whole and turn it into an experiment by asking the right questions, implementing decisions, collecting the right data and learning from the experience (Holling 1978; Lee 1993). Meffe *et al.* (2002) define adaptive management as 'the process of treating natural resource management as an experiment such that the practicality of trial and error is added to the rigour and explicitness of the scientific experiment, producing learning that is both relevant and valid'.

South African scientists have developed a form of strategic adaptive management for protecting both rivers and natural resources (Biggs & Rogers 2003). The reference to 'strategic' means it is forward looking in that it asks the stakeholders to settle on some longer-term vision that captures the values of the majority and encapsulates some common purpose. This is a vital first step, because finding a common purpose is about seeking consensus rather than focusing on the inevitable differences of opinion among the various water stakeholders. The consensus seeking approach is about moving beyond the problem and 'developing a set of shared values that guide future decision making' (Rogers 2006). It differs from the more familiar compromise situation, when we are forced to trade off conflicting demands on the system against those who hold a contrary position, thus creating winners and losers.

Once the vision is agreed, the planning phase sets the objectives needed to attain the vision and finally a scoping of the options available to meet those objectives. Within this planning process, it is important to set measurable targets so everyone can keep track of how things are progressing. These targets may revolve around, *inter alia*, river flow, groundwater depth and quality, water use efficiency and crop productivity. During the implementation phase, the preferred options selected during the planning phase are enacted and the monitoring data collected. The most important part of this process shown in Figure 5.1 is the feedback loops, because this is where we can learn in a structured way. By monitoring the consequences of our actions we answer the following questions: a) Did the intended plan materialize? b) Was the monitoring feasible and cost effective? (c) Were the selected options appropriate? (d) Were the predicted consequences correct? (e) Were the consequences acceptable? (f) Are the objectives and vision being met? (Roux & Foxcroft 2011).

According to Stankey *et al.* (2005), the principles of adaptive management are widely acclaimed but are difficult to achieve in practice. One of the reasons is that monitoring is expensive. A bigger problem is that scientists often want to measure too many things, so the learning process becomes overloaded with information. The key is to identify and monitor 'slow' or underlying variables that integrate system behaviour. All stakeholders should share a common conceptualisation of the problem and have some expectation of how their management options will affect the processes they are measuring, allowing the group to learn in a structured way (Stirzaker *et al.* 2010).

Figure 5.1 The strategic adaptive management learning cycle



Source: Adapted from Roux, DJ & Foxcroft, LC 2011, 'The development and application of strategic adaptive management within South African national parks', Koedoe, 53(2), Art. No. 1049, doi:10.4102/koedoe.v53i2.1049.

Many elements are now in place to make adaptive management a methodology of choice for improving water productivity in sub-Saharan Africa. First, the concept of social–ecological complexity is widely recognised and many people are willing to work across traditional disciplinary boundaries. Second, processes that link institutional and technical innovations are needed to succeed in areas where the straight technical or silver-bullet solutions have failed. Third, monitoring equipment is becoming simpler and more cost effective and, when combined with smart phones, will revolutionise data collection, display and sharing. The most recent FAO report concerning 'coping with water scarcity' urges us to move in this direction:

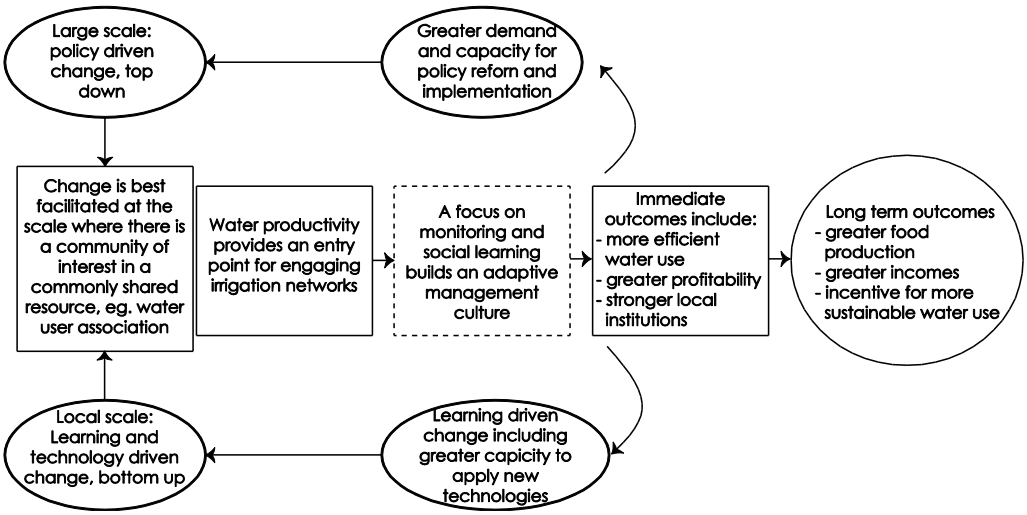
> *Planning and management systems need to be flexible, adaptive and based on continuous social and institutional learning. Adaptive management recognizes the high level of uncertainty associated with future situations, and places emphasis on flexible planning that allows regular upgrading of plans and activities. Such a level of responsiveness is only possible if information and knowledge are updated, and if monitoring and information management systems continually provide decision-makers with reliable information (FAO 2012).*

African governments are embarking on a massive expansion in irrigation without fully addressing the reasons why many previous schemes have been unsuccessful.

It is essential that the mistakes of the last irrigation expansion of the 1960s to 1980s are not repeated, where low profitability did not allow the ongoing investment into infrastructure and the associated institutions that govern equitable and sustainable use. Both a bottom-up technology push and a top-down organizational reform are necessary for lifting irrigation production.

Figure 5.2 gives a framework for how we might implement a new research agenda. We propose the scale of intervention as a water user association. This scale captures the interests of the community in terms of the shared resource and infrastructure, and also represents the financial interests of farmers who are making a living from irrigation. Enhancing these local institutions reinforces social capital and can be a force for equity. We propose that the adaptive management approach is the methodology of choice when trying to bridge institutional and technical innovation (see Figure 5.2, dashed shape). The issues raised by the water user association frame the problem in terms of their long-term goals (see Figure 5.2, far right circle), the policy and institutional environment (top down) and the current technology and aspirations of the farmers (bottom up). Problem framing helps the scientists to determine which aspects of the system need to be monitored in order to structure learning across the network. The information from the monitoring and subsequent learning fosters the intermediate outcome of building capacity in the local institutions and the skill of the farmers.

Figure 5.2 A framework for linking institutional and technological knowledge to improve water productivity



There are two key feedback loops which sustain learning. The first loop is directed upwards as the water user association better understands their requirements and obligations and articulates for better investment of funds or reform of policy. The second loop is directed downwards as farmers see how their practices impact individually on productivity and collectively on sustainability. This creates the awareness and appetite to employ better skills and technology. The process works towards the longer term outcome which includes more productive resources use, profitable and sustainable irrigation schemes and greater food security.

References

Backeberg, GR and Sanewe, AJ 2010, Towards productive water use and household food security in South Africa, 6th Asian Regional Conference of ICID, 10–16 October, Yogyakarta, Indonesia.

Biggs, HC & Rogers, KH 2003, 'An adaptive system to link science, monitoring and management in practice', in JT du Toit, KH Rogers & HC Biggs (eds), *The Kruger Experience. Ecology and management of savanna heterogeneity*, Island Press, Washington, DC, pp. 59–80.

Chilundo, M, Brito, R and Munguambe, P 2004, *Mozambique Country Report on Land and Water Management*, University of Eduardo Mondlane, Maputo.

Food and Agriculture Organization (FAO) 2012, *Coping with water scarcity. An action framework for agriculture and food security*, FAO Water Reports 38, Food and Agriculture Organization, Rome.

Giordano, M, de Fraiture, C, Weight, E & van der Bliek, J (eds) 2012, *Water for wealth and food security: supporting farmer-driven investments in agricultural water management*, Synthesis Report of the AgWater Solutions Project, International Water Management Institute, Colombo, doi:10.5337/2012.207.

Holling, C.S., 1978, *Adaptive environmental assessment and management*, John Wiley, London.

Hsiao, TC, Steduto, P & Freres, E 2007, 'A systematic and quantitative approach to improve water use efficiency in agriculture', *Irrigation Science*, 25(3): 209–31.

International Fund for Agricultural Development (IFAD) 2010, *Rural Poverty Report 2011. New realities, new challenges: New opportunities for tomorrow's generation*, International Fund for Agricultural Development, Rome.

International Food Policy Research Institute (IFPRI) 2011, *Global Hunger IndexThe challenge of hunger: Taming price spikes and excessive food price volatility*, International Food Policy Research Institute, Washington, DC, www.ifpri.org/sites/default/files/publications/ghi11.pdf.

Inocencio, A, Kikuchi, M, Tonosaki, M, Maruyama, A, Merrey, D, Sally, H & de Jong, I 2007, *Costs and performance of irrigation projects: a comparison of sub-Saharan Africa and other developing regions*, IWMI Research Report 109, International Water Management Institute, Colombo.

Jones, WI 1995, *The World Bank and Irrigation*, The World Bank, Washington, DC.

Khan, S, Rana, T & Hanjra, M 2008, 'A cross disciplinary framework for linking farms with regional groundwater and salinity management targets', *Agricultural Water Management*, 95: 35–47.

Kijne, JW 2006, 'Abiotic stress and water scarcity: identifying and resolving conflicts from plant level to global level', *Field Crops Research*, 97: 3–18.

Lankford, BA 2005, *Rural infrastructure to contribute to African agricultural development: the case of irrigation*, Report for the Commission for Africa, ODG, University of East Anglia, Norwich.

Lee, K 1993, *Compass and Gyroscope: Integrating science and politics for the environment*, Island Press, Washington, DC.

MacDonald, AM, Bonsor, HC, Dochartaigh, BEO & Taylor, RG 2012, 'Quantitative maps of groundwater resources in Africa', *Environmental Research Letters*, 7(024009).

Makurira, H 2012, *Rainwater harvesting and conservation agriculture in the southern African region. Potential incentives for sustainable farming for food and water security and poverty reduction in southern Africa*, A scoping study.

Meffe, GK, Nielsen, LA, Knight, RL & Schenborn, DA 2002, *Ecosystem Management: Adaptive community-based conservation*, Island Press, Washington, DC.

Newman, B, Adams, T, Biswas, T, Meissner, T & Smith, K 2012, Irrigation recharge to saline aquifers in the Australian Murray Mallee region, Irrigation Australia Limited Conference, 24–29 June, Adelaide.

Pahl-Wostl, C., Hare, M., 2004. Processes of social learning in integrated resources management. *Journal of Community and Applied Social Psychology* 14, 193-206.

Perry, C, Steduto, P, Allen, RG & Burt, CM 2009, 'Increasing productivity in irrigated agriculture: agronomic constraints and hydrological realities', *Agricultural Water Management*, 96(11): 1517–24.

Pretty, J, Toulmin, C & Williams, S 2011, 'Sustainable intensification in African agriculture', *International Journal of Agricultural Sustainability*, 9: 5–24.

Rogers, KH, 2006, 'The real river management challenge: Integrating scientists, stakeholders and service agencies', *River Research and Applications* 22: 269–280. doi:10.1002/rra.910.

Roux, DJ & Foxcroft, LC 2011, 'The development and application of strategic adaptive management within South African national parks', *Koedoe*, 53(2), Art. No. 1049, doi:10.4102/koedoe.v53i2.1049.

Shah, T, van Koppen, B, Merrey, D, de Lange, M & Samad, M 2002, *Institutional alternatives in African smallholder irrigation: lessons from international experience with irrigation management transfer*, IWMI Research Report 60, International Water Management Institute, Colombo.

Stankey, GH, Clark, RN & Bormann, BT 2005, *Adaptive Management of Natural Resources: Theory, concepts, and management institutions*, Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland.

Stirzaker, RJ, Biggs, HC, Roux, DJ & Cilliers, P 2010, 'Requisite simplicities to help negotiate complex problems', *Ambio*, 39: 600–7. doi:10.1007/s13280-010- 0075-7, PMid:21141779.

Svendsen, M, Ewing, M & Msangi, S 2009, *Measuring irrigation performance in Africa*, IFPRI Discussion Paper 00894, International Food Policy Research Institute, Washington, DC.

van Averbeke, W, Denison, J & Mnkeni, PNS 2011, 'Smallholder irrigation schemes in South Africa: a review of knowledge generated by the Water Research Commission', *Water SA*, 37: 797–808.

van Koppen, B, Smits, S, Moriarty, P, Penning de Vries, F, Mikhail, M & Boelee, E 2009, *Climbing the Water Ladder: Multiple-use water services for poverty reduction*, IRC International Water and Sanitation Centre and International Water Management Institute, [TP series; no. 52], The Hague.

World Bank [nd], *Investment in agricultural water for poverty reduction and economic growth in sub-Saharan Africa*, Synthesis Report, A Collaborative program of AFDB, FAO, IFAD, IWMI and The World Bank, The World Bank, Washington, DC.

You, L, Ringler, C, Nelson, G, Wood-Sichra, U, Robertson, R, Wood, S, Guo, Z, Zhu, T & Sun, Y 2010, *What is the irrigation potential for Africa? A combined biophysical and socioeconomic approach*, IFPRI Discussion Paper 00993, International Food Policy Research Institute, Washington, DC.

Chapter 6

Towards catchment-based water and food security

Exploring the role of incentives for sustainable farming within the context of integrated water resources management in South Africa

DERICK DU TOIT, SHARON POLLARD, DONNA HORNBY AND BRIAN MANDIKIANA

Introduction

The context of planning for food and water security is rapidly changing as there is greater acknowledgment of a looming crisis in agriculture at an international level. This is borne out in the Ministerial Declaration on Food Price Volatility and Agriculture that emanated from a meeting of G20 agricultural ministers in Paris in June 2011 (Declaration G20 Agriculture Ministers June 2011). In this declaration, the ministers recognise that food security will remain a critical issue despite actions taken, in particular at the L'Aquila Summit, the 2009 World Food Summit in Rome and other G20 summits. The declaration goes on to state that all countries have stressed the need for improved and more effective agricultural policies at the global and national levels, better international coordination and concrete implementation of political commitments to promote food security and sustainable agricultural production. They maintain, however, that progress has been made in reforming the Committee on World Food Security (CFS), implementing the Global Partnership for Agriculture, Food Security and Nutrition, and carrying out the L'Aquila Food Security Initiative.

Yet despite these actions, the declaration notes, the situation is still worrying, especially in developing countries, with many challenges remaining. Global population is projected to reach more than 9 billion by the middle of this century. Much of this increase is projected to occur in developing countries, which currently face the greatest level of food insecurity. To feed more than 9 billion people in 2050, it is estimated that agricultural production will have to increase by 70 percent over the same period, and more specifically by almost 100 percent in developing countries (Declaration G20 Agriculture Ministers June 2011).

The G20 ministers affirm that to strengthen global food security, steps must be taken to improve access to and the availability of safe and nutritious food for the most vulnerable, particularly women and children in developing countries, through, for instance, national food-security programs. They stress the need to increase agricultural productivity on a sustainable basis, noting that it requires improvements in land and water management and agricultural technologies, an appropriate and enabling environment that could lead to increased investments—notably from the private sector—well-functioning markets and means to mitigate and manage risks associated with excessive price volatility of agricultural commodities.

The declaration recognises the importance of water in agricultural production and acknowledges that much still needs to be done in this regard:

> *We will promote sustainable crop diversification and agricultural systems which contribute to positive externalities and a sustainable use of natural resources in particular land, water and biodiversity. We emphasize the need for a sustainable supply of water resources. We take note of the concerns expressed by countries with scarce or insufficient water resources and therefore we invite international organizations to produce a report on how water and related issues could be addressed in 2012.*

The pressures of water scarcity on food security are currently evident in southern Africa. South Africa is the most water-stressed country in the Southern African Development Community (SADC) region (DWAF 2004e), meaning that it will have to address issues of scarcity ahead of its neighbours through policy changes, systemic transformation and innovation. South Africa is acclaimed for its water reform and the adoption of integrated water resources management as the framework for managing catchment water resources to achieve equity and sustainability. One of the key changes flowing from the *National Water Act* (*NWA*) (RSA 1998) is that water is now managed on the basis of water management areas (equivalent to basins) and their constitutive catchments.

The proposed process for managing water is inherently adaptive, allowing for reflection and learning in complex, uncertain environments such as catchments. Attention has now turned to practice. Findings from a three-year study in eight catchments (Pollard & du Toit, forthcoming) that examines factors either constraining or enabling implementation suggest the following are critical: integrated approaches; a practice-based understanding of policy; and the role of leadership, governance, collective action and regulation, as well as self-

organisation and feedback. The authors suggest that self-organisation and responsive, multi-scale *feedback loops* are essential for managing complex systems, providing the basis for learning and response to an evolving context. The existence of feedback loops in the reported case studies is, however, highly variable yet there are examples in which leadership, governance and the ability to self-organise are central. In other cases, despite good efforts to self-organise, the feedback loops are limited to a local scale, which constrains transformation and leadership at a wider scale.

The Incomati Basin, which lies in the south-east of southern Africa, has been the focus of much research as it is not only a trans-boundary basin, it is also one of the pioneer water management areas (WMAs) designated by the Department of Water Affairs (DWA, previously the Department of Water Affairs and Forestry: DWAF) on the South African side of the border. The Inkomati WMA—as it is called within South Africa's borders—is the centre of major policy reform initiatives in land, water and agriculture. The WMA has an estimated total of 1.5 million residents, with the highest density in the Sand River Catchment. A large number of rural settlements exist in the Mhala, Mapulaneng, Nsikazi, Nkomazi and Mswati regions. The Inkomati WMA is the site of various institutional reforms such as the newly established Inkomati Catchment Management Agency (ICMA), the Coordinating Committee on Agricultural Water (CCAW), various land and water reform projects such as the Water Allocation Reform (see below) and land-restitution efforts aimed at returning agricultural land to those dispossessed under the apartheid regime. The Inkomati WMA has some of the most numerous and largest land claims (restitution programs) in the country (ICMA 2010a).

The Inkomati WMA has many commercial farmers as well as the largest number of previously disadvantaged and emerging farmers in the country (ICMA 2010a). Access to natural resources by these communities is an important contextual issue. Under the apartheid regime in South Africa, many key resources such as water and prime agricultural land were co-opted by white colonial settlers. Under the democratic dispensation, attempts are being made to shift such inequities.

Mozambique is still emerging from the effects of a harrowing civil war that ended just more than a decade ago. During that time rural agriculture was a primary target of the Renamo armed forces. All of these factors rendered the livelihoods of the majority of people living in the basin extremely vulnerable (Pollard & Cousins 2008). For many years, Mozambique could consistently be found among the poorest five countries listed in the World Bank's annual *World Development Report* (Simler & Nhate 2005). According to Mozambique's first national poverty assessment, in 1996–97 almost 70 percent of the Mozambican population was living below the poverty line (MPF *et al.* 1998). The adult literacy rate is only 40 percent, with female literacy especially low at only 26 percent (INE 2000).

In many respects Mozambique is following regional SADC development protocols but also specifically the policy and approach for water resources management adopted by South Africa. There is a Joint Water Commission

between South Africa and Mozambique that is tasked with overseeing issues of joint concern, and there is a Tripartite Permanent Technical Committee (TPTC) with Mozambique and Swaziland focusing on issues specifically involving the three countries. The Departmento Nacional Aguas (DNA) (Department of Water Affairs in Mozambique has a similar identity to the South African Department of Water Affairs, and Ara-Sul in Mozambique is the competent river basin authority similar to the ICMA in South Africa.

That water is one of the major constraints to food production is starkly apparent along the eastern seaboard of southern Africa. The average rainfall over a large part of the basin hovers around 550 mm per annum, which, together with other constraints such as soils, access to markets and so on, renders, without intervention, a sustainable agricultural-based livelihood highly unlikely. The role of water, however, is extremely poorly considered by the government departments concerned with agriculture. For example, Pollard and du Toit (forthcoming) found that a provincial department of agriculture (DoA) had not one single staff member dedicated to the issue of water in their planning strategies—despite the major constraints posed by water. Moreover, with some local exceptions (Perez de Mendiguren & Mabelane 2001), the role of water in the livelihoods of the poor is not well understood in the Incomati Basin other than at a very generalised level. For example, we do not know how many rural households are involved in agriculture and what the contribution is to people's livelihoods and overall wellbeing, let alone the role of water in this. One study, conducted in the Sand River Catchment (a sub-catchment of the Incomati), indicated that an *additional* 25–30 L of water per person per day (over a basic allocation of 25 L for domestic use) offered people economic opportunities that they otherwise would not have—one of which was agriculture (Perez de Mendiguren & Mabelane 2001).

In both countries major policy overhauls are attempting to encourage small-scale production but more notably the move to commercial production by the historically disadvantaged—that is, African farmers. One of the challenges to fast-tracking agricultural production under such conditions is that the pressure for economic development will outweigh other considerations and introduce unanticipated and yet persuasive incentives for unsustainable production and water use. The imperative to drive small-scale production towards commercialisation appears to be an issue that is not being explicitly addressed either by default or by design. Perhaps the lack of incentives for and/or experience with small-scale technologies is a constraining feature at the current time.

But how is water secured for such needs? Here, we will focus on water security for small-scale agriculture from a basin perspective. In South Africa important policy guidelines exist for securing water at the catchment level—including General Authorisation (GA), Schedule 1 Use (Sch. 1) and so on (RSA 1998)—but these do little more than 'earmark' an overall quantity of water. Without knowing the demographics of people's livelihood dependencies and where these are distributed in space and time, it is hard to give real meaning to such generalised amounts. The incentives for securing, monitoring and enforcing such amounts

under the banner of integrated water resources management (IWRM) are therefore weak and there is a very real danger that the needs of the poor—and less powerful—will go unheard. And, moreover, as people try to exercise their rights, they will do so in unsustainable ways. The situation is similar in Mozambique, with much of the water reform process being informed by the direction taken by South Africa.

The challenge of context

Agricultural practice cannot proceed in a vacuum; it needs to be referenced against important contextual factors of which three of the most important are water, land and governance. In this chapter we will look at each of these in order to establish the foundation for a discussion on the challenges facing sustainable agriculture in the region. No two water management areas in South Africa are the same and working with averages and generalised situations is less than useful. We will therefore introduce one water management area and use it as a basis for the discussion on institutions and incentives that follows later. We also note that the number of WMAs is set to be reduced from 19 to nine by the end of 2012; however, we present this work within the context of the 19 WMAs, as it was conducted prior to the change.

The Inkomati Water Management Area

The Inkomati WMA (WMA No. 5) covers an area of approximately 28,757 sq km. It is divided into the following three sub-catchments:

1. The Sabie-Sand River Catchment, which lies in the north of the WMA. The Sand River is the main tributary of the Sabie.
2. The Crocodile Catchment (which includes the regional capital of Nelspruit).
3. The Komati Catchment. The Komati River, which rises in South Africa, flows through Swaziland and then re-enters South Africa before flowing on into Mozambique. The confluence of the Crocodile and Komati rivers lies just upstream of the Mozambique border at Ressano Garcia, where after the river is known as the Incomati River. The Sabie flows into the Incomati below Corumana Dam near the town of Moamba.

These rivers are all part of the Incomati international watercourse, which is shared between the Republic of Mozambique, the Kingdom of Swaziland and the Republic of South Africa. The transboundary nature of the Inkomati WMA places certain international obligations on South Africa for cross-border flow.

Topography

The topography of this WMA varies from the high mountains of the Drakensberg Escarpment in the west, with altitudes of more than 2000 m above sea level, through foothills in the central part to the low-lying plains in the east. The escarpment effectively divides the WMA into a western plateau or high veld and

a subtropical lowveld in the east. The Lebombo range forms the eastern border of the catchment. The topography strongly influences rainfall. The mean annual rainfall varies from 1445 mm pa in the escarpment and mountainous areas (near Swaziland) to as low as 470 mm pa in the low-veld region.

Land use

The Inkomati WMA is dominated by extensive afforestation and irrigated commercial agriculture (see Table 6.1). It also has the largest number of previously disadvantaged and emerging farmers in the country. There are also significant urban, rural and industrial users in the catchment (ICMA 2010b). According to the Catchment Management Strategy (ICMA 2010a), conservation areas cover some 35 percent of the catchment, including the Kruger National Park, the Sabie-Sand Wildtuin and other smaller reserves. Mining occurs mainly in the upper reaches of the Komati Catchment and to a lesser extent in the Crocodile and Sabie catchments. Prospecting applications have increased significantly in the past two years (Foundation for Sustainable Environment, pers. comm.). Approximately nine percent of the WMA comprises 'communal lands'; essentially these are the former *bantustans* of the apartheid system: Gazankulu, Lebowa and Kangwane.

The most important sectors in terms of contribution to gross geographic product (GGP)[5] are (ICMA 2010b): manufacturing, 24.6 percent; agriculture, 18.6 percent; government, 16.4 percent; trade, 13.4 percent; and other, 27 percent. Irrigated commercial agriculture is by far the biggest water user but also the largest provider of jobs. No data are available for subsistence agriculture.

Table 6.1 Land use, water use, labour and economics for the Crocodile Catchment as an example

User group	Land use	Water use		Labour		Economics (GDP)	
	(%)	(mm^3 pa)	(%)	(jobs)	(%)	(R million)	(%)
Forestry	17	158	22.0	9,990	25.4	657	7.1
Agriculture	9	482	67.2	19,362	49.3	1,717	18.5
Industry	<2	22	3.1	3,461	8.8	5,057	54.4
Mining	<1			6,500	16.5	1,859	20.0
Domestic	~3	55	7.7	?	?	?	?

Note: Water use figures for commercial agriculture only.

Data sources: Inkomati Catchment Management Agency (ICMA) 2010a, The Inkomati Catchment Management Strategy (CMS), Inkomati Catchment Management Agency, Nelspruit, South Africa, DWA 2009.

[5] GGP is the total income or payment received by the production factors (land, labour, capital and entrepreneurship) for their participation in the production within that area.

Demography

The population of the IWMA is estimated at 1,511,348 (ICMA 2010b). With a population of about 616 000, the Sabie-Sand has the highest population of the three catchments and, within that, by far the largest number occurs in the smallest Sand sub-catchment (Figures 4.4 and 4.5). The population of the Komati Catchment is 415,000 while that of the Crocodile is 478,000. The area is predominantly rural and, as in the other two WMAs, poverty is still rife in the former *bantustans*, underscoring the pressing need for development, including the increasing demands for water.

Water balance for the Inkomati WMA

DWA has recently revised the Internal Strategic Perspective (ISP) 2004 figures for water resource availability and demand. The purpose is to understand the impacts of increased demand and to set up a water resources model with the latest water use and system configuration so as to facilitate water reallocation. The following section summarises these findings. The results differ from those of the ISP in a number of ways. The mean annual runoff (MAR) is about 15 percent less than that of the ISP estimates in the Sand Catchment, ten percent lower in the Sabie and five percent lower in the Crocodile and Komati. The water use in the Crocodile Catchment is higher than originally estimated by the ISP, as is that of the Komati in both Swaziland and South Africa following the completion of Maguga Dam.

In terms of infrastructure, the WMA has a number of dams, including the Injaka Dam in the Marite River (completed in 2002), and the Driekoppies and Maguga dams on the Komati River, as well as a number of smaller dams. There are also a number of water schemes throughout the WMA.

Table 6.2 indicates that total demand, which takes into account the requirements of the reserve, far exceeds the available resources; also, the reserve is not built into the operating rules of most of the systems such as that of the Kwena Dam on the Crocodile River.

As noted, South Africa's international obligations according to the Piggs Peak Agreement and the more recent Interim Inco-Maputo Water Use Agreement (TPTC 2002) are to ensure a minimum cross-border flow of 2.6 cu m/s at Ressano Garcia for environmental purposes. Over and above this are requirements for 29 cu Mm/pa for irrigation and 1 cu Mm/pa for domestic purposes.

Currently South Africa is managing the Inkomati River to meet the Piggs Peak Agreement of 2 cu m/s at the South Africa–Mozambique border. In due course this will be replaced with the more sophisticated flow pattern requirements of the more recent Interim Inco-Maputo Agreement (IIMA), which has a higher minimum flow requirement of 2.6 cu m/s for ecological purposes plus a further amount for downstream demands (B. Jackson, ICMA, pers. comm.). This is likely to change, however, once the Comprehensive Inco-Maputo Agreement comes into effect. Meeting the international allocation is a major concern for the commercial

users in the WMA as they maintain that during low flows the first sector to have restrictions applied is that of agriculture (Pollard & du Toit forthcoming).

Table 6.2 Water availability, demand and water balance of the Inkomati WMA, including the reserve estimates

Availability/use	X1: Komati	X2: Crocodile	X3: Sabie	Inkomati WMA
Availability	775	555	116	1,446
Current use (excluding reserve)	858	632.3	179.5	1,670
Allocated use with reserve				
Cross-border	62	51	0	112
Reserve	228	205	209	
Domestic	47	73	82	202
Industry/mining	2	27	0	29
Irrigation	642	482	98	1,222
Strategic	105	0	0	105
Total demand with reserve	**1,086**	**837**	**389**	**2,311**
Afforestation	117	158	90	365
Alien vegetation	32	32	16	80
Current balance	**– 83**	**– 77.3**	**– 63.5**	**– 223.8**
Balance with reserve	**–311**	**– 283**	**– 6273**	**– 865**

Notes: Figures in million cu m pa. Based on the preliminary estimate for 2008.

Sources: Department of Water Affairs and Forestry (DWAF) 2009, Assessment of Water Availability in the Inkomati Water Management Area by Means of Water Resource Related Models, [Project No. W8147/02], Department of Water Affairs and Forestry, Pretoria (IWAAS).

Institutional reform for water resources management, agriculture, land and rural development

Institutional change in South Africa has involved a comprehensive overhaul of the legislative and institutional frameworks of the apartheid era. Not only were reforms directly pertaining to water introduced, but also to agriculture, as well as many other legal instruments that have direct (for example, the *National Environmental Management Act*) or indirect (the *Municipal Structures Act*) implications for water resources management and food security. The depth and breadth of such change are beyond the scope of this document and have been reviewed by a number of authors over the past decade (see, for example, Dlamini & Cousins 2009; DWAF 2003d; Pejan *et al.* 2007). We will focus on the role of water

in providing incentives for pro-poor food production through various provisions under the umbrella of integrated water resource management (IWRM).

Water institutions and reform

The Department of Water Affairs (DWA) is the overall authority responsible for water resources management and water services provision. It has four directorates that are directly focused on water resources management (WRM). It has nine regional offices, two of which are relevant to the study area: the Limpopo and Nelspruit regional offices. The Inkomati WMA falls under the Mpumalanga office in Nelspruit.

There are a number of water management and services institutions that together fulfil roles related to IWRM. In terms of the *NWA* (s.1), 'water management institutions' include catchment management agencies (CMAs), water user associations (WUAs), international water management bodies and 'any person who fulfils the functions of a water management institution in terms of the Act'.

As noted, the national office of the DWA holds overall responsibility for the management of water resources and the development of the national water resource strategy. As CMAs are established and take up their role of IWRM, the department will play an oversight role. Certain key functions will remain the overall responsibility of the national water office for strategic uses including international agreements, determination of the class and reserve, transfers, assignment of functions to the CMAs and approval of the Catchment Management Strategy (CMS).

CMAs provide the second sphere of the water management structure, under the national department, as provided for in the Act. They are governed by a board, which represents a broad stakeholder group, together with experts. The department is in the process of establishing a CMA in each of the 19 WMAs. At the time of writing two had been established: the Inkomati CMA, which includes the Inkomati study catchment, and the Breede-Overberg CMA in the Western Cape. Also involved in WRM to some degree are the WUAs, established through the transformation of old irrigation boards. They are intended to ensure the representation of major water users, thus extending beyond the agricultural sector. This transformation is being supported in Inkomati WMA through a number of facilitators of the ICMA. The lack of capacity and resources via the ICMA has constrained much of the work.

In addition to the water resources institutions, there are also various non-statutory bodies such as the Crocodile River Forum and the Low Flows Forum. The overall WRM functions fall under the DWA regional office in Nelspruit; however, certain dams[6] and former 'government-controlled areas' are managed under the newly established National Water Resources Infrastructure Branch (B. Jackson, ICMA, pers. comm.). As with the other WMAs, a number of institutions are in the process of being established or transformed in accordance with the *NWA*. The primary

[6] For flood control and dams that supply more than one sector.

institution is the Inkomati Catchment Management Agency (ICMA), which is still being assigned functions. In order to ensure participation in WRM, the CMA is to be supported through catchment management forums (CMFs) or committees, created for each sub-catchment.

Agricultural institutions and reform

Although the aim of this chapter is not to provide a comprehensive overview of the agricultural institutions, we will provide an overview of the basic structure and function of the Department of Agriculture. It is from this context that a better understanding of the challenges of transforming agricultural practices to more sustainable ones should be derived.

The national and provincial departments of agriculture derive their competences from Schedule 4 of the Constitution. The Department of Agriculture, as part of the system of concurrent governance, derives its administrative mandate from the National Parliament and the Provincial Legislature.[7]

The national department is organised around the key areas for supporting agriculture. A number of these operational functions are aimed at various aspects of reform addressing food security and sustainable resources management—for example: policy, planning, monitoring and evaluation; food security and agrarian reform; health and food safety; and natural resources management.[8]

The provincial structures are based on districts. In Mpumalanga there are four district offices: Ehlanzeni South, Ehlanzeni North, Gert Sibande and Nkangala. Key programs that have a bearing on food security and resources management are: land care; land use management; farmer support services, including food security; and rural development and land reform.

The department has focused its energy on a number of priority programs, broadly aimed at supporting black economic empowerment (BEE) in the (commercial) agricultural sector (known as AgriBEE) (Ortmann 2005): revolving credit access schemes aimed at encouraging mechanisation in farming; crop support schemes (called Crop Input Supply), aimed at providing various inputs such as seeds, fertilisers and so on; and agrarian reform.

The department's policies and programs require liaison with a range of agricultural institutions, including: Grain SA, Red Meat Producers (RMP), Agri SA, agribusinesses, commercial farmers, emerging farmers and homesteads involved in land reform and homestead food-security production. The key recent engagements with big business stakeholders (Grain SA, RMP, AgriSA) have involved: the development of the AgriBEE charter; movement of South African farmers to other parts of Africa, involving cooperation between the Department of Agriculture and Agri SA; agricultural mentoring and partnerships with emerging

[7] <www.lda.gov.za/ [accessed 22 August 2011].
[8] <www.lda.gov.za/ [accessed 22 August 2011].

black farmers, especially those on farms transferred under land reform; and a number of other programs not specific to the reform and incentives processes.

Land reform and rural development

An important characteristic of the Inkomati WMA is the high number of land claims and beneficiaries. These are mainly on farmland, so water plays a central role in ensuring their long-term sustainability. The CMS (ICMA 2010a) points out that in the Nkomazi region alone there were at least 125 124 beneficiaries of land as of June 2007. The total gazetted area under claim totals 83 783 hectares.

Whilst many of the basic issues related to land reform and rural development programs in the WMA are area-specific, they stem from national policies aimed at addressing access to land and inequalities introduced under apartheid rule. Land reform is a national competence that is institutionally located in the Department of Land Reform and Rural Development (DLRRD). Policy and legal development, fiscal responsibility and monitoring and evaluation are centralised functions, while implementation takes places provincially and locally through decentralised offices with limited authority to approve financial expenditure.

The main land and agricultural development policy reforms entail a focus on: tenure security for farm dwellers and people living on land in the former homelands or on state lands; poverty, with targeted beneficiaries being farm workers, labour tenants and rural women; subsidisation of land purchases to groups of willing buyers from willing sellers for multiple purposes including farming, homestead food security, livelihood diversification and tenure security; and the restitution of land rights or alternative compensation for landowners and labour tenants who were forcibly removed from land as a result of racial discrimination under apartheid and who were not compensated.

The rights and poverty focus in the *White Paper on South African Land Reform Policy* (1997) began to give way to new emphases from 1998 with a program review and a change of minister, and it has continued to consolidate into a new direction that entails: maintaining legislative frameworks for tenure security for labour tenants and farm occupiers to provide a constitutionally acceptable legal framework for securing rights in former homelands; preferred beneficiaries shifting from the poor to all black people wanting to farm (Land Redistribution and Agricultural Development [LRAD] Programme, 1999); further consolidation of the move from homestead food security to emerging farmers to commercial agriculture (Recapitalisation and Development Program [RADP] Policy, 2011); redistribution from state leaseholds to individuals or groups (Proactive Land Acquisition Strategy, PLAS) with new emphasis on individuals purchasing farms for commercial farming using cheap finance (Ithala Bank and Land Bank policies in the 2000s); and the restitution program increasingly aimed not simply at land rights but to ensure the 'proper use' of transferred land, including maintaining commercial farming enterprises and infrastructure through strategic partnerships.

New policy developments include the *Green Paper on Agrarian Transformation and Land Reform*, which introduces three significant changes to the current land reform

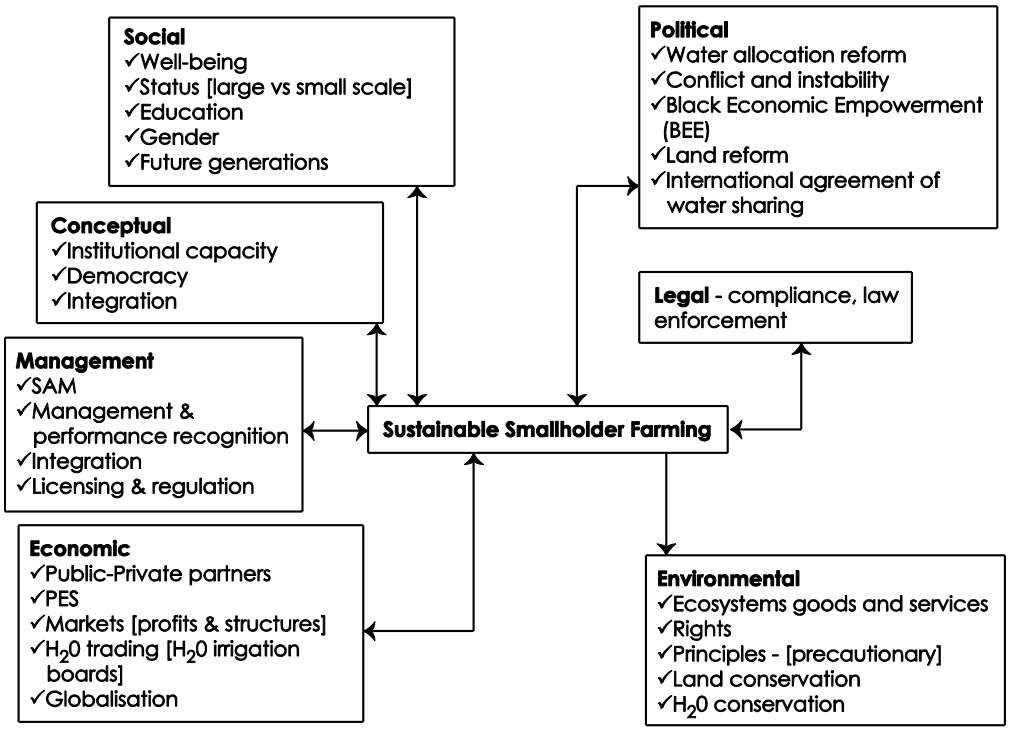
program, their financing and structuring: tenure reform, recapitalisation and a comprehensive rural development program (CRDP).

In addition, to address issues relating to the costs of land acquisition under land reform, which limits the expansion of the program, the Green Paper proposes introducing a multi-tier pricing regime (which is a combination of the willing seller–willing buyer model, capped land prices linked to just and equitable compensation for land reform transactions and land tax) along with a new valuation regime.

The Recapitalisation and Development Program (RADP) component aims to recapitalise and develop (mainly) farms transferred under past and future land reform programs and has a number of purposes, including increasing agricultural production, guaranteeing food security, creating agricultural job opportunities and 'graduating' emerging farmers into commercial farmers. The key forms of proposed intervention involve the development of strategic partnerships (which should invest own equity) and could involve share equities, contract farming or partnerships. The appointment of mentors is also proposed.

Incentives and disincentives for sustainable agriculture under the IWRM framework

Figure 6.1 A framework for exploring incentives for sustainable farming within the context of IWRM



Since agriculture cannot proceed without water, it is imperative that a study of incentives for particular shifts in the nature of agricultural practice be taken together with a study of the water management framework. In the Association for Water and Rural Development (AWARD) study, we looked specifically at the IWRM framework in order to understand if it provides incentives for sustainable farming that supports water and food security for the poor and those with vulnerable livelihoods. A major concern for the agricultural sector is how high levels of production can be met without undermining the potential of the natural environment to continuously provide for future generations. A tentative framework for understanding such incentives and disincentives is provided in Figure 6.1.

In the next section, we provide a study of incentives that might be supported by the IWRM framework. Each of the incentives will be analysed or subject to a particular case study within the site. Key to the analysis will be whether the IWRM framework provides incentives or disincentives for supporting sustainable farming that is pro-poor.

Legal incentives

South Africa has both an enabling Constitution and a set of statutes that can potentially act as incentives to support sustainable farming that is pro-poor. The Constitution makes provision for the right to an environment that is not harmful to health or wellbeing, and to have the environment protected for the benefit of present and future generations through reasonable legislative and other measures that prevent pollution and ecological degradation. It also promotes conservation, and secure, ecologically sustainable development and use of natural resources while promoting justifiable economic and social development (s.24). The Constitution also protects rights in terms of property (s.25) (whether communal or commercial), and the right to have access to sufficient food and water (s.27). How the Constitution will ultimately drive agriculture in more sustainable directions and support pro-poor food production from a legal point of view (that is, legal rulings) is still in its infancy (Pejan *et al.* 2007); however, regardless of the current legal discourse, the Constitution remains an important instrument in providing guidance and is the basis for particular government action in practice. The way in which the Constitution can be used to support sustainability as well as secure food for vulnerable groups is an issue that needs to be investigated.

As far as water is concerned, the *National Water Act* (1998) provides a number of instruments that are clear incentives for transformation that supports both equity and sustainability. In fact, these are two underlying principles clearly articulated in the Act. There is an obligation on water management institutions to design programs that are in harmony with these principles. In terms of sustainability, over the past few decades we have increasingly come to understand the interdependence between humans and ecosystems. The DWA (2009) now recognises that the more we compromise the quality and quantity of available water, the more we compromise our own livelihoods—and that an obligation to protect the natural environment must also take into account the needs of future

generations. The DWA also recognises that since ecological and socioeconomic sustainability depend on water resources, sustainability should be a guiding principle in all management decisions.

Historically meaningful access to water lay in the hands of a minority of South Africans. A cornerstone of democratic transformation is the need to ensure that this situation is reversed so that all South Africans share in the country's water resources; the imperative to fair access is also true for neighbouring countries with which we share rivers. Thus, allocation of water should directly address the issue of fair access to water resources, benefits and services. A special focus should be on those who have historically not benefited from water resources management, such as women and the poor.

In terms of the *NWA*, various instruments can be seen as regulatory but they are at the same time enabling and therefore potential incentives for encouraging particular types of practice. The key ones in respect of this are associated with the *authorisation of water use* where the issuing of water-use licences, the approval of applications to trade entitlements and the setting of priorities for allocation—including water allocation reform—can be used to steer the way water is used and managed at a catchment level. Where water resources are stressed or 'over-allocated', the *NWA* makes the instrument of compulsory licensing available. The application of compulsory licensing allows the regulator to revoke and reissue licences according to the principles of sustainability and equity.

The Act includes provision for capturing and regulating water uses that reduce river flows through the concept of stream flow reduction activities (SFRAs). This provision has largely been applied to commercial forestry but it can also have implications for large-scale rainwater harvesting and associated agricultural techniques. Discussion of this has, however, not happened in any significant way. Should rainwater harvesting escalate through projects of either the Department of Agriculture or the local municipality it is conceivable that policies will be required. Since SFRAs attract a water-use charge, there are cost implications for such use. The quantification of charges is, however, likely to be a source of research and discussion before it is implemented.

Financial regulations and incentives also exist. Through the National Pricing Strategy (NPS), the regulator can control *economic incentives and disincentives* for small-scale agriculture. This has already been instituted through waiving water-use charges for a period for new small-scale farmers and also through staggered charges for different agricultural uses.

Last, the *NWA* provides a supportive framework for farmers to work together in WUAs and to convene meetings through CMFs. These bodies are important for *self-regulation and enforcement* especially where water demand management and promoting sustainable mechanisms of production are to be encouraged. These multiple stakeholder platforms are discussed in more detail below.

Social incentives

Social values and how they promote or hamper particular shifts in practice are an important aspect of understanding the incentive processes. Power issues are highly prominent in post-colonial regimes in Africa and Asia, with resource abuse in farming often reflecting power abuse. To support this notion, Paarlberg (1994) highlighted that, in East Asia, farmers usually have more political power within the agricultural sector than non-commercial farmers. In addition, much of the environmental damage they do reflects the subsidies they are able to command, and most of the suffering from that damage is felt by politically weaker non-commercial farmers. On the other hand, in Africa farmers tend to be politically weaker than urban dwellers and they are the victims of the environmental damage done by more powerful organisations. Hence, lack of power is likely to be a disincentive for rural households who are interested in participating in farming. Further studies of power within the southern African context are likely to be useful in understanding the social dynamics of access to water and food production.

The status and societal value of smallholder agriculture differ by context. In some cases, smallholder farming is viewed as a safety-net for the resource poor who are seen as low-status members of society. On the other hand, smallholder farming is seen as part of the solution to sustaining growth as well as delivering reasonably equitable development (Hazell *et al.* 2007). Hence, the scale of production has the capacity to act as both an incentive and a disincentive for households to participate in agriculture.

One of the social incentives for sustainable farming examined was the prospect of shifting to organic systems of production that: a) have less impact on water resources; b) create more opportunities for small growers; and c) are more economically viable due to lower operation costs. The production of organic food is frequently undervalued for a number of reasons. According to van der Ploeg (1999), organic farming is a niche market that can yield high returns; however, it is unclear whether organic farming can maintain these high earnings as more and more farmers slowly tap into the market. Hence, for smallholder farmers, participation in organic farming can act as both an incentive and a disincentive. In summary, van der Ploeg (1999) notes that, if organic farming remains 'just farming' without fertilisers and pesticides, it could suffer from competition from non-organic methods. On the other hand, if the potential already present in organic farming can be expressed as an all-embracing program, its strengths might be reproduced and escalated. To do so an appropriate understanding of the social construction of power and agency is needed.

Another key social issue is gender. Women's contribution to production and food security is of paramount importance yet it is often undervalued in southern Africa. Most agricultural production is done by women and they are income earners and guardians of family health and nutrition. According to the UN Environmental Program (UNEP) statistics in Alamgir and Arora (1991), two decades ago in Africa 85 percent of rural women were involved in agriculture and

produced up to 80 percent of the food consumed by the family. Recent statistics note that in sub-Saharan Africa, women produce up to 80 percent of basic foodstuffs both for household consumption and for the market (Omwoha 2007). This suggests that sound decision making in agriculture should take account of the views of women. Furthermore, farming can act as an efficient incentive to stimulate employment creation for women who in some cases are marginalised from finding employment in the male-dominated formal economy (Alamgir & Arora 1991).

Youth involvement in agriculture is also overlooked. Youth make up nearly 30 percent of the world's population, and their involvement in environmental and developmental decision making and in the implementation of programs is critical to the long-term success of sustainability plans (UNCED, Agenda 21, 1992). In addition to their intellectual contribution and their ability to mobilise support, youth bring unique perspectives that need to be taken into account. Numerous actions and recommendations within the international community (Declaration G20 Agriculture Ministers June 2011) have been proposed to ensure that youth are provided with a secure and healthy future, including a good-quality environment, improved standards of living and access to education and employment. These issues need to be addressed in development planning as well as in the national curricula of formal education systems.

Economic incentives

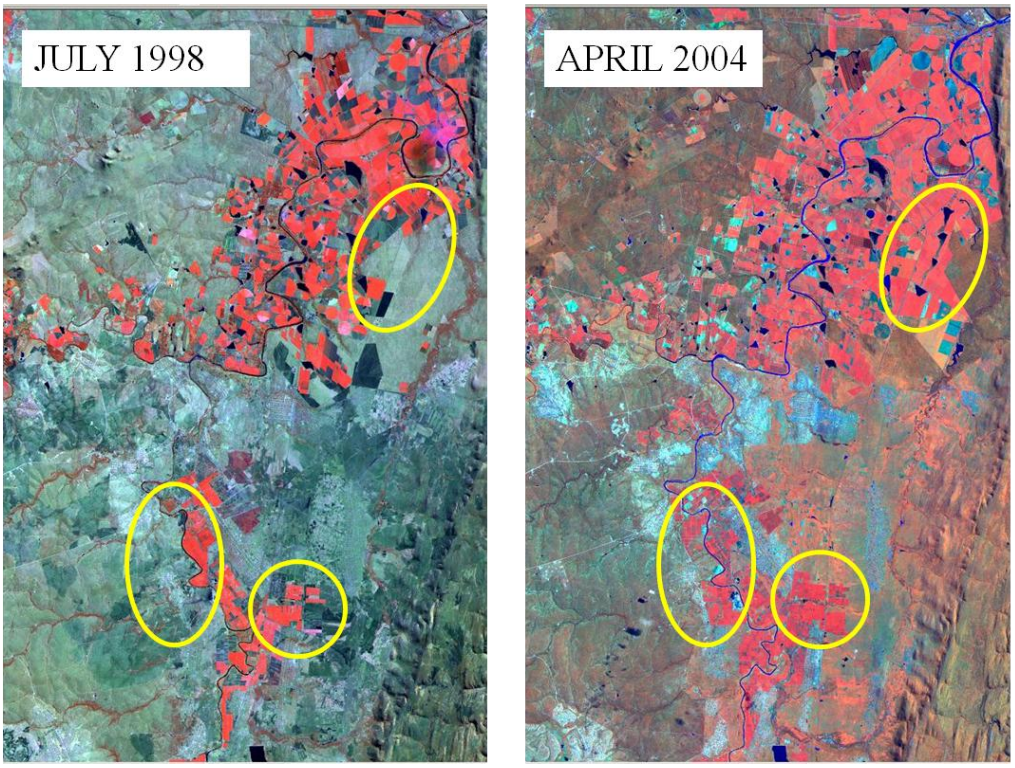
The transformation of the small-farm economy is an enormous economic challenge (Hazell *et al.* 2007). For some, it entails growth into specialised, market-oriented farms; for others, it is part-time farming combined with off-farm rural jobs; and for others, a move out of agriculture. The pathways to transformation differ by region and location and will take decades (Hazell *et al.* 2007). According to Denison and Manano (2007), currently there is a debate about whether small plots have the capacity to make sufficient cash income to cover operational costs such as water charges, maintenance and organisation and still yield a profit; however, cases studies reveal that the Water Care project in Limpopo Province of South Africa yields R 1500 to R 2000 per hectare annually. In addition, case studies conducted in Eastern Cape Province revealed that smallholder farmers discontinued irrigation schemes on small plots as a result of low returns to scale. Hence, the scale of production was a disincentive for households to continue farming. Despite the low returns to scale, in Limpopo Province smallholder farmers indicated that they are willing to continue farming (the case of Makuleke Irrigation Scheme) due to limited livelihood strategies (Denison & Manano 2007, p. 49).

From a global perspective, agriculture has changed from primarily supply-driven to being driven by consumer demands for quality, safety, convenience and choice (Rich & Narrod 2010). Although such market forces tend to be a disincentive for smallholder farmers to participate in the supply chain (Delmar 2005; Qaim 2009), there is potential for public–private partnerships (PPPs) to link farmers to high-value agricultural markets. According to the PPP manual (DoA 2004 in Farlam

2005), a PPP is 'a contract between a public sector institution and a private party, in which the private party assumes substantial financial, technical and operational risk in the design, financing, building and operation of a project'. Dittoh *et al.* (2010) suggested that PPPs are instrumental in the establishment of financially viable, sustainable and effective smallholder drip-irrigation systems, the users of which on their own lack the capacity to meet such essential prerequisites for participation in high-value agriculture. In the Inkomati WMA there is considerable experience with PPPs in agriculture as they were the main strategy in the transformation of the apartheid 'homeland' agriculture schemes into viable entities. Many of these schemes have since collapsed and alternative models are being sought. The application of PPPs as an incentive for the establishment of sustainable agricultural practices is still uncertain.

The images in Figure 6.2 show the progress towards increasing the number of small-scale producers in the Komati Catchment between 1998 and 2004 as a direct result of the land and water reform processes—in this case, driven by the partnerships between government, commercial farmers and emerging small-scale agriculture.

Figure 6.2 Images showing the increase in small-scale agriculture from 1998 to 2004 along the Lower Komati River, giving an idea of how small-scale growers have been encouraged under the water reform process and partnership programs



Source: ICMA internal report 2004.

Market instruments to enhance or protect ecosystem services—the services provided to humans by nature—are increasingly being proposed by environmental economists and policymakers alike as an efficient and cost-effective solution. Such solutions are based on efficiency-related outcomes as the overriding goals. Increasingly, however, equity issues are being raised as possible deterrents to individuals taking part in such payment for ecosystem services (PES) or market-based instrument (MBI) schemes, and these schemes are failing to meet the necessary sustainability objectives of natural resource management (Proctor *et al.* 2008). Despite this, the Sand River Catchment is a national study site for a Water Research Commission study (WRC 2010, which should provide valuable insights into the application of the PES approach in the region.

Water trading has also been applied as a financial incentive to encourage agricultural production under the *NWA*. According to Cummings and Nercessiantz in Backeberg *et al.* (1996, p. 86), water trading embraces the 'willing seller–willing buyer' principle. Under the *NWA* (s.25), water-use entitlements may be transferred between users in two ways: *temporary transfer of water*, which applies only to the transfer of an entitlement for irrigation purposes, either on the same property or to another property; and *permanent transfers*, where a user may surrender all or part of an entitlement to facilitate a licence application by another user. In South Africa, however, where agriculture is typically dualistic, one of the major prerequisites for a successful water market is the involvement of government in order to prevent monopolistic behaviour, and hence to provide incentives for resource-poor smallholder farmers to engage in farming. A survey conducted in 2003 in the Lower Orange River Catchment, which focused on water marketing as a tool to promote agricultural production, concluded that traders of water rights tend to specialise in the production of few crops that yield high earnings—such as export grapes (Gillitt *et al.* 2005). Pollard and du Toit (forthcoming) suggest water trading might act as a disincentive for small-scale growers as more and more powerful commercial farmers capture entitlements to water through trading.

Environmental incentives

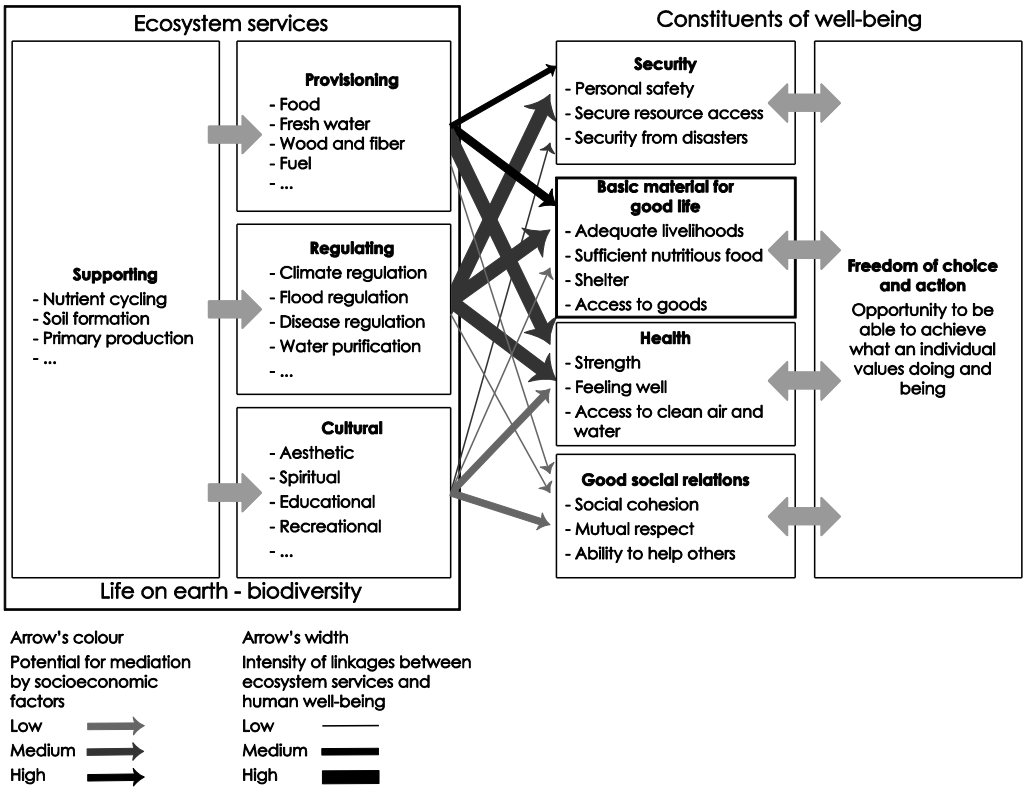
An ecosystem can be defined as 'a set of interacting species and their local, non-biological environment functioning together to sustain life' (Moll & Petit 1994), whilst ecosystem services can be defined as 'the benefits human populations derive, directly or indirectly, from ecosystem functions' (Constanza 1997). Clearly, one ecosystem can generate a number of different services simultaneously, and this depends on how the ecosystem is managed.

Various ecosystem service projects including ecosystem services for poverty alleviation (ESPA) and payment for ecological service (PES) have emerged under the Millennium Ecosystem Assessment (MA) (Figure 6.3).

Environmental water requirements (EWRs) have been adopted in South Africa and Mozambique as a way of securing ecosystem goods and services (Pollard & du Toit, forthcoming) An important component of meeting EWRs relates to basin-

scale issues—that is, *meeting EWRs across international boundaries*. This means widening the scope of EWRs to consider sustainability at the basin scale, irrespective of political boundaries. Such issues are of high priority in the Incomati Basin, where, amongst other things, EWRs are being considered through the PRIMA project, which will formalise a comprehensive water-sharing agreement between Mozambique, Swaziland and South Africa. Each state is committed to determining national EWRs and this has raised a number of issues regarding 'up-scaling' these to a basin-wide commitment. A considerable amount of work has been done in South Africa (Pollard *et al.* 2009).

Figure 6.3 Depiction of the links between ecosystems goods & services and wellbeing



Source: Constanza, RR, d'Arge, R, de Groot, S, Farberk, M, Grasso, B, Hannon, K, Limburg, S, Naeem, RV, O'Neill, J, Paruelo, RG, Raskin, P, Sutton, K & Belt, MVD 1997, 'The value of the world's ecosystem services & natural capital', Nature, 387:253–60.

Political incentives

Land tenure reform refers to, for instance, a planned change in the adjustment of the terms of contracts between landowners and tenants or the conversion of more informal tenancy into formal property rights (Adams *et al.* 1999). A fundamental goal is to enhance and secure people's land rights. The process of economic empowerment in South African agriculture is said to start with improved access to land for black people and the vesting of secure tenure rights with black people

in areas where these do not exist (Adams *et al.* 1999; DTI 2008). This suggests that the issue of land tenure is central to participation in farming.

A discussion of whether title deeds are an incentive to agricultural investment by the poor is pertinent in this regard. Individual property rights and ownership may enhance the willingness of individuals to invest in land and water resources and their conservation, thereby facilitating change. According to Grafton *et al.* (2008), well-defined individual or community user or property rights that are accepted by stakeholders are necessary for better governance, but have failed to fully align private and societal incentives to maximise public benefits. Whilst access to land might be an incentive to farming, it is not clear whether it acts as an incentive or a disincentive in promoting *sustainable* agriculture.

AgriBEE draws from the *Broad-Based Black Economic Empowerment Act* (No. 53 of 2003). The rationale for the enactment of this law is to promote access for previously disadvantaged people to South Africa's productive resources, and thus to attempt to seek stability and growth of the economy, increased employment and more equitable income distribution. The Act calls for the agricultural sector to develop a charter for transformation. The Broad Based Black Economic Empowerment Transformation Charter for Agriculture (DTI 2008) sets as its aims the inclusion of black people along the entire agricultural value chain; the publication of sector codes for determination of BEE status; facilitation of access to BEE funds available from government departments, state enterprises and financial institutions; and provision of agricultural skills development. The overall object of the AgriBEEE charter suggests that promotion of economic transformation creates an enabling environment for the participation of black people in the economy.

One of the major instruments driving water reform in South Africa is a national program called Water Allocation Reform (WAR) (see below). The program, guided by a position paper (DWAF unpublished), aims to address skewed access to water by colonial elites and upheld by the riparian principle. The WAR program aims to provide incentives for historically disadvantaged emerging farmers by making water allocations available to them over a specified period. Whether this has taken place is contended (Pollard & Du Toit, forthcoming).

International agreements are an important political driver for creating stability in the region but to what extent they act as an incentive for sustainable agriculture is unclear. SADC protocols for agriculture have been developed but it is uncertain to what extent they influence agricultural planning and action.

Management incentives

Integrated water resources management (IWRM) offers an incentive to planning for sustainable water resources management and supporting the transformation to more sustainable modes of agricultural production. IWRM recognises that water management cannot be decoupled from surrounding land use.

The IWRM framework also encourages transformative learning and the adoption of new approaches through support for strategic adaptive management (SAM). Realising the implications of managing complex systems—which is what catchments are—means functioning within a context of external and multiple influences, changing values and unpredictability. An adaptive management process that encourages learning-by-doing, based on the best available information, is gaining acceptance as an appropriate approach (see Biggs & Rogers 2003).

The IWRM framework explicitly adopts a pro-vulnerable and pro-poor approach and, while the principle of equity aims to adjust the imbalances and inequities of decades of skewed water access, it is unlikely to adequately emphasise the need to provide water for the most vulnerable groups in society. Water management institutions have a central role to play, essentially through the CMS, to ensure that special attention is given to water for vulnerable and poor members of society: rural and urban poor, landless/homeless people, rural women, those affected by HIV/AIDS, the disabled and pensioners. Water management institutions are expected to work in an integrated manner with water service providers, non-governmental organisations (NGOs) and social welfare institutions in ensuring that water reaches these groups.

Another central aspect of IWRM is involving stakeholders in all of the main processes of water management. This offers a huge incentive for small-scale productive users to be heard in the management and decision-making processes. First, small-scale users are represented on the catchment management agency boards, they are participants as members of WUAs, and their voices can be heard at the meetings of CMFs. Although their participation here is an incentive, the opportunity may be lost if their participation is ill informed or misdirected. Capacity building and awareness are therefore integral to a meaningful uptake of the opportunity to influence water and food-security related decisions.

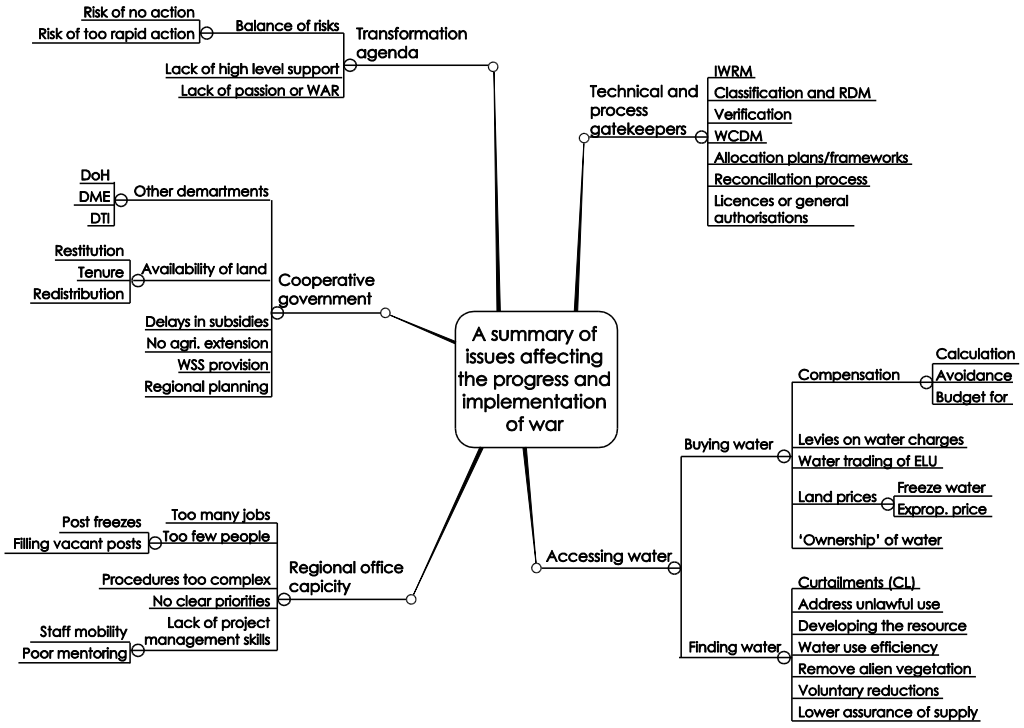
In the study area there is an important collaboration between government departments. The Coordinating Committees on Agricultural Water (CCAW) work between the DWA and the national and provincial departments of agriculture and other relevant departments in each of the provinces to make decisions regarding the allocation of water to agricultural activities, including small-scale ventures. Although the CCAW in Mpumalanga has been beset with management and leadership problems (Pollard & du Toit, forthcoming), it represents an important platform for decision making.

Progress in terms of water for food production and poverty alleviation

Although we cannot provide a comprehensive evaluation of the government's efforts to address water for food security and poverty reduction at this point, we are able to provide an overview of the main efforts on the part of the two key departments: the DWA and the DoA.

The DWA has launched a number of projects that are important for supporting sustainable agriculture and pro-poor food security. The first, and possibly most extensive, is the WAR, the aim of which is to use water to eradicate poverty and promote economic growth. It involves a number of actions including the provision of financial support to resource-poor farmers, compulsory licensing to support the equitable (re)allocation of water in particularly water-stressed catchments, and the processing of licences and/or general authorisations to support the uptake of water by historically disadvantaged people. The WAR has made progress in many respects but there have been some major challenges. These are summarised in Figure 6.4.

Figure 6.4 Summary of issues affecting the Water Allocation Reform in order to bring about sustainable livelihoods



Source: Internal presentation by Ash Seetal, DWA 2004.

The WAR program, in particular, has adopted a specific focus on livelihood projects that have a focus on: a) resource-specific general authorisations where 'small' producers need not apply for a licence; b) an empowerment strategy, helping small producers cope; and c) cooperative government protocols for supporting municipalities with their economic development projects including food production and farming.

The water-use licensing and registration process of the DWA is a mammoth task of gathering the information that is needed for management of water resources, ensuring fair allocation and protection of the environment and enabling the department to charge for water. The licensing process is aimed at setting

conditions to water entitlements so that water use can be collectively managed for a particular catchment. One of the aims of the process is to understand water availability and to whom it is apportioned. The reapportioning of water in the case of inequitable allocation is done by a process called compulsory licensing. No compulsory licensing has yet been attempted in South Africa.

Another program embarked upon in the water sector is the Water for Growth and Development (WfGD) (DWA 2006). The DWA has developed a framework to guide actions and decisions that will ensure water security in terms of quantity and quality to support South Africa's requirements for economic growth and social development. Sufficient supply of water is a requirement for the country to achieve its economic growth targets. The application of water for economic activities is one of the mechanisms aimed at poverty reduction through job creation; however, these goals must be achieved without compromising the ecological sustainability of water resources.

One of the biggest users of water is commercial agriculture; however, the entry of multiple small-scale growers is likely to have a cumulative impact on the water resources of a catchment. In order to mitigate the effects of wasteful or inefficient water use, the Water Conservation and Water Demand Management (WCWDM) strategy has been devised; it is expected to play a crucial role to ensure social equity, economic development and environmental sustainability. The agricultural sector represents about 62 percent of the total water used in South Africa (NWRS 2004e). Efficient water use has the potential to release sufficient water for extended use in the sector, especially by new entrants, and also by other sectors. The DWA maintains that the WCDM program has the potential to assist South Africa to achieve greater food security not only at the national level, but also at the household level, especially for the rural poor (DWAF 2004e).

Commercial agriculture in mostly the Crocodile and Komati catchments has invested in water-efficient irrigations systems; however, emerging farmers and home growers cannot afford these technologies and require support from the DoA in order to make improvements (see below). Special tariffs apply to small growers for the first five years of operation.

The equitable supply program of the DWA is responsible for covering policy, planning and regulatory functions required to ensure reliable and equitable supply of water for sustainable economic and social development, including the eradication of poverty. This includes assessing the available water in particular areas (priority nodes).

The sustainable supply program is responsible for the provision of a reliable and equitable supply of bulk water, as well as the Working for Water (WfW) program, which is an alien invasive plant-clearing program that aims to improve water availability through the removal of non-indigenous plants with high water demands. Through engaging the unemployed in the extended public works project, it provides remuneration for labour. In this way the program aims to eradicate poverty.

The protection policies program covers policy, planning and regulatory functions required to ensure the protection of water resources, such as developing a system for classifying water resources as required by the *NWA*, so that they may be used sustainability. This program has proceeded very slowly but it nonetheless offers an important benchmark for using water sustainability at the catchment level.

The efforts of the DoA to stimulate activities in the sector are conceptualised in the Strategic Plan for South African Agriculture. The plan is designed to meet the challenges of constrained global competitiveness and low profitability, skewed participation, low investor confidence, inadequate support and delivery systems and poor and unsustainable management of natural resources (DTI 2008). This vision aims to dovetail with the AgriBEE Charter and sets a platform of incentives for the participation of formerly marginalised rural households in agriculture.

The key activities focusing on the group the DoA calls 'black emerging farmers and homestead producers' include interventions such as grants and subsidies for the provision of inputs, mainly infrastructure (for example, fencing, dips, production units such as broiler houses, abattoirs), but also mechanisation (provision of tractors and planting and harvesting equipment). There are also product inputs such as seed and animal stock as well as expansion projects in the former homelands aimed at producing on scales for local markets. The department provides extension services (soil testing, agronomic and crop advice) and animal health support focused on prevention of disease as well as support for the development of business plans.

The Land and Agrarian Reform Project (LARP 2008) creates a delivery paradigm for agricultural and other support services. It aims to redistribute 5 million ha of white-owned agricultural land to 10,000 new agricultural producers; increase black entrepreneurs in agribusiness by ten percent; provide the target groups with universal access to agricultural support services; and increase both agricultural production and agricultural trade by 10–15 percent for the target groups.

The LARP promotes PPPs as an incentive for black entrepreneurs to enter commercial agriculture.

The Comprehensive Agricultural Support Programme (CASP) provides grants for comprehensive agricultural support targeting 'the hungry and vulnerable, food security and subsistence, farm and business level activity and agricultural macro system[s] within [the] consumer economic environment'. It uses six 'pillars' of support: knowledge management, technical support, financing, capacity building, marketing, and business and infrastructure development.

Through the Agribusiness Development Unit, the department provides support for farmers to acquire mechanisation equipment in what is called the Mechanisation Revolving Credit Access Scheme (2006). This unit promotes commercialisation and mechanised farming practices. The department facilitates financing (through the Land Bank and Ithala Bank), and financial investment in partnerships with agribusinesses and commercial farmers (including contract farming, mentoring and share equity schemes).

Another significant intervention by the department is the Crop Input Supply program (2007). Through the Crop Production Unit, the department provides crop production inputs for farmers, which include seeds, seedlings, fertiliser and mechanical assistance such as heavy machinery for ploughing; however, AWARD has witnessed unsustainable practices in the catchment where tractors are ploughing land in a way that encourages erosion and soil degradation. What is meant to be a benefit to the small-scale farmer in fact has a negative long-term outcome.

Concluding comments

In this chapter we have attempted not only to reflect the challenges being faced in the region, but also to show how the relevant government departments have responded through different policies and programs. We have also attempted to highlight the importance of referencing water availability and governance against catchments rather than the political boundaries of countries, provinces and districts in planning for water security. We believe that the priorities for intervention are mostly located in the realm of governance, with the principal needs associated not with *what* is done but rather with the *way* it is done. Our research highlights the need for, amongst others: enhanced communication amongst managers at every level, joint priority setting, feedback loops and reflexive learning within the relevant sectors, and a stronger focus on strategic adaptive management.

With growing water scarcity, it is clear that countries in southern Africa will need to be strategic and pragmatic in finding solutions to food-security challenges. The imperatives of equity and sustainability, together with the increasing pressure on water resources, have meant that water-sharing arrangements are under much closer scrutiny than in the past. Catchments such as the Incomati Basin are challenged by the fact that they are home to many poor rural communities, spanning three countries, necessitating a regional strategy. As mentioned in the introduction, the combination of apartheid and civil wars has rendered the livelihoods of the majority of people living in the basin extremely vulnerable. A critical factor in transforming this is water; however, the historical legacy in southern Africa has a profound influence on how and where water is used. Overturning this legacy is a mammoth task that cannot be done without political will, appropriate levels of prioritisation and curtailing of skewed water-use dynamics. It is incumbent on government departments to represent sections of the community that struggle to access water for food production.

From a food-security perspective, the major policy overhauls—although they encourage small-scale production—are not enough. There is notably a move by the various departments to promote commercial production amongst the historically marginalised. One of the challenges of fast-tracking agricultural production under such conditions is that the pressure for economic development will outweigh other considerations and introduce unanticipated and yet persuasive incentives for unsustainable production and water use.

We need to understand the landscape of incentives for small-scale production and poverty alleviation as it currently exists in the region with the aim of synthesising the expected outcomes and developing practices over the coming years in collaboration with the various departments and relevant farmer groups. It is imperative that there is greater integration and coordination across government sectors, specifically the Department of Water Affairs and the Department of Agriculture in respect of water allocation, regulation of use and management for small-scale production and poverty alleviation. We should aim to work collaboratively with farmers and department officials to prepare a supportive environment for sustainable agriculture in the region.

One of the most glaring issues facing the progress towards improved food security and poverty reduction is that of integrating the administrative actions of various government departments. The lack of—or very rudimentary—cooperation between key players (that is, various government departments) is a serious obstacle to transforming small-scale agriculture, as the realisation of a host of policies and instruments falls into their ambit. Since commercial agriculture cannot be expected to provide funding for developing a thriving small-scale sector (other than through controversial contract farming and PPP schemes), the onus falls on governments to drive the process.

Furthermore, as water resources in the lowveld come under increasing pressure, regulators and users will need to find 'solutions' to oversubscription of the resource. The challenge is to develop appropriate practices that address unsustainable use; arguably this can only be done with a certain level of self-organisation within and between the various sectors at different scales. We have shown that nowhere in the lowveld have self-organisation or feedback loops been set out as explicit water governance objectives; rather they are emergent properties of the evolving context of IWRM. In recognising their central role, support needs to be given to developing and strengthening leadership and coherent, robust and multi-scale feedback loops that provide the basis for action and learning; current efforts are largely formative. Key areas are being identified but these will necessitate further exploration and evaluation in order to understand new ways forward; however, a window of opportunity has been created by major policy reforms and there is renewed dialogue between the different countries regarding water sharing and regional economic growth. The time is right to participate in these dialogues and make a call for a renewed and considered focus on water and food security.

Critically attention must be paid to strengthening linkages at higher scales (such as to the DWA and sovereign states), which may require a protracted focus on learning to address the contextual realities. If collective action through multi-sectoral participation is an essential component for robust feedback loops then we need to accept that learning has a vital role to play in ensuring that feedback loops have an impact on self-organisation and regulation. In this regard, learning is taken to be a social process where engagement, communication and dialogue provide the basis for reflecting on and responding to feedback in a way that is open to change and that encourages creative and innovative responses to an ever-

evolving context. An important feedback loop requiring attention is that between academics, practitioners and managers, and in particular the need to develop tenable methodologies and processes. We suggest that functional, responsive, multi-scale feedback loops are essential for the management of complex systems. Earlier research (Pollard & du Toit, forthcoming), however, shows these vary from non-existent to emergent in the lowveld rivers. It then becomes critical to support collective action towards the establishment of resilient, sustainable systems that can support pro-poor food security.

References

Adams, M, Sibanda, S & Turner, S 1999, *Land Tenure Reform and Rural Livelihoods in Southern Africa*, Natural Resources Perspectives 39, Overseas Development Institute, London.

Agterkamp, JW 2009, Allocating contested water: a case study on the (non-) compliance with environmental water allocations in the Sand sub-catchment, South Africa, [MSc thesis], Wageningen University, Wageningen, The Netherlands.

Aihoon, JK, Groenewald, JA & Von Bach, HJS 1997, 'The potential use of pollution insurance as environmental policy: an empirical analysis', *Agrekon*, 36(2): 101–22.

Alamgir, M & Arora, P 1991, *Providing food security for all*, Studies in Rural Poverty No. 1, International Fund for Agricultural Development, London.

Alchian, AA & Demsetz, H 1973, 'The property right paradigm', *The Journal of Economic History. The Tasks of Economic History*, 33(1): 16–27.

Altman, M, Hart, T & Jacobs, P 2009, 'Household food security status in South Africa', *Agrekon*, 48(4): 345–61.

Anderies, JM, Walker, BH & Kinzig, AP 2006, 'Fifteen weddings and a funeral: case studies and resilience-based management', *Ecology and Society*, 11(1): 21, www.ecologyandsociety.org/vol11/iss1/art21/.

Anderson, K 2003, Agriculture and agricultural incentives in China and India post-Uruguay Round, Invited Paper for the IATRC International Conference on Agricultural Policy Reform and the WTO: Where Are We Heading?, Capri, Italy.

Armour, RJ & Viljoen, MF 2000, 'Towards quantifying the economic effects of poor and fluctuating water quality on irrigation agriculture: a case study of the Lower Vaal and Riet rivers', *Agrekon*, 39(1): 99–110.

Bach, H, Clausen, TJ, Dang, TT, Emerton, L, Facon, T, Hofer, T, Lazarus, K, Muziol, C, Noble, A, Schill, P, Sisouvanh, A, Wensley, C & Whiting, L 2011, *From Local Watershed Management to Integrated River Basin Management at National and Transboundary Levels*, Mekong River Commission, Laos.

Backeberg, GR 1997, 'Water institutions, markets and decentralised resource management: prospects for innovative policy reforms in irrigated agriculture', *Agrekon*, 36(4): 350–84.

Backeberg, GR 2004, 'Research management of water economics in agriculture—an open agenda', *Agrekon*, 48(4): 357–74.

Backeberg, GR, Bembridge, TJ, Bennie, ATP, Groenewald, JA, Hammes, PS, Pullen, RA & Thompson, H 1996, *Policy proposal for irrigated agriculture in South Africa*, Report KV96/96, Water Research Commission, Pretoria.

Baiphethi, MN & Jacobs, PT 2009, 'The contribution of subsistence farming to food security in South Africa', *Agrekon*, 48(4): 459–82.

Biggs, H & Toit, DR 2008, *Preliminary Exploration of Two Approaches to Documenting Elements of the Mental Models of Stakeholders in the Crocodile Catchment*, Water Research Commission, Pretoria.

Biggs, H. & Rogers, K.H., 2003, 'An adaptive system to link science, monitoring and management in practice. The Kruger Experience.' in J.T. du Toit, K.H. Rogers & H.C. *Biggs, Ecology and Management of Savanna Heterogeneity*, pp. 59−80, Island Press, Washington DC.

Brown, CA, Berg, E, Sparks, A & Magoba, RN 2010, 'Options for meeting the ecological reserve for a raised Clanwilliam Dam', *Water SA*, 36.

Burns, M, Audouin, M & Weaver, A 2006, 'Advancing sustainability science in South Africa', *South African Journal of Science*, 102: 379–84.

Constanza, RR, d'Arge, R, de Groot, S, Farberk, M, Grasso, B, Hannon, K, Limburg, S, Naeem, RV, O'Neill, J, Paruelo, RG, Raskin, P, Sutton, K & Belt, MVD 1997, 'The value of the world's ecosystem services and natural capital', *Nature*, 387: 253–60.

De Lange, WJ & Vink, N 2003, 'Opportunistic behaviour by private irrigators within a capacity-sharing regime', *Agrekon*, 42(4): 366–78.

Delmar, DP 2005, 'Agriculture in the developing world: connecting innovations in plant research to downstream applications', *PNAS*, www.pnas.org [accessed 5 June 2010].

Denison, J & Manono, S 2007, *Principles, approaches and guidelines for the participatory revitalisation of smallholder irrigation schemes: concepts and cases*, Report TT309/07, Water Research Commission, Pretoria.

Department of Trade and Industry (DTI) 2008, *Broad Based Black Economic Empowerment: Transformation charter for agriculture*, Department of Trade and Industry, Pretoria www.daff.gov.za/docs/Gazettes/Notice30886_314.pdf [accessed 25 August 2011].

Department of Water Affairs and Forestry (DWAF) 1994, *Report on the proposed Sabie River government water scheme (first phase: Injaka Dam and Bosbokrand transfer pipeline)*, White Paper WP D-94, Department of Water Affairs and Forestry, Pretoria.

Department of Water Affairs and Forestry (DWAF) 1996, *Sabie Sand instream flow requirements*, Starter document Aan de Vliet, 18–22 August 1996, Department of Water Affairs and Forestry, Pretoria.

Department of Water Affairs and Forestry (DWAF) 1997, *White Paper on a National Water Policy for South Africa*, Department of Water Affairs and Forestry, Pretoria, p. 37.

Department of Water Affairs and Forestry (DWAF) 2003a, *Development of Internal Strategic Perspective Inkomati Water Management Area (WMA 5)*, Department of Water Affairs and Forestry, Pretoria.

Department of Water Affairs and Forestry (DWAF) 2003b, *Luvuvhu and Letaba Water Management Area overview of water resources availability and utilisation*, [Prepared by BKS on behalf of the Directorate], National Water Resources Planning, DWAF Report No. PWMA02/000/0203, Department of Water Affairs and Forestry, Pretoria.

Department of Water Affairs and Forestry (DWAF) 2003c, *Water Conservation and Water Demand Management – A planning framework for catchment management agencies. Volume 1*, [Draft], Department of Water Affairs and Forestry, Pretoria.

Department of Water Affairs and Forestry (DWAF) 2003d, *Water Management Institutions: Overview*, Department of Water Affairs and Forestry, Pretoria.

Department of Water Affairs and Forestry (DWAF) 2004a, *Guidelines for Stakeholder Participation in Integrated Water Resources Management in Water Management Areas. Integrated water resource management strategies, guidelines and pilot implementation in three water management areas, South Africa*, Department of Water Affairs and Forestry, Pretoria.

Department of Water Affairs and Forestry (DWAF) 2004b, *Internal Strategic Perspective. Inkomati WMA*, Department of Water Affairs and Forestry, Pretoria.

Department of Water Affairs and Forestry (DWAF) 2004c, *Internal Strategic Perspective. Luvuvhu/Letaba WMA*, Department of Water Affairs and Forestry, Pretoria.

Department of Water Affairs and Forestry (DWAF) 2004d, *Internal Strategic Perspective. Olifants River WMA*, Department of Water Affairs and Forestry, Pretoria.

Department of Water Affairs and Forestry (DWAF) 2004e, *National Water Resources Strategy*, [First edn], Department of Water Affairs and Forestry, Pretoria.

Department of Water Affairs and Forestry (DWAF) 2004f, *The Olifants WMA – Overview of water resources availability and utilisation*, [P WMA04/000/00/0203], Department of Water Affairs and Forestry, Pretoria.

Department of Water Affairs and Forestry (DWAF) 2007a, *Guidelines for the Development of Catchment Management Strategies*, Department of Water Affairs and Forestry, Association for Water and Rural Development (AWARD), Zinkwazi Consulting and Water for Africa, Pretoria, p. 135.

Department of Water Affairs and Forestry (DWAF) 2007b, *Guidelines for the Development of Catchment Management Strategies: Towards equity, efficiency and sustainability in water resources management*, Department of Water Affairs and Forestry, Pretoria.

Department of Water Affairs and Forestry (DWAF) 2009, *Assessment of Water Availability in the Inkomati Water Management Area by Means of Water Resource Related Models*, (IWAAS) [Project No. W8147/02], Department of Water Affairs and Forestry, Pretoria.

Department of Water Affairs and Forestry (DWAF) 2010, *Blue Drop Report. South African drinking water quality management performance*, Department of Water Affairs and Forestry, Pretoria.

Dittoh, S, Akuriba, MA, Issaka, BY & Bhattarai, M 2010, 'Sustainable micro-irrigation systems for poverty alleviation in the Sahel: a case for "micro" public–private partnerships?', *Symposium Proceedings Joint 3rd African Association of Agricultural Economists (AAAE) and 48th Agricultural Economists Association of South Africa*

(AEASA), Cape Town, South Africa, http://ageconsearch.umn.edu/97045 [accessed 25 August 2011].

Dlamini, VG & Cousins, T 2009, *Case Study on Bushbuckridge Water Service Delivery Challenges in the Context of Integrated Water Resource Management (IWRM) and Sustainable Water and Sanitation Services (WATSAN): Turning advocacy into action in the South African water sector*, Association for Water and Rural Development (AWARD), Acornhoek, South Africa.

D'Souza, GE & Ikerd, JE 1996, 'Small farms and sustainable development: is small more sustainable?', *Journal of Agricultural and Applied Economics*, 28(1): 73–83, http://purl.umn.edu/15243 [accessed 27 August 2011].

Farlam, P 2005, *Assessing public–private partnerships in Africa*, Nepad Policy Focus Report 2, Organisation for Economic Cooperation and Development, Pretoria, http://www.oecd.org/dataoecd/44/4/34867724.pdf [accessed 26 August 2011].

Ferrer, SRD & Nieuwoudt, WL 1997, 'Factors affecting soil conservation decision of KwaZulu-Natal commercial sugar cane farmers', *Agrekon*, 36(4): 453–61.

Food and Agriculture Organization (FAO) 2004, *Drought impact mitigation and prevention in the Limpopo River Basin: a situation analysis*, Land and Water Discussion Paper 4, Food and Agriculture Organization, Rome.

G20 Ministerial Declaration 2011. Action Plan On Food Price Volatility and Agriculture. Meeting of G20 Agriculture Ministers Paris, 22 and 23 June 2011

Gillitt, CG, Nieuwoudt, WL & Backeberg, GR 2005, 'Water markets in the Lower Orange River Catchment of South Africa', *Agrekon*, 44(3): 363–82.

Gonzalez, LA, Kasryno, F, Perez, ND & Rosegrant, MW 1993, *Economic incentives and comparative advantage in Indonesia food crop production*, Research Report 93, International Food and Research Institute, Washington, DC.

Gordon, A, Davis, J, Long, A & Meadows, K 2000, *The Role of Natural Resources in the Livelihoods of the Urban Poor*, Policy Series 9, Natural Resources Institute, Chatham, UK, www.nri.org/publications/policyseries/PolicySeriesNo09.pdf [accessed 28 August 2011].

Grafton, RQ, Arnason, R, Bjørndal, T, Campbell, D, Campbell, HF, Clark, CW, Connor, R, Dupont, DP, Hannesson, R, Hilborn, R, Kirkley, JE, Kompas, T, Lane, DE, Munro, GR, Pascoe, S, Squires, D, Steinshamn, SI, Turris, BR & Weninger, Q 2005 2006, *Incentive-based approaches to sustainable fisheries*, Economics and Environment Network Working Paper EEN0508.

Grafton, RQ, Hilborn, R, Ridgeway, L, Squires, D, Williams, M, Garcia, S, Groves, T, Joseph, J, Kelleher, K, Kompas, T, Libecap, G, Lundin, CG, Makino, M, Matthiasson, T, McLoughlin, R, Parma, A, Martin, GS, Satia, B, Schmidt, CC, Tait, M & Zhang, LX 2008, 'Positioning fisheries in a changing world', *Marine Policy*, 32: 630–4.

GWP 2003, 'Dialogue on effective water governance: learning from the dialogues', *Proceedings of Third World Water Forum, Kyoto, Japan*, p. 36.

Hart, T 2009, 'Exploring definitions of food insecurity and vulnerability: time to refocus assessments', *Agrekon*, 48(4): 362–83.

Hazell, P, Poulton, C, Wiggins, S & Dorward, A 2007, *The future of small farms for poverty reduction and growth*, Vision 2020 Discussion Paper No. 42, International Food Policy Research Institute, Washington, DC.

Holland, JH 1992, *Adaptation in Natural and Artificial Systems: An introductory analysis with applications to biology, control, and artificial intelligence*, MIT Press, Cambridge, Mass.

Inkomati Catchment Management Agency (ICMA) 2010a, *The Inkomati Catchment Management Strategy (CMS)*, Inkomati Catchment Management Agency, Nelspruit, South Africa.

Inkomati Catchment Management Agency (ICMA) 2010b, *Strategy Framework for the Inkomati Catchment Management Agency*, Inkomati Catchment Management Agency, Nelspruit, South Africa.

Instituto Nacional de Estatística (INE) 2000, *II Recenseamento Geral da População e Habitação: Resultados Definitivos*, Instituto Nacional de Estatística, Maputo.

James, AJ & Robinson, E 2001, *Water and sustainable rural livelihoods in Andhra Pradesh: background paper*, WHIRL Project Working Paper 3, [Draft], Water Supply and Sanitation and Watershed Development: Positive and Negative Interactions, Andhra Pradesh, India.

King, J & Brown, C 2006, 'Environmental flows: striking the balance between development and resource protection', *Ecology and Society*, 11(2): 26, www.ecologyandsociety.org/vol11/iss2/art26/.

Kirsten, JF, Ohene-Anyang, E & van Rooyen, J 1998, 'An analysis of the comparative advantage and policy incentives of commercial wheat production in South Africa', *Agrekon*, 37(4): 528–40.

Kotter, JP 1996, *Leading Change*, Harvard Business School Press, Boston.

Kumar, MD 2003, *Food security and sustainable agriculture in India: the water management challenge*, Working Paper 60, International Water Management Institute, Colombo, www.iwmi.cgiar.org/Publications/Working_Papers/working/WOR60.pdf [accessed 27 August 2011].

Lahiff, E 2003, *The politics of land reform in southern Africa*, Sustainable Livelihoods in Southern Africa Research Paper 19, Institute of Development Studies, Brighton, UK.

Louw, DB & Van Schalkwyk, HD 2000, 'Water markets an alternative for central water allocation?', *Agrekon*, 39(4): 484–94.

Ministry of Planning and Finance (MPF), Eduardo Mondlane University (UEM) and International Food Policy Research Institute (IFPRI) 1998, *Understanding Poverty and Well-Being in Mozambique: The first national assessment, 1996–97*, Ministry of Planning and Finance (Mozambique), Eduardo Mondlane University and International Food Policy Research Institute, Maputo.

Moll, G., & Petit, J., 1994. *The urban ecosystem: putting nature back in the picture*. Urban Forests Oct/Nov, 8–15

Munro, B 1995, *Water for sustainable development in Africa*, Discussion Paper, [Expert Group Meeting on the Implications of Agenda 21 for Integrated Water Management in Africa], p. 28.

Nieuwoudt, WL 2000, 'Water market institutions: lessons from Colorado', *Agrekon*, 39(1): 57–67.

Nieuwoudt, WL, Backeberg, GR & Du Plessis, HM 2004, 'The value of water in the South African economy: some implications', *Agrekon*, 43(2): 162–83.

Nieuwoudt, WL, Gillitt, CG & Backeberg, GR 2005, 'Water marketing in the Crocodile River, South Africa', *Agrekon*, 44(3): 383–401.

Oettle, N, Fakir, S, Wentzel, W, Giddings, S & Whiteside, M 1998, *Agricultural Services Reform in Southern Africa: Encouraging sustainable smallholder agriculture in South Africa*.

Ommani, AR 2011, 'Analysis of sustainable water resources management (SWRM) in agriculture in Khuzestan Province, Iran', *African Journal of Agricultural Research*, 6(1): 1–6.

Omwoha, JN 2007, 'Gender contribution and constraints to rural agriculture and household food security in Kenya: case of Western Province', *AAAE Conference Proceedings, Accra, Ghana*, pp. 369–72.

Ortmann, GF 2005, 'Promoting the competitiveness of South African agriculture in a dynamic economic and political environment', *Agrekon*, 44(3): 286–320.

Ostrom, E 2000, Private and common property rights, Workshop in Political Theory and Policy Analysis, Center for the Study of Institutions, Population, and Environmental Change, Indiana University, http://encyclo.findlaw.com/2000book.pdf, pp. 332–52.

Paarlberg, RL 1994, *Sustainable farming: a political geography*, Vision 2020 Brief 4, International Food Policy Research Institute, Washington, DC.

Parker, AN 1997, 'Participation and decentralisation in rural development: lessons from the Lesotho Highlands Water Project', *Agrekon*, 36(4): 501–12.

Pejan, R, Norberg, A, du Toit, D & Pollard, S 2007, *The Development of a Framework for Understanding Human Rights-Based Approaches and Integrating them into Water Resources Management in South Africa*, Water Research Commission, Pretoria, p. 119.

Penning de Vries, FWT, Acquay, H, Molden, D, Scherr, SJ, Valentin, C & Cofie, O 2002, *Integrated land and water management for food and environmental security*, Comprehensive Assessment Research Paper 1, Comprehensive Assessment Secretariat, Global Environment Facility, International Water Management Institute, Colombo, p. 70.

Perez de Mendiguren, JC & Mabelane, M 2001, *Economics of Productive Uses for Domestic Water in Rural Areas: A case study from Bushbuckridge, South Africa*, Association for Water and Rural Development, Acornhoek, South Africa.

Pollard, S & Agterkamp, JW (forthcoming[a]), *Constraints to Meeting the Reserve in the Sand River Catchment*.

Pollard, S & Agterkamp, JW (forthcoming[b]), *Managing in Complex Systems: Understanding the multiple drivers and their interactions that underlie sustainable and equitable water resources in the Sand River Catchment*.

Pollard, S. and D. Du Toit, 2009. *Drawing Environmental Water Allocations into the World of Realpolitik: Emerging Experiences on Achieving Compliance with Policy in the*

Lowveld Rivers, South Africa. Implementing Environmental Flow Allocations Conference. Port Elizabeth, South Africa.

Pollard, SR & Cousins, T 2008, *Towards integrating community-based governance of water resources with the statutory frameworks for integrated water resources management: a review of community-based governance of freshwater resources in four southern African countries to inform governance arrangements of communal wetlands*, Report TT.328/08, Water Research Commission, Pretoria, p. 105.

Pollard, SR & du Toit, D 2004, *The Save the Sand Project: A case study*, Both Ends, The Netherlands.

Pollard, SR & du Toit, D 2005, 'Achieving integrated water resource management: the mismatch in boundaries between water resources management and water supply', *African Water Laws: Plural legislative frameworks for rural water management in Africa*, Johannesburg.

Pollard, SR & du Toit, D 2006, *Recognizing heterogeneity and variability as key characteristics of savannah systems: the use of strategic adaptive management as an approach to river management within the Kruger National Park, South Africa*, Report for UNEP/GEF Project No. GF/2713-03-4679, Ecosystems, Protected Areas and People Project.

Pollard, SR & du Toit, D 2008, 'Integrated water resources management in complex systems: how the catchment management strategies seek to achieve sustainability and equity in water resources in South Africa', *Water SA*, [Special Edition: IWRM], 34(6), www.wrc.org.za.

Pollard, SR & du Toit, D 2009a, *Drawing Environmental Water Allocations into the World of Realpolitik: Emerging experiences on achieving compliance with policy in the Lowveld Rivers, South Africa*, Implementing Environmental Flow Allocations, Port Elizabeth, South Africa.

Pollard, SR & du Toit, D 2009b, *The Sabie-Sand Catchment: contextual profile on factors that constrain or enable compliance with environmental flows*, [Draft Report], Project K5/1711, Shared River Programme.

Pollard, SR & du Toit, D (forthcoming), *The Importance of Feedback Loops in Ensuring Catchment Resilience: An examination of six catchments in South Africa*.

Pollard, SR, Biggs, H & du Toit, D 2008, *Towards a socio–ecological systems view of the Sand River Catchment, South Africa: an exploratory resilience analysis*, Report to the Water Research Commission, Project K8/591, Water Research Commission, Pretoria.

Pollard, SR, Mallory, S, Riddell, E & Sawunyama, T 2010, *Compliance with the reserve: how do the Lowveld Rivers measure up? Towards improving the assessment and implementation of the ecological reserve*, [K8/881/2], Unpublished report prepared for the WRC: Reserve Assessment of Lowveld Rivers, [Del. 1].

Pretty, JN, Morison, JIL & Hine, RE 2003, 'Reducing food poverty by increasing agricultural sustainability in developing countries', *Agriculture, Ecosystems and Environment*, 95: 217–34.

Proctor, W, Köllner, T & Lukasiewicz, A 2008, *Equity considerations and payments for ecosystem services*, Discussion Paper Series, Environmental Economy and Policy Research, University of Cambridge, Cambridge.

Qaim, M 2009, 'The economics of genetically modified crops', *Annual Review of Resource Economics*, 1(3): 665–94.

Republic of South Africa (RSA) 1995, *The Development Facilitation Act*, Act No. 67 of 1995, Republic of South Africa, Cape Town.

Republic of South Africa (RSA) 1997, *White Paper on South African Land Reform Policy* , Republic of South Africa, Cape Town.

Republic of South Africa (RSA) 1996, *Constitution of the Republic of South Africa Act*, Act No. 108 of 1996, Republic of South Africa, Cape Town.

Republic of South Africa (RSA) 1997, *Water Service Act*, Act No. 108 of 1997, 69, Republic of South Africa, Cape Town.

Republic of South Africa (RSA) 1998, *National Water Act*, Act No. 36 of 1998, Republic of South Africa, Cape Town.

Republic of South Africa (RSA) 2000, *Local Government: Municipal Systems Act*, Act No. 32 of 2000, Republic of South Africa, Cape Town.

Republic of South Africa (RSA) 2005, *Intergovernmental Relations Framework Act 2005*, Republic of South Africa, Cape Town.

Rich, KM & Narrod, CA 2010, *The role of public–private partnerships in promoting smallholder access to livestock markets in developing countries: methodology and case studies*, Discussion Paper 01001, International Food Policy Research Institute, Washington, DC, www.ifpri.org/sites/default/files/publications/ifpridp01001.pdf [accessed 26 August 2011].

Saunders, J 2004, *Sowing the Seeds: Supporting smallholder farmers in South Africa*, FARM-Africa, South Africa, www.farmafrica.org.uk [accessed 25 May 2010].

Schlager, E & Ostrom, E 1992, 'Property-rights regimes and natural resources: a conceptual analysis', *Land Economics*, 68(3): 249–62.

Scoones, I 1998, *Sustainable rural livelihoods: a framework for analysis*, IDS Working Paper 72, Institute of Development Studies, Brighton, UK.

Sellick, C & Bonthuys, B 2003, *Sabie River Catchment: Operating rules and decision support models for management of the surface water resources. User Manual: Daily ecological reserve estimate model*, National Water Resources Planning, Department of Water Affairs and Forestry, Pretoria.

Sellick, E, Bonthuys, B, Benade, N, Veelen, MV, Hughes, D, Louw, D & Birkhead, A 2002, *Sabie River Catchment. Operating rules and decision support models for management of the surface water resources. Main report*, [volume 1 of 2], [First Draft], June 2002, Report No. P.X300/00/3802, Department of Water Affairs and Forestry, Pretoria, p. 140.

Simler, K & Nhate, V 2005, *Poverty, inequality, and geographic targeting: evidence from small-area estimates in Mozambique*, FCND Discussion Paper 192, International Food Policy Research Institute, Washington, DC.

Smakhtin, V, Revenga, C & Döll, P 2004, *Taking into account environmental water requirements in global-scale water resources assessments*, Comprehensive Assessment Research Report 2, Comprehensive Assessment Secretariat, International Water Management Institute, Colombo.

Tengo, M & Hammer, M 2003, 'Navigating social–ecological systems', in F Berkes, J Colding & C Folke (eds), *Navigating Social–Ecological Systems*, Cambridge University Press, Cambridge, pp. 132–62.

Tripartite Permanent Technical Committee with Mozambique and Swaziland (TPTC) 2002, *Tripartite Interim Agreement between the Republic of Mozambique and the Republic of South Africa and the Kingdom of Swaziland for Co-Operation on the Protection and Sustainable Utilisation of the Water Resources of the Incomati and Maputo Watercourses*, Inco-Maputo, p. 62.

Tsang, EWK 1997, 'Organizational learning and the learning organization: A dichotomy between descriptive and prescriptive research', *Human Relations*, 50(1): 73–89.

UNCED 1992, 'Agenda 21', United Nations Conference on Environemnt and Development, United Nations General Assembly, New York.

van der Ploeg, JD 1999, 'On power and weakness, capacity and impotence: rigidity and flexibility in food chains', *International Planning Studies*, 4(3): 333–47.

van der Ploeg, JD 2010, 'The food crisis, industrialized farming and the imperial regime', *Journal of Agrarian Change*, 10(1): 98–106.

Van Zyl, J & Vink, N 1997, 'The effects of water policies on the farm sector in the Western Cape', *Agrekon*, 36(4): 573–85.

Versfeld, D 2003, Water for livelihoods: bringing equity and opportunity to the rural poor in South Africa, International Symposium on Water, Poverty and Productive Uses of Water at the Household Level, Muldersdrift, South Africa.

Williams, JR 1990, 'Social traps and incentives: implications for low-input, sustainable agriculture', *Journal of Soil and Water Conservation*, 45(1): 28–30.

Chapter 7

Rainwater harvesting and conservation agriculture in the southern African region

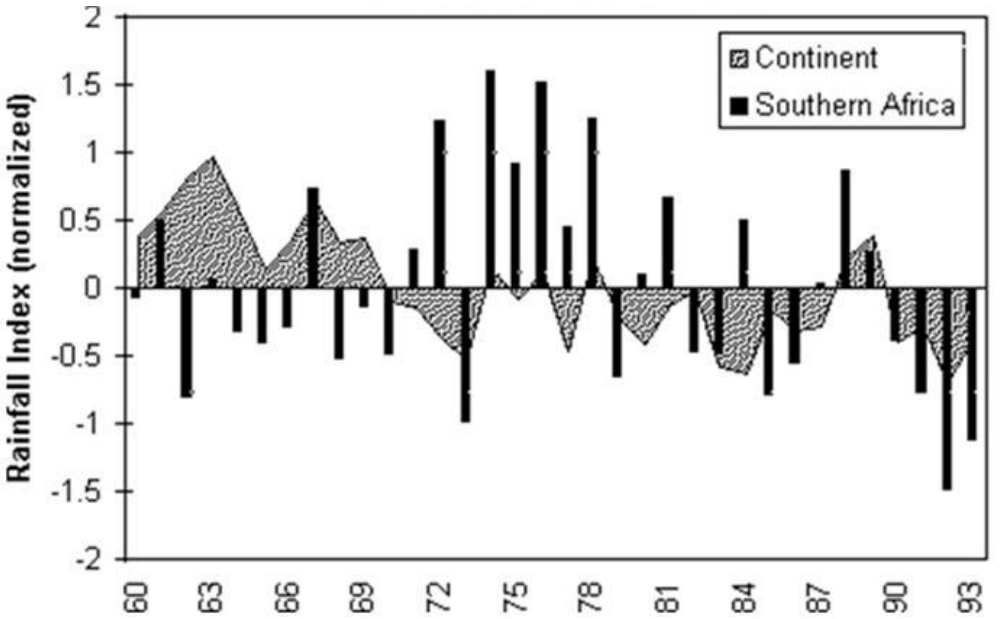
Potential incentives for sustainable farming for food and water security and poverty reduction in southern Africa

HODSON MAKURIRA

Introduction

The African continent has a long history of rainfall fluctuations of varying lengths and intensities (Figure 7.1). The sub-Saharan Africa (SSA) region is characterised by high population concentrations and low seasonal rainfall and rapidly degrading soils. The potential evaporation is high and is closely linked with high temperatures, which implies that most of the available water may be lost to evaporation, leaving much less available for other components of the hydrological cycle, mainly transpiration, which is responsible for biomass production. Due to a combination of factors, sub-Saharan Africa is the only developing region in the world where food insecurity has worsened instead of improving in recent decades (Rosegrant *et al.* 2005).

Figure 7.1 Rainfall distribution in Southern Africa



Source: Gommes, R & Petrassi, F 2006, Rainfall variability and drought in sub-Saharan Africa since 1960, FAO Agrometeorology Series Working Paper No. 9, Food and Agriculture Organization, Rome.

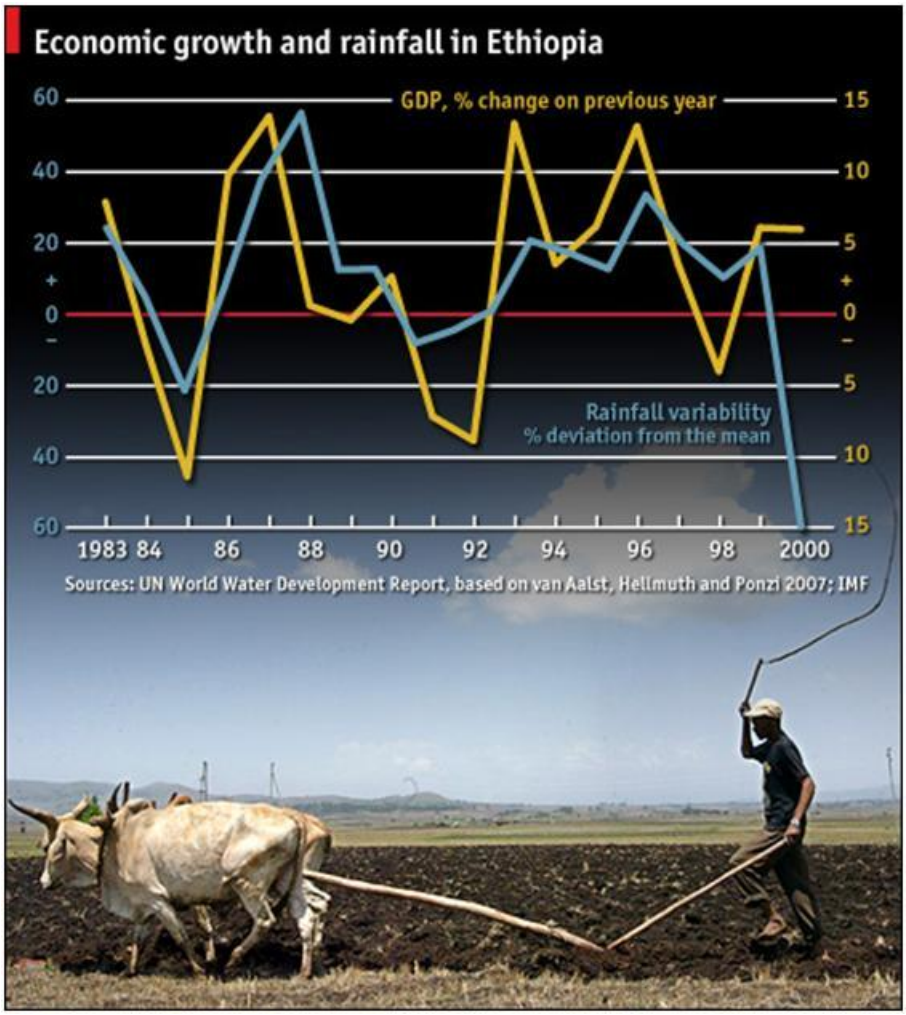
There are concerns that SSA will not be able to achieve the Millennium Development Goals (MDGs), with the goal on food security seeming particularly unachievable by the target date of 2015. A significant number of the region's population relies on rain-fed subsistence farming and, with highly erratic rainfall patterns in the region, the challenges of increased poverty have escalated. The link between rainfall availability and poverty is evident, with patterns in economic growth following precipitation trends closely (Figure 7.2).

Increasing water scarcity, rapidly degrading soils, nutrient deficits and inefficient agricultural practices combine to result in suboptimal cropping yields, which have led to the region scoring poorly on food security indices. The rising population in the region will need to be fed from the scarce and diminishing water resources if food security and agricultural sustainability are to be achieved. The unpredictable rainfall patterns, combined with these challenges, have accelerated food insecurity in SSA and, hence, exposure to poverty and poor regional economic performance.

Traditionally, the water component of food security has been largely achieved through large-scale irrigation schemes (blue water); however, concern has been raised over the viability of some irrigation schemes, with technical and socioeconomic challenges contributing to the poor performance of many communal and small-scale irrigation schemes. In addition, further expansion in irrigation is highly threatened in many river systems as there is less water available to share due to increasing competition from other water-use sectors and diminishing river flows. The possibility of further reduction in flows due to climate change will worsen the situation. In fact, it is feared that some basins

already have no water for further allocation (Falkenmark & Molden 2008; Mazvimavi *et al.* 2007).

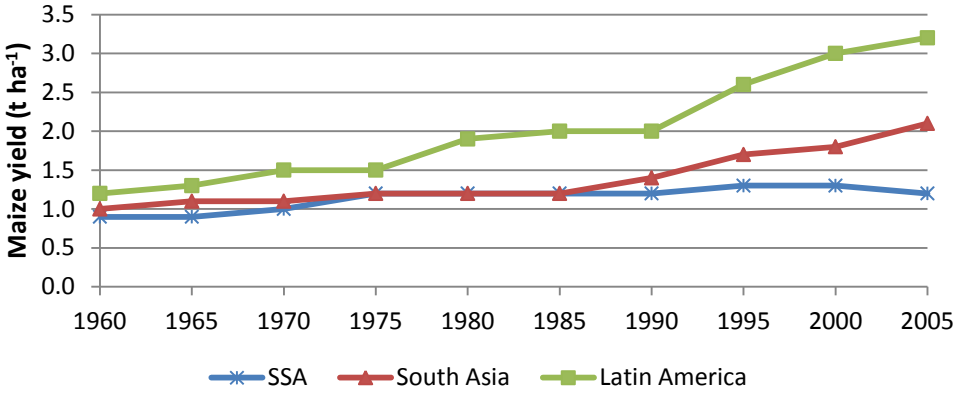
Figure 7.2 Link between economic performance and rainfall received



Source: The Economist 2009, 'Rainfall and GDP, let it rain: how rainfall can affect economic growth', The Economist, www.economist.com/node/13432503.

Asia, South America and Africa together are home to most of the developing countries of the world; however, unlike in Asia and South America, in SSA grain yields have not shown any upward improvements despite the advances in farming technology (FAO 2005). Figure 7.3 illustrates this fact for maize yields.

Figure 7.3 Maize productivity levels in selected sub-continents in the past decades



Source: Adapted from Food and Agriculture Organization (FAO) 2005, FAOSTAT, Food and Agriculture Organization, Rome.

Maize is the staple food crop in sub-Saharan Africa. The reasons for such low maize yields range from inconsistencies in the quality of rainfall seasons and lack of resources to invest in proper farming practices, to poor soils, which cannot support higher yields without the application of fertilisers and pesticides. The report of the Comprehensive Assessment of Water Management in Agriculture (2007) discusses the challenges of food security and highlights the following interesting points.

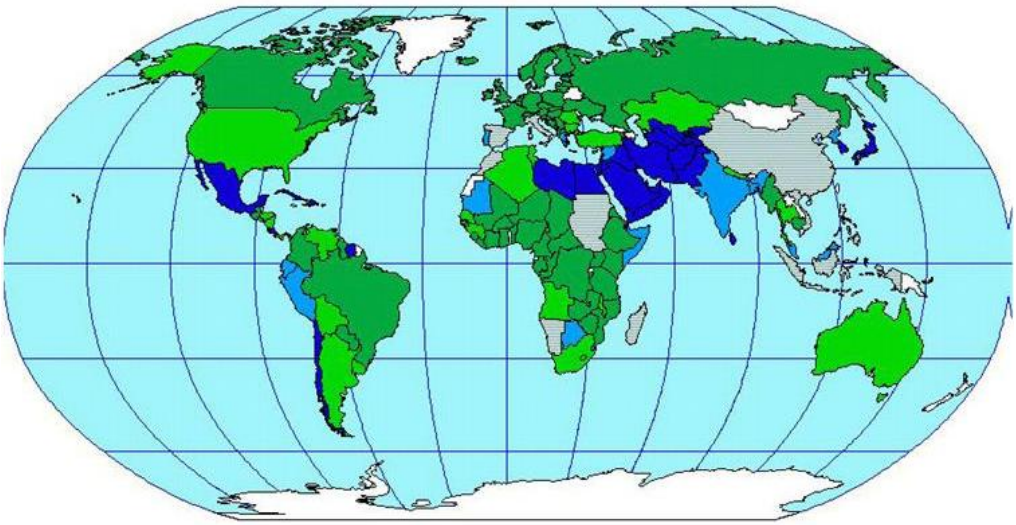
1. Seventy-five percent of the additional food needed over the next decades could be met by bringing the production levels of the world's low-yield farmers up to 80 percent of what high-yield farmers get from comparable land. Better water management plays a key role in bridging that gap.
2. The greatest potential increases in yields are in rain-fed areas, where many of the world's poorest rural people live and where managing water is the key to such increases. Only if leaders decide to do so will better water and land management in these areas reduce poverty and increase productivity.
3. While there will probably be some need to expand the amount of land we irrigate to feed 8–9 billion people, and while we will have to deal with the associated adverse environmental consequences, with determined and focused change there is real scope to improve production on many existing irrigated lands. Doing so would lessen the need for more water in these areas and allow even greater expansion of irrigated land.

Given that the majority of the population in SSA relies on rain-fed systems (Figure 7.4), the facts presented above need serious consideration in the region if food security and economic sustainability are to be achieved.

Water for food

As highlighted, the potential of surface water is increasingly losing attention in the search for a continuing supply of water for food. Besides, for the SSA region, the majority of the population relies on rain-fed systems, as shown in Figure 7.4. This situation therefore supports greater focus on rain-fed farming systems where the benefits impact on wider sectors of society. In dryland farming systems, it is acknowledged that farming plays a dominant role in poverty alleviation and food security, but, unfortunately, does not generate sufficient household income regardless of farm size (Machethe *et al.* 2004).

Figure 7.4 Global dependence on green and blue water



Source: Rockström, J, Barron, J & Fox, P 2003, 'Water productivity in rainfed agriculture: challenges and opportunities for smallholder farmers in drought-prone tropical agro-systems', in JW Kijne, R Barker & D Molden (eds), Water Productivity in Agriculture: Limits and opportunities for improvement, CAB International, Wallingford, UK.

Rain-fed agriculture is more vulnerable to water stress as a result of high crop sensitivity to moisture deficits due to insufficient rainfall and mid-season dry spells. This has contributed to low yields in rain-fed SSA agriculture where, in the case of maize, yields of only 1.4 t/ha and less are realised against potentials of about 6 t/ha (Bhatt *et al.* 2006; de Fraiture *et al.* 2007; Rockström *et al.* 2004).

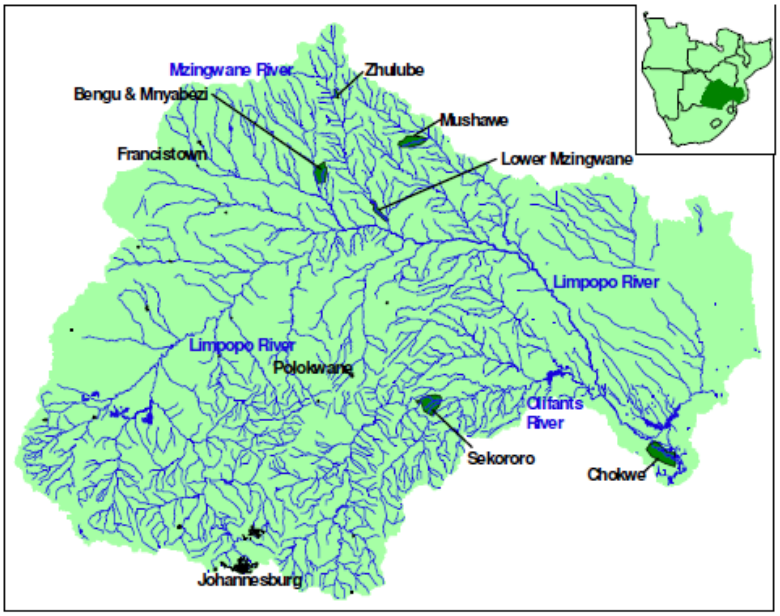
More biomass can be obtained from rain-fed agriculture by either opening more land for cultivation or increasing the efficiency of water use at the farm scale. This efficiency can be achieved by repartitioning the field-water balance to reduce unproductive moisture fluxes such as evaporation and run-off while maximising green-water fluxes (transpiration) (Makurira 2010). Given the increasing population rates and rapidly degrading soils, the former option is unsustainable and, hence, less feasible. The scope to improve crop productivity in rain-fed systems exists in SSA (Bossio *et al.* 2011; Kosgei *et al.* 2007; Mupangwa *et al.* 2006; Mwenge Kahinda *et al.* 2007). While it is acknowledged that rainfall variability is

high, 70 percent of the little water that becomes available is lost to unproductive purposes (Hatibu 2002). This calls for innovative approaches in rain-fed agriculture such as rainwater harvesting and conservation tillage (Enfors & Gordon 2008; Ngigi 2003; Rockström *et al.* 2004). These techniques allow for the concentration of rainfall to areas of need, minimising evaporation losses and promoting soil and nutrient retention in the field. Rainwater harvesting is largely dependent on the efficiency of the run-off collection area (Hatibu 2002), while conservation agriculture uses any combination of techniques to promote infiltration and retain the infiltrated water in the root zone.

The challenges highlighted above for rain-fed systems lead to two promising options to improve yields in rain-fed systems. These options—rainwater harvesting (RWH) and conservation agriculture (CA)—are practised across the SSA region with varying degrees of success. The next sections highlight some cases of such activities in the southern African region, particularly in the Limpopo Basin. The Limpopo Basin drains parts of Botswana, Mozambique, South Africa and Zimbabwe.

Water for food in the Limpopo Basin

Figure 7.5 The Limpopo Basin



Source: Ncube, B, Manzungu, E, Love, D, Magombeyi, M, Gumbo, B & Lupankwa, K 2010, The Challenge of Integrated Water Resource Management for Improved Rural Livelihoods: Managing risk, mitigating drought and improving water productivity in the water scarce Limpopo Basin, CPWF Project Report Series, Challenge Program for Water and Food, Sri Lanka.

The southern African region is institutionally coordinated through the Southern African Development Community (SADC). The regional bloc has desks

responsible for all key sectors such as water, food security, power supply and minerals. Many protocols, including that on shared watercourse systems, have been signed and ratified by member countries and are being used to manage water at trans-boundary levels. In addition, basin commissions such as the Zambezi Basin Commission and Limpopo Basin Commission have been formed to focus management at the basin scale.

While food security is a topical issue, there is, however, no clear statement in the region that clearly acknowledges the significance of rain-fed agriculture on issues of food security.

The Limpopo Basin has large variability in resource distribution including some of the driest areas in the region. Being one of the most water-scarce basins in the region, any successes against water stress in agriculture are most welcome, and successful techniques in the Limpopo Basin will most likely score even better in higher rainfall zones. For this reason, much research has been conducted in the Limpopo.

The Limpopo Basin profile is presented in Table 7.1 and shows that the catchment is already significantly irrigation developed, which means that surface (blue) water options are no longer feasible unless inter-basin transfers are intensified. In Mozambique, for instance, there is insufficient water on the Limpopo to support all the planned irrigation projects (van der Zaag *et al.* 2010).

Table 7.1 Limpopo Basin profile

Catchment area	About 413,000 sq. km
Rainfall	Average 530 mm/a. Range: 200–1 200 mm/a
Evaporation	Average 1,970 mm/a. Range: 800–2 400 mm/a
Run-off	5.5×10^9 cu m/a or 13 mm/a
Water transfers	Water is transferred into the basin under six separate transfer schemes.
Main issues	A short and intense rainy season, with highly unreliable rainfall leads to frequent droughts. Crop production is not secure.
	On major reaches of the Limpopo and many of its tributaries, the flow of water in the river's dry years can occur for 40 days or less.
	Insufficient training and support services for small-scale farmers.
	Difficulty in obtaining development capital.

Source: Challenge Program on Water and Food, www.arc.agric.za/limpopo/profile.htm.

Communities in the Limpopo Basin are severely affected by water stress with those on the Zimbabwean side falling below the food security threshold. On the South African side, the Limpopo Province records the highest poverty rate in the

country (UN-HABITAT & UNEP 2007). The irrigation statistics of member countries in the Limpopo Basin are presented in Table 7.2.

Table 7.2 Irrigation statistics and developed storage in Limpopo Basin

Country	Existing irrigated area (ha)	Potential irrigable area (ha)	Total storage capacity developed (cu mm)
Botswana	1,381	5,000	280
Mozambique	40,000	148,000	2,840
South Africa	198,000	131,500	2,200
Zimbabwe	2,000	10,900	1,210
Total	**241,381**	**295,400**	**6,530**

Source: United Nations Human Settlements Programme (UN-HABITAT) & United Nations Environment Programme (UNEP) 2007, Limpopo Basin strategic plan for reducing vulnerability to floods and droughts, Draft for Discussion with Riparian Governments 23, United Nations Human Settlements Programme & United Nations Environment Programme, Nairobi.

Cases of selected system innovations in the Limpopo Basin

Water scarcity has forced farmers, extension services and researchers to explore options of, at least, stabilising grain yields. Increased levels of scarcity drive affected farmers into considering and adopting alternative farming techniques to stabilise yields. Fears of climate change and associated impacts accelerate the rates of adoption of promising techniques. These techniques are being practised at different scales including household and village levels and are often promoted by governments, non-govermental organisations (NGOs) and, in some cases, through individual initiatives.

A few selected case studies in the Limpopo Basin in Mozambique, South Africa and Zimbabwe are presented here.

Mozambique

Project MZ1: Rooftop harvesting

Rooftop harvesting is promoted throughout the country by both the Government and NGOs, especially in the drier provinces of Maputo, Inhambane and Gaza. The project targets buildings with relatively large surface area to act as rainfall collection areas. The harvested water is mainly used in the household for washing and drinking. Communities are encouraged to reuse any 'grey water' that is generated to irrigate vegetable gardens.

Figure 7.6 Simple rooftop water harvesting techniques being promoted in Mozambique

Source: Courtesy of the Department of Water Affairs (Mozambique).

The cost of a standard 1,000 L household rainwater jar is $50 if built according to the UN-HABITAT manual. This volume will satisfy household water requirements for two to three days depending on the type of activities planned for the day—for example, bathing, laundry, cooking.

Project MZ2: Excavated dams

The Government is assisting in the construction of excavated dams to store run-off for use in drier periods. Each dam measures 100 m x 70 m x 7 m (approximately 50,000 cu m). A typical layout of the excavated system is shown in Figure 7.7 and costs MZN 25 million (approximately A$1 million). Such a dam provides water for up to eight months depending on use.

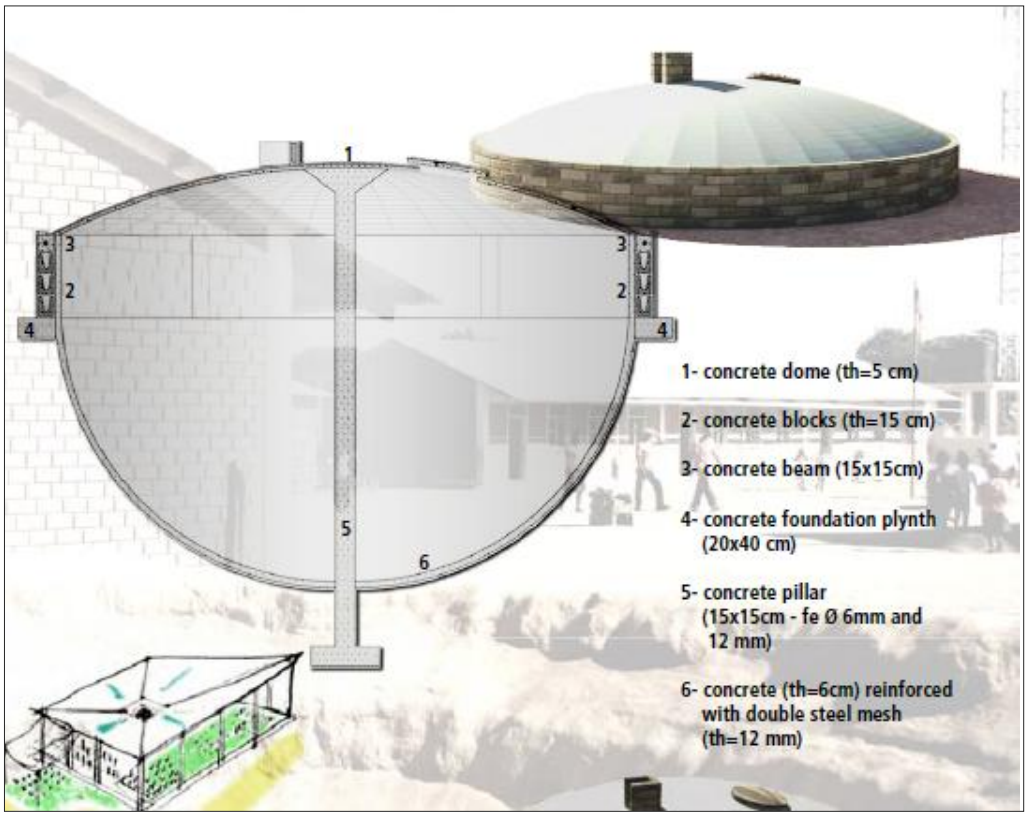
Figure 7.7 The Model of an excavated dam (a) and a completed dam (b) in Mozambique

Project MZ3: Subsurface tanks

Subsurface tanks are being promoted by the Ministry of Water and NGOs such as UN-HABITAT, particularly in the Chicualacuala area in the Lower Limpopo Basin. This technique is more appropriate for this area, where high evaporation rates necessitate the application of innovations that are less susceptible to water loss through evaporation. Minimising evaporation implies that the stored water

can be optimally used as harvested water. Local materials are used as much as possible to minimise costs. A typical tank has a capacity of 90,000 L and costs between $5,000 and $7,000 depending on site conditions. The biggest challenge so far is that this technique requires pumping to access the water. Solar-powered pumps are being considered as sustainable technology. In light of this, the designs are being improved in consultation with communities and other stakeholders.

Figure 7.8 The subsurface tank for Mozambique



Source: UN-HABITAT, Mozambique.

Project MZ4: Flexi approach

The National Institute for Disaster Management (IGNC) is a government department mandated with helping communities to cope with disasters. These disasters include extreme events such as droughts. The approach taken by the department is to promote appropriate solutions for identified challenges at the local level. They acknowledge that water supply, nutrition and food security are inter-related and, hence, interventions to one aspect will impact on the other aspects. They have developed a handbook to be used at the district level, which outlines typical solutions for various challenges.

In this approach, IGNC identifies the main interests and activities of a community and promotes these. For example, if the main livelihood activity in the community is handicraft, IGNC promotes the improvement of the quality of the final products

so that they fetch better prices at the market. The assumption here is that higher income derived from markets will mean more income to spend on food requirements and other necessities. The handbook covers a large variety of innovations including in-situ, micro and macro rainwater harvesting techniques such as storage tanks, run-off diversion, semicircular planting basins and mulching. The approach targets schools and the elderly on the basis that the elderly are the most vulnerable while children are believed to be more open to new messages, which can work favourably for sustainability. In the field, IGNC establishes demonstration sites where local materials and labour are used to impart knowledge to locals. Capacity building is achieved by involving in construction local people, who automatically become experts and future trainers locally.

Since the approach covers a wide range of rainwater harvesting options, no cost guidelines are available and communities are encouraged to adopt techniques that they find interesting and affordable.

South Africa

Project SA1: Mbonisweni garden project

This project consists of 24 members who have access to spring water all year round. The members grow horticultural crops throughout the year. The project takes advantage of the existence of a steep gradient, which favours gravity flow, and the high water table results in easy access to spring water throughout the year. Some members of the scheme have received assistance to construct 5 000 L ferro-cement storage tanks. In principle, a tank fills up at least twice per week.

The major inputs for a typical 5,000 L tank are 14 bags of cement and 10 m of wire mesh; however, the bigger project consisting of an earth dam and other components is estimated to cost about $ 50,000.

Figure 7.9 The Mbonisweni Garden Project with storage dam under construction

Members without storage tanks take advantage of gravity to direct the water directly onto their fields. A local NGO, EcoLink, is now further assisting the members by constructing a 1,000 cu m earthen dam, which will be lined with

geotextile material to minimise seepage losses. When complete, the extra storage will provide more reliable water for irrigation.

Project SA2: Ndawaleni group project

This project is applying rooftop rainwater harvesting to a chicken abattoir as well as irrigating an adjacent 0.5 ha vegetable garden. The rainwater harvesting project is aimed at supplementing erratic water supply from the municipality as well as to cut down on water bills. Water harvested from the rooftop is either diverted into a 50,000 L ferro-cement tank or directed into in-field trenches for temporary storage (Figure 7.10) and irrigation of the vegetable garden.

Figure 7.10 The Ndalweni rooftop rainwater harvesting scheme

The estimated cost for this project is approximately $ 10,000.

Project SA3: Mjejani village project

This project is yet to be implemented but aims to harvest run-off from a rock outcrop. A storage facility will be constructed to store the water from where it will be used for supplemental irrigation by gravity.

Figure 7.11 The rock outcrop at Mjejani village and the targeted irrigation plots

The estimated project cost is approximately $ 45 000.

Project SA4: Luphisi Project

The project consists of 17 members on a plot of 4 ha. The technique applied here is run-off diversion from a road drainage and culvert. The harvested water gravitates into the just-completed storage dam, with a capacity of 100 cu m, from where it can irrigate maize and horticultural crops. For this field, a full dam would provide 2.5 mm of water as supplemental irrigation.

Figure 7.12 Road pavement and drainage collection and the lined dam constructed at Luphisi village

The run-off generation potential at this site is very high and, according to the group members, it is possible to fill the dam from one or two rainfall/run-off events. This may imply that the storage ratio of this dam is very small considering that the stored water is intended for use during dry spells.

The estimated cost for this project is approximately $47,000.

Zimbabwe

Case ZW1: Patrick Khumalo

Patrick Khumalo is an ambulance driver at a district hospital. His salary, combined with that of his wife, who works as a primary schoolteacher, has not been enough to take care of their six children (and the extended family). Khumalo used to be a member of the government-supported Valley Irrigation Scheme, which has 400 plots of about 0.5 ha each. He was frustrated by the lack of coordination among the members, which has seen the scheme lying idle for the past two seasons due to breakdowns in pumping equipment and frequent power cuts.

With the economic situation in Zimbabwe getting worse, Khumalo decided to abandon the communal irrigation scheme to concentrate on his 0.5 ha plot at his homestead. His Phase 1 project consists of a 1 km PVC pipeline, a 9.8 HP secondhand engine and a pumphouse. He obtains water through sand abstraction and pumps it to a 5,000 L ferro-cement tank, which he constructed at his homestead (Figure 7.13). Presently, he grows onions, tomatoes, beans, carrots, cucumbers, lettuce, pumpkins and melons among other horticultural crops.

Figure 7.13 Irrigation system at Khumalo homestead

Khumalo has now embarked on Phase 2 of his project. He has acquired an additional 3 ha, which he has cleared and fenced. He has so far purchased three sprinklers and has installed a 5 000 L plastic tank at the new site (Figure 7.14). He is presently experimenting with the efficiency of the sprinkler system compared with flooding. He uses fuel consumption as an efficiency indicator in his experiments.

Since Kezi District is dry, he gets good prices for his produce at the markets. His workforce includes four permanent and six contract workers in addition to his family. In the 2010 agricultural season, he applied fertilisers to his maize crop and obtained 2 t/ha. Although he has enough food for his family and produces for the market, he feels there is potential to produce much more, especially when his Phase 2 project is fully operational. His main challenge is a shortage of funds to quickly achieve his goals. His other challenge is transport to markets as his vehicle broke down last season.

Figure 7.14 Irrigation trials in Patrick Khumalo's new field

Phase 1 cost approximately $ 3 000, and Khumalo believes that he recovered his investment within two years. Phase 2 would cost much more. His wish is to access loan financing for his project and he is confident that, with the experience gained so far, he can recover his investment—again, in two years.

Case ZW2: Mr and Mrs Tshuma

The Tshumas are a family of three. The husband and wife have retired and now stay in the village. Their homestead is close to two dams that were built in 1947 and 1994 but they do not have resources to draw water from the dams for irrigation. Upon advice from the local extension officer, they have ventured into in-situ rainwater harvesting for which they have constructed trenches across their 1 ha plot to capture run-off from the roof and, hence, retain more moisture within the field (Figure 7.15). This construction is new and they are still to confirm if the technique works. Their basis of comparison will be last season's yields, which were 550 kg (maize), 100 kg (sorghum), 200 kg (millet) and 350 kg (groundnuts).

The cost of construction for a 70 m trench was equivalent to 100 kg of millet. The preferred method of payment is food since this is a water-scarce and, hence, food-insecure region. The family acknowledges that some of the techniques being encouraged by extension services are not new as they were also applied in the 1950s but could not be adopted as they were associated with colonialism and oppression of communities. Although this particular technique is still at trial stage, with the farmer yet to learn more, it is clear that the farmer is willing to try new techniques in order to contain the perennial challenge of low yields obtained as a result of water scarcity in the region.

Figure 7.15 Collection of run-off into in-field trenches

Case ZW3: Mr and Mrs Mbangeni

The Mbangenis are another elderly couple who are practising rainwater harvesting from a rock catchment and diverting the water to in-field trenches on a 0.6 ha plot (Figure 7.16). According to the farmer, the trenches capture run-off and, consequently, raise the water table, which benefits downstream plants. The farmer has been practising this technique since the devastating drought of 1974. The farmers grow horticultural crops throughout the year, although, in 2011, the crop was severely affected by frost.

The small rock catchment collects a lot of water after a modest rainfall event. The success at this plot has resulted in many field days being conducted at this homestead. The only concern shown by the couple is that they are now old and all

their children prefer to work in towns and mines but return to collect grain when food is scarce. While they have guaranteed food security, possibly for the rest of their lives, they are concerned about the future of their project with their children preferring to work away from the village.

Figure 7.16 Rainwater harvesting from a rock catchment

Case ZW4: Liza Khumalo

The farmer at this site responded to the promotion by World Vision International (WVI) of infiltration pits as an in-situ soil and water conservation technique. She has a 0.4 ha plot. The NGO offered seed and fertiliser provided the farm owner dug the pits in 0.5 m x 0.5 m grids (Figure 7.17). Yields at this farm increased tremendously, with last season's harvest recording 1 350 kg of sorghum and enough maize to see the family through to next season.

Figure 7.17 Planting pits practised as soil and water conservation

Although this practice has shown great promise to boost yields and, despite the farmer coming first in farming competitions on several occasions, this technique is the one least adopted in the community. The reason given by the farmer is that it is labour intensive.

Case ZW5: Mrs Moyo

Mrs Moyo is widowed. She has two projects in Gwanda District. At the homestead, run-off is harvested into an excavation (similar to a coffer dam). From the dam, water is pumped into the adjacent horticultural field plots as supplemental irrigation. This technique helps the crops to survive not-so-severe dry spells. The challenge faced by the family is that pumping is generally expensive and the pump frequently breaks down; however, even with these challenges, the family is more food secure compared with the rest of the community as they harvest enough food for themselves and also sell some at market.

Figure 7.18 Excavation to collect run-off before pumping into horticultural field (right)

Ma Moyo's second project is a 16 ha farm located 4 km from the Mzingwane River. Water is pumped using a 40 HP engine into a concrete tank of 20 cu m capacity. The main crop grown is maize, with minor crops being roundnuts and groundnuts. In 2008 she harvested 30 t of maize but, due to water challenges and lack of resources, she only cultivated 8 ha, from which she harvested 10 t of maize in 2010.

As an investment in water security, an excavated storage reservoir is being constructed, which will be lined to minimise water loss through seepage (Figure 7.19). There are presently no plans to minimise open water evaporation. So far, 15 beasts (approximate cost $ 6 000) have been sold to raise money for this project. Extra income is obtained from the sale of tomatoes. The current workforce consists of three permanent staff and seven contract workers during peak periods.

The major challenge faced by the farmer is lack of capital to finance the project. Because of the large size of the farm, mechanisation is required but it is extremely difficult to access the tractors that are available from the Government.

The farmer has applied for loans on several occasions but, so far, has been unsuccessful due to tight security requirements demanded by banks before approving loans.

Figure 7.19 Ma Moyo at her unaccomplished water-security project

Discussion of highlighted cases

The activities sampled and presented here confirm that water for food is a serious issue and that different approaches for managing rain-fed systems are being practised in the Limpopo Basin and, certainly, throughout the region. These activities also show complementary efforts by NGOs, governments and individuals to address issues of food security on the ground. A range of techniques is common across borders and there is a growing realisation that, in addition to merely diverting run-off through whatever means, investment in storage increases the potential benefits from harvested water. This makes sense given the fact that rainfall and run-off events are few and the characteristic short duration and high-intensity type of rainfall that is common in the region generates substantial run-off for short periods but more is usually required after 10 days or more when the impacts of dry spells are felt.

There is consensus among the farmers that yield increases have been observed where any form of technique has been adopted. For individual farmers, the quantification of costs and benefits is too simplistic as some key inputs are not measured using standard agricultural economics techniques. Indicators of costs and benefits range from numbers of bags (of grain) obtained for known seasons and numbers of beasts sold to the number of days that water in storage lasts and the period that available food stocks may last. Mostly, these are not documented and feedback during interviews depends on the memory of the respondents; however, a positive conclusion that is drawn from analysis of the operation of individual farmers is that there is consensus that the innovations contribute towards food security, and the return on investment is a minimum of two years for the small farms.

Community schemes are more organised and, hence, keep records. The main feature of community schemes is that they are mostly supported by external agencies, hence their lifespan is strongly related to the length of stay of the donors. The sites visited in South Africa are supported by an NGO and the beneficiaries look to the next contribution by the donor. The Mozambican approach is taking a deviation from this path, especially for smaller scale projects

where they believe that demonstration sites are more sustainable as only interested farmers will adopt promising technologies. That way, the sense of ownership is stronger and, hence, such projects are likely to be more sustainable in the long term.

Observations on economic analysis of innovations

Economics plays a critical role in the adoption of systems innovations (SIs). Favourable economic returns positively influence adoption especially if the returns can be realised in a short time; however, comprehensive economic analysis is more complicated than assumed. The case studies presented above show that all stakeholders agree that the SIs are viable. Viability is measured in many ways with the most common being that of comparing yields before and after adoption, assuming inputs and other conditions remain the same. Total economic analysis, however, considers additional variables such as labour, time and capital injection. Benefits are measured differently, with water managers concentrating on additional storage and/or yield obtained, with the unit cost of water calculated on the basis of financial investment against the amount of water used. The beneficiary would be interested in aspects such as improved water security, improved crop yields and extra income that may be obtained from marketing the produce.

The country cases presented here give an idea of the investment cost in infrastructure; however, the economics of the SI goes beyond capital investment only. Similarly, returns are measured by incremental yields or income from sales without proper benefit–cost analyses. From additional sampled projects presented in Appendix 7.1, it is clear that the least studied parameter in any study involving SIs is economics. Researchers pay more attention to observed yields and volumes of water harvested and less to socioeconomic considerations.

Only a few studies have reported on the economic performance of SIs. Hatibu *et al.* (2006) conclude that returns on SIs involving macro-catchments, especially road drainage, provided higher returns than micro-catchments and small storages. Moges *et al.* (2011) suggest that household rainwater harvesting in maize systems is not economically viable regardless of the technique applied but may be favourable to vegetables especially when labour input is not considered. Another economic dimension of analysing the economic returns of SIs is by the reduction in demand for area required to attain food security (Mwenge Kahinda *et al.* 2008). Practising single SIs only does not offer optimum results as, often, a cocktail of techniques is needed to improve system performance (Makurira 2010). A study conducted in India by Srivastava *et al.* (2004) showed that the benefit–cost ratio for a treatment increased from 1.89 when a single crop was tested to 2.27 when horticultural crops were planted on the embankment of the tank, and further increased to 2.80 when fish culture was taken up in the stored water.

It is clearly important that detailed economic analyses be undertaken for enhanced understanding of these SIs. Only when economic viability is well understood can farmers consider adoption.

Regional research to support attainment of food security

The Challenge Program (Phase 1)

The Challenge Program on Water and Food aims to contribute to food security by conducting multidisciplinary research towards improved crop-water productivity. The program focused on nine river basins in Africa, Asia and Latin America. The program had four key research projects that are relevant to the Limpopo Basin.

Box 7.1

Highlights of the Challenge Program on Water and Food PN17

The PN17 project in the Limpopo Basin aimed to achieve the overall program goal by capacity building through conducting participatory research. A minimum of six PhD and 31 masters students were trained. Practical research was also conducted, which involved key stakeholder institutions and farming communities.

The findings from the research point to the fact that agricultural production and water management in general are affected by physical and socioeconomic effects, among them poverty, low rainfall and weak institutions.

Adoption of conservation agriculture by farmers, promotion of the use of drip kits, further exploration of alluvial aquifers and legal and institutional strengthening were considered as the immediate action lines to be followed.

Source: Adopted from Ncube, B, Manzungu, E, Love, D, Magombeyi, M, Gumbo, B & Lupankwa, K 2010, The Challenge of Integrated Water Resource Management for Improved Rural Livelihoods: Managing risk, mitigating drought and improving water productivity in the water scarce Limpopo Basin, CPWF Project Report Series, Challenge Program on Water and Food, Colombo.

Box 7.2

Highlights of the Challenge Program on Water and Food PN53

The project aimed to provide farmers, policymakers and other stakeholders with tools to make better adaptive decisions in the face of climate-related risk. The research methods included stakeholder forums and household

surveys to establish local perceptions in relation to climate change. The study acknowledges that vulnerability is a function of the exposure, sensitivity and adaptive capacity to climate change hence adaptive measures need to be incorporated into sustainable development strategies.

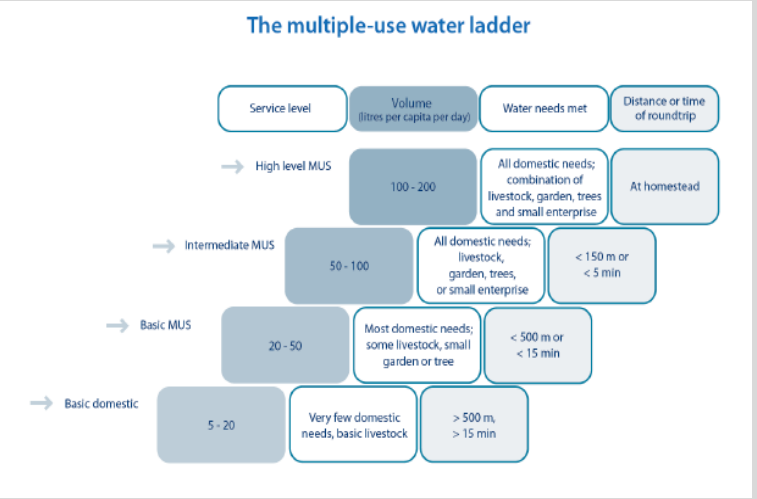
While effective early warning systems are necessary to reduce the shocks of climate change, development strategies should also explore improved access to information, loan facilities and markets to empower communities to adapt better to these shocks. The study estimates that US$ 5 billion per year would be required to support vulnerable groups so as to reduce the number of malnourished children to one-third of its current level over the next 50 years.

Box 7.3

The Challenge Program on Water and Food PN28

The project was formulated on the understanding that water sources designed for multiple uses rather than for either productive or domestic uses improve more dimensions of wellbeing, especially for women, and, hence, should be promoted. The project therefore aimed to forge synergy across the conventional sectoral boundaries between the productive and domestic water sectors and between researchers and implementers.

The key analysis is that, for homestead users, water provision should target in excess of the 50 L per capita per day, which is commonly used in demand calculations, as this does not leave excess water from which to derive livelihoods. It is recommended to provide 50–200 L per capita per day to enable poor people 'to climb the water ladder'. Out of this, 3–5 L per capita per day should be safe for drinking.



Source: Adapted from van Koppen, B, Smits, S, Moriarty, P, de Vries, FP, Mikhail, M & Boelee, E 2009, The multiple-use water services (MUS) project, Project Report PN28, Challenge Program on Water and Food, Colombo.

Box 7.4

The Challenge Program on Water and Food PN30

The project aimed to contribute to enhancing food security and improving the livelihoods of wetland-dependent communities by increasing the productivity of water and optimising and maintaining wetland ecosystem services.

The findings acknowledge that, at the local level, the value derived from wetland farming and the harvesting of other wetland products forms a significant part of households' income and livelihood. Wetlands affect and are affected by hydrology, and farmers sometimes compromise this by imposing desired crops rather than suitable crops for the wetland. Wetlands are characterised by high water tables, hence management should focus on managing the water table rather than drainage. It was, however, noted that rules and regulations towards wetland conservation are enforced at the local level, which means that this would be the most logical entry level for sustainable management interventions. While capacity building is required in the form of training, awareness and finances, the penalties for wetland degradation are not prohibitive enough.

Adoption of conservation agriculture by farmers, promotion of the use of drip kits, further exploration of alluvial aquifers and legal and institutional strengthening were considered as the immediate action lines to be followed.

Source: Adopted from Ncube, B, Manzungu, E, Love, D, Magombeyi, M, Gumbo, B & Lupankwa, K 2010, The Challenge of Integrated Water Resource Management for Improved Rural Livelihoods: Managing risk, mitigating drought and improving water productivity in the water scarce Limpopo Basin, CPWFProject Report Series, Challenge Program on Water and Food, Colombo.

The Smallholder Systems Innovations Program (Phase 1)

Box 7.5

Smallholder Systems Innovations Program

The Smallholder Systems Innovation (SSI) program was conducted in

Tanzania and South Africa as a multinational and multidisciplinary study to understand hydrological, agricultural, institutional and social linkages to improve food security levels in rain-fed semi-arid environments. The study focused on field-scale dynamics and basin and watershed scales to better understand the impact of up-scaling local successes of systems innovations.

The research confirmed that the frequency of dry spells is increasing while rainfall variability is high. This, coupled with nutrient deficits and lack of resources to apply proper farming practices, means that serious interventions are required to assist vulnerable farmers to escape the poverty trap.

Systems innovations have been shown to boost yields significantly without necessarily compromising the watershed hydrology but the interventions required will need to go beyond just water issues.

Source: Adopted from Bossio, D, Jewitt, G & van der Zaag, P 2011, 'Smallholder system innovation for integrated watershed management in sub-Saharan Africa', Agricultural Water Management, 98(2011): 1683–6.

The Challenge Program (Phase 2)

The Challenge Program on Water and Food has launched Phase 2, which will build on the outputs from Phase 1. The goal of Phase 2 is to 'improve governance and management of rainwater and small water infrastructure in the Limpopo Basin to raise productivity, reduce poverty, and improve livelihoods resilience'. Again, the Limpopo Basin is the focal study area in southern Africa.

It is highly likely that Phase 2 will address issues that could not be achieved in Phase 1, while also pursuing recommendations from Phase 1 and tackling emerging issues through five thematic areas:

- L1—targeting and scaling out
- L2—small-scale infrastructure
- L3—farm systems and risk management
- L4—water governance
- L5—learning for innovation and adaptive management (coordination project).

Similar to Phase 1, in Phase 2 the approach will be action research oriented with active involvement of all stakeholders in the Limpopo Basin.

The DEWFORA project

The Improved Drought Early Warning and Forecasting (DEWFORA) project to strengthen preparedness for and adaptation to droughts in Africa has been launched in four river systems: Eastern Nile Basin, Limpopo, Niger and the Oum-er-Rbia basins. The project is funded by the European Community and will involve 19 partners in Africa and Europe.

The project aims to contribute to the mitigation of droughts through improved early warning systems, and intends to establish risk and vulnerability to drought through monitoring and mapping. Improved early warning systems will be developed to help communities cope with meteorological, agricultural and hydrological droughts.

The WHaTeR project

This is an EU-funded project that has just started, with the aim to contribute to the development of appropriate water harvesting techniques for strengthening rain-fed agriculture, food security and livelihoods. This is a collaborative project involving eight partners in Europe and Africa, and will run for five years. Currently, a scoping study coordinated by the University of KwaZulu-Natal (UKZN) is being conducted at selected sites in South Africa to evaluate the current status of RWH structures in comparison with the time of commissioning.

The expected impacts of the project comprise technology support for farmers, development of stakeholder communication networks, innovative water harvesting systems, tools for impact assessment, upstream–downstream land use, and policy support for integrated water management and adaptation to climate change to promote EU and African strategies.

Barriers to implementation, adoption and capacity building and governance needs for better application of these measures

There is general consensus that food security will continually be threatened by a number of challenges including water insecurity. SIs, especially those which promote water and nutrient retention, are therefore necessary to improve crop yields throughout southern Africa. The success of these SIs depends on a wide range of factors that, if not correctly addressed, will present barriers to adoption and implementation.

Financing, affordability and viability

The islands of success of SIs highlighted here have obviously been witnessed and appreciated by smallholder farmers in many parts of the region. Many of the communities in the region are classified as 'poor'. Poverty affects adoption as, even if the farmers appreciate and would be willing to adopt some techniques, they may be discouraged by the costs involved as they lack capital to invest. Interviewed farmers who have adopted SIs tell stories of the challenges encountered to raise the capital to invest in systems innovations. It is difficult for smallholder farmers to secure loans as they do not have acceptable collateral to offer. The majority of the farmers do not have title to the land that they occupy. Those who have adopted SIs sacrificed livestock and personal savings and resorted to indirect means of raising cash. On the other hand, externally supported projects easily attract individuals and groups who are willing to

participate. Interestingly, many participating farmers in such schemes stop these practices as soon as the sponsors leave at the end of the project (Machethe *et al.* 2004). This clearly shows that smallholder farmers are not willing to part easily with any little savings they may have to experiment in SIs.

In addition, the question of viability is not easily and readily answered. Viability in most research is measured in incremental yields or additional water obtained; however, it has been observed that despite obvious incremental yield benefits, some farmers resist taking up these innovations, citing high labour inputs and time constraints. Viability should therefore be considered in a context broader than common approaches. What may appear to be a viable SI may be rejected by farmers on the basis of considerations besides cash investment and yields realised.

Local knowledge and preferences

Locals have their own established knowledge systems. They can predict the quality of a season from local indicators such as vegetation or winter temperatures. These communities have employed their own forms of coping mechanisms during times of water stress (Chikozho 2010). Sometimes research and extension do not acknowledge or agree with these, leading to resistance from the local communities to accepting scientific advice. In addition, donors and research projects enter communities with preconceived solutions, which sometimes also leads to resistance at the local level. Furthermore, social and traditional preferences tend to drive households to maintain practices that do not necessarily agree with the natural system. A typical example is that of maize, which is the most preferred crop in the region yet the seasonal water requirements for maize far exceed the effective rainfall in many parts of the region. Every household aims to harvest enough maize to last at least a season even where land size, agronomy and climatic factors dictate otherwise. Again, interventions need to acknowledge these local preferences and develop solutions accordingly. NGOs and extension agents should have adequately trained staff to deal with such situations when they enter communities (Machethe *et al.* 2004).

Local practices take time to change, which suggests that the influence of typical short-term (two to five years) research may not be noted during the life of such projects.

Access to key information

The level of success achieved in convincing farmers of the additional benefits to be derived through adoption is measured by uptake levels. The decision of whether to adopt or not is dependent on many factors, with different innovations appropriate for different situations. Terraces, for instance, work more effectively on steep slopes whereas dead-level contours are more effective on gentle slopes. Research and science, on the other hand, have mapped vulnerability indices, soil types and natural geographic and climatic regions; however, these efforts do not match local preferences and it has not been easy to convince locals to act otherwise.

There seems to be a gap, however, between communities' expectations, on one hand, and science and research, on the other, in as far as agreeing on the best common ground. There is a wide information gap between scientific findings and information that is accessible to farming communities. If such information was easily accessible and in an appropriate format, there would be less challenges of farmers still cultivating crops that are not suitable for their areas, which, at the end of the day and in average seasons, results in total crop failure.

Smallholder farmers may not have a lot of information about their farming systems. They appreciate the climate, soils and suitable crops in a crude way. On the other hand, research and extension have more refined information about the farming systems that leads to the promotion of specific crops, innovations and varieties that offer optimum returns (for example, Mzezewa *et al.* 2011). This information is not, however, usually packaged for the farmers in the most convincing manner and follow-up information and advice are not readily forthcoming. This is necessary to boost confidence for adoption. In the end, smallholder farmers fill that gap through their own trials and with little confidence.

Involving farmers in research and extension

The more recent approaches of participatory research generate more interest among farmers and they can identify better with research design, outcomes and recommendations (Chikozho 2010). This was successfully applied in the Challenge and SSI programs.

Substantial research has been conducted within the region with wide-ranging, promising results; however, the results are generally site specific and will not necessarily be valid for neighbouring catchments and sub-catchments. This means that much more research should be conducted to cover as many scenarios as possible. Promotion of innovations should therefore be conducted based on known outcomes from research conducted in similar environments, as much as possible. Research should also inform extension services and the farmers that research outcomes are not conclusive as they are usually site specific and usually report on success that may have been obtained from a few non-representative seasons.

Policy, legal and institutional issues

Nearly all literature consulted points to weak policy, legal and institutional structures to support SIs. Successes in rain-fed agriculture benefit governments immensely in reducing food imports and improving standards of living for the general society; however, it is clear that institutional structures are still concerned more with blue-water issues through irrigation schemes. This is despite wider acknowledgment that success in irrigation will not translate to immediate benefits to rain-fed farming systems. The reasons for these weaknesses range from insufficiently trained personnel within the institutions themselves (including

understaffing) and lack of finance to run programs to insufficient political backing to implement policies.

On a positive note, rainwater harvesting and conservation agriculture are being promoted in wider spheres now, particularly through the media (for example, The Herald 2011). These are interesting features that promote SIs at the community level, but the fact that this still generates news shows that this concept is not widely adopted nationally.

Research and sharing of research outputs

The disadvantages of research that does not involve the relevant stakeholders have been discussed already. Advances in communication now facilitate more sharing of research and research outputs. This was not the case a decade ago. There is now greater exposure to the depth of knowledge that has been added to particular topics through research. Even with that, there is still plenty of research that is being conducted and the outputs of which are not shared with wider society. The disadvantages of this are obvious as this often leads to duplication of efforts without building on knowledge that has already been generated. Relevant research databases should therefore be compiled for easier access to information and easier identification of research gaps that need to be filled through further research.

Some of the research that is conducted is not necessarily driven by needs, but aims to satisfy the agenda of the sponsors. This leads to redundant research as the outputs are not easily taken up for implementation. Research outputs also have to be packaged in a form that end users can easily understand to facilitate implementation.

Incentives for improving extension of better practices

Incentives to promote better practices are, to a large extent, strategies to overcome the challenges of implementation that have been highlighted above. Assistance to farmers to attain food security implies increasing smallholders' purchasing power so that adequate numbers of farmers can buy inputs for producing sufficient food domestically (FFSSA 2004).

Financing mechanisms

The biggest challenge is that of finance. The southern African region does not have excess resources that can be diverted to experimentation. While efforts to promote SIs have been noted throughout the region, it is clear that more support is required for wider outreach. Many individual farmers have shown interest in and have set up their own SIs, but they could do much more if they could access more financing. Similarly, national budgets have to cater for wide-ranging issues, leaving very little to support smallholder farmers even where the will exists.

A number of financing mechanisms can be explored that are applicable to the wide spectrum of farming communities. These range from formal loans, finance

clubs and grants to input support. For sustainability, financing should be extended to potential beneficiaries who have demonstrated initiatives in soil and water conservation.

Regional cooperation and international partnerships

The Southern African Development Community is a strategic regional partnership that thrives on unity and cooperation between states. This is a big incentive for any efforts to promote food security as, in fact, the food security desk at SADC should be in a strategic position to coordinate food security activities in the region. Collaboration and cooperation between local, regional and international partners through SADC work favourably in the adoption and implementation of SIs. Also, within SADC, basin commissions such as the Zambezi Watercourse Commission (ZAMCOM) and the Limpopo Water Course Commission (LIMCOM) are strategic partner institutions and they are directly involved in the management of resources in their respective basins. Institutional strengthening and policy adoption are achieved more easily through these channels.

There are also opportunities to learn from experience elsewhere in the world at different levels. Twinning of institutions and general sharing of experiences between institutions would add greater depth to efforts on the ground and will likely yield more success in less time.

Already, partnerships and networks exist in the region that offer incentives for the promotion and adoption of SIs. WaterNet, a SADC program, is strongly linked to many research and academic institutions in East and southern Africa. The annual symposium organised through WaterNet offers a platform to share integrated water resources management (IWRM) research in the region and beyond, which leads to publication in rated journals. The Water Research Commission also coordinates a wide range of research with its publications easily available to the public. CAPNET is also actively involved in the region and offers links to other capacity-building efforts throughout the world.

Funding partnerships can also be explored through regional and international cooperation to cover training, project funding and institutional strengthening.

Concentrating on appropriate and promising innovations and critical research gaps

Research has established that a wide range of innovations has proved to be effective; however, there are also thresholds where specific interventions are effective. Where too much water is available, for instance, the impact of many innovations would be negligible. Where there is too little water to harvest, RWH would also be ineffective. A given rainfall event may not provide sufficient soil moisture in a sandy soil yet the same amount would do well for a crop in soils with high waterholding capacities.

There is therefore a need to establish thresholds for specific areas and specific types of innovations for optimum results. Such thresholds should provide insight

into the added value obtained by application of SIs when, say, successive droughts occur during seasons.

Similarly, the wide range of research that has been conducted regionally and abroad means that there are substantial useful data that already exist; however, significant research gaps also exist, which, if narrowed, would help to produce better results. It is therefore necessary to identify such research gaps so that the critical areas for interventions can be targeted.

At the end of the day, the smallholder farmer is seeking interventions that empower them to make their own decisions. Access to water beyond household requirements is necessary for this to be realised (Senzanje *et al.* 2008).

Establishment of reliable markets

As has been articulated elsewhere in this chapter, smallholder farmers are still trapped in the poverty cycle, which largely arises from unfavourable climatic conditions coupled with inappropriate farming techniques; however, where promises of better yields have been highlighted, the farmers are faced with the challenge of lack of markets to dispose of excess produce beyond household requirements. The extra income derived from marketing produce improves general livelihoods as it can be used to buy other household needs. Without reliable markets, there is no incentive to produce beyond household requirements. Large distances to established markets and low prices at local markets offer little incentives to produce in excess of normal household food security.

Most of the smallholder farmers are, hence, caught in the poverty trap due to lack of extra income that can be obtained through marketing produce.

Climate change and variability, early warning systems and information exchange

It has been shown that the impacts of climate change and climate variability will worsen an already undesirable situation. Even without climate change, rainfall variability within seasons has affected many farming systems hence the need for coping mechanisms against dry spells. Several sets of research, such as PN53 and DEWFORA among others, attempt to directly deal with issues of climate change while others, such as SSI programs and PN17, deal with coping mechanisms, but there is still a lot of research that needs to be undertaken in this area to better equip farmers.

Currently, the timing of early warning systems to predict the quality of seasons and occurrence of extreme events is not useful to farming operations as this may provide only vague guidance for crop selection; however, timely forecasts during seasons would assist farmers immensely as they could make decisions on when to apply supplementary irrigation. This information also needs to reach recipients who are often located in remote areas with little access to radio bulletins, newspapers or other telecommunications.

More important is the need to develop region-specific models that predict more accurately the situation in the region. At the moment, the global models in use are too general and not basin or region specific, which often leads to inaccuracies in information that can be shared with the stakeholders. This compromises the resilience of farmers against these extreme events.

Conclusions

There is no doubt that the sub-Saharan region is faced with the challenge of food insecurity, which is largely driven by poverty, harsh climatic conditions, highly variable seasonal weather and the uncertainties of climate change. Efficient and robust approaches are required to deal with this challenge especially given that this region is also hosting high populations compared with other parts of the world.

Many interventions can be applied to cope with food insecurity with scope to produce even more food under the current difficult challenges. Some research has already indicated that without sufficient water to go beyond household water needs for drinking and sanitation, communities will not be able to escape the poverty cycle. The interventions that will be advanced should aim to provide enough water for multiple uses, which includes food production at such levels that necessitate market creation.

Rainwater harvesting and soil and water conservation have assisted to increase the productivity of the little available water but, even with such practices, research has noted that there are high levels of inefficiency. Green-water fluxes are compromised by excessive run-off and deep percolation. The popularity of storage structures shows that action is now being taken to address this challenge; however, without sound financial bases, good institutional structures and implementation policies and general integration of efforts, it will still be difficult to escape this vicious cycle. With only limited resources available, it makes more sense to complement other global efforts through research into identified gaps and funding of promising interventions.

The fact that the seasonal rainfall is insufficient to support many crops in the region emphasises the need for rainwater harvesting and soil and water conservation in agriculture. Investments in micro-storages should be promoted more widely. The cases highlighted in this study show different efforts in storing harvested water for use during water-stress periods; however, most of the storage structures would be inefficient if seepage and evaporation losses are not contained. Consideration should be given to established sites, for example, those highlighted here, for testing more efficient water harvesting and storage systems. In the process, more detailed water balances and economic analyses should be conducted so that the viability of the techniques is better understood. This way the question of why adoption is still poor may be better understood.

Capacity building should also be promoted through training of all water management institutions and users as well as assistance in procurement of equipment that facilitates monitoring and better informed decision making. This

can be achieved through short and long-term targeted training programs using existing and established networks.

Aspects of food security are strongly related to the quality of rainfall seasons and these will further deteriorate if the projected climate change impacts are confirmed. There is therefore a need to invest more in climate science, including more accurate prediction of the impacts of climate change at the local scale. This should be strongly linked to information sharing for awareness raising and better preparedness on adaptation measures. The easiest entry point is to work together with climate change researchers such as DEWFORA.

References

Bhatt, Y, Bossio, D, Enfors, E, Gordon, L, Kongo, V, Kosgei, JR, Makurira, H, Masuki, K, Mul, M & Tumbo, SD 2006, Smallholder system innovations in integrated watershed management (SSI): strategies of water for food and environmental security in drought-prone tropical and subtropical agro-ecosystems, IWMI Working Paper 109, International Water Management Institute, Colombo.

Bossio, D, Jewitt, G & van der Zaag, P 2011, 'Smallholder system innovation for integrated watershed management in sub-Saharan Africa', Agricultural Water Management, 98(2011): 1683–6.

Chikozho, C 2010, 'Applied social research and action priorities for adaptation to climate change and rainfall variability in the rainfed agricultural sector of Zimbabwe', Physics and Chemistry of the Earth, 35: 780–90.

Comprehensive Assessment of Water Management in Agriculture 2007, Water for Food, Water for Life: A comprehensive assessment of water management in agriculture, Earthscan & International Water Management Institute, London & Colombo.

de Fraiture, C, Wichelns, D, Rockström, J & Kemp-Benedict, E (eds) 2007, Looking Ahead to 2050. Scenarios of alternative investment approaches, International Water Management Institute, Colombo.

Enfors, E & Gordon, L 2008, 'Dealing with drought: the challenge of using water system technologies to break dryland poverty traps', Global Environmental Change, 18(4): 607–16.

Falkenmark, M & Molden, D 2008, 'Wake up to realities of river basin closures', Water Resources Development, 24(2): 201–15.

Food and Agriculture Organization (FAO) 2005, FAOSTAT, Food and Agriculture Organization, Rome.

Forum for Food Security in Southern Africa (FFSSA) 2004, Achieving food security in southern Africa: policy issues and options, FFSSA Synthesis Paper, Forum for Food Security in Southern Africa, London, http://www.odi.org.uk/food-security-forum.

Gommes, R & Petrassi, F 2006, Rainfall variability and drought in sub-Saharan Africa since 1960, FAO Agrometeorology Series Working Paper No. 9, Food and Agriculture Organization, Rome.

Hatibu, N 2002, Rainwater Management: Strategies for improving water availability and productivity in semi-arid and arid areas. Issues of water management in

agriculture: a compilation of essays, International Water Management Institute, Colombo.

Hatibu, N, Mutabazi, K, Senkondo, EM & Msangi, ASK 2006, 'Economics of rainwater harvesting for crop enterprises in semi arid areas of East Africa', Agricultural Water Management, 80: 74–86.

Kosgei, JR, Jewitt, GPW, Kongo, VM & Lorentz, SA 2007, 'The influence of tillage on field scale water fluxes and maize yields in semi-arid environments: a case study of Potshini catchment, South Africa', Physics and Chemistry of the Earth, 32(15–18): 1117–26.

Machethe, CL, Mollel, NM, Ayisi, K, Mashatola, MB, Anim, FDK & Vanasche, F 2004, Sustainable local management of smallholder irrigation, WRC Report No. 1050/1/04, Water Research Commission, Harare.

Makurira, H 2010, Water productivity in rainfed agriculture: redrawing the water rainbow to achieve food security in rainfed smallholder systems, PhD thesis, TU Delft/UNESCO-IHE, Delft.

Mazvimavi, D, Madamombe, EK & Makurira, H 2007, 'Assessment of environmental flow requirements for river basin planning in Zimbabwe', Physics and Chemistry of the Earth, 32: 995–1006.

Moges, G, Hengsdijk, H & Jansen, HC 2011, 'Review and quantitative assessment of ex situ household rainwater harvesting systems in Ethiopia', Journal of Agricultural Water Management, 98(8): 1215–27.

Mupangwa, W, Love, D & Twomlow, S 2006, 'Soil water conservation and rainwater harvesting strategies in the semi arid Mzingwane Catchment, Limpopo Basin, Zimbabwe', Physics and Chemistry of the Earth, 31: 893–900.

Mwenge Kahinda, J-M, Rockström, J, Taigbenu, AE & Dimes, J 2007, 'Rainwater harvesting to enhance water productivity of rainfed agriculture in the semi-arid Zimbabwe', Physics and Chemistry of the Earth, 32(15–18): 1068–73.

Mwenge Kahinda, J-M, Sejamoholo, BBP, Taigbenu, AE, Boroto, JR, Lillie, ESB, Taute, M & Cousins, T 2008, Water resources management in rainwater harvesting: an integrated systems approach, WRC Report No. 1563/08, Water Research Commission, Harare.Mzezewa, J, Gwata, ET & van Rensburg, LD 2011, 'Yield and seasonal water productivity of sunflower as affected by tillage and cropping systems under dryland conditions in the Limpopo Province of South Africa', Agricultural Water Management, 98: 1641–8.

Ncube, B, Manzungu, E, Love, D, Magombeyi, M, Gumbo, B & Lupankwa, K 2010, The Challenge of Integrated Water Resource Management for Improved Rural Livelihoods: Managing risk, mitigating drought and improving water productivity in the water scarce Limpopo Basin, CPWF Project Report Series, Challenge Program on Water and Food, Colombo.

Ngigi, SN (ed.) 2003, Rainwater Harvesting for Improved Food Security. Promising technologies in the Great Horn of Africa, Greater Horn of Africa Partnerships, Kenya Rainwater Association.

Rockström, J, Barron, J & Fox, P 2003, 'Water productivity in rainfed agriculture: challenges and opportunities for smallholder farmers in drought-prone tropical agro-systems', in JW Kijne, R Barker & D Molden (eds), Water Productivity in

Agriculture: Limits and opportunities for improvement, CAB International, Wallingford, UK.

Rockström, J, Folke, C, Gordon, L, Hatibu, N, Jewitt, G, Penning de Vries, F, Rwehumbiza, F, Sally, H, Savenije, H & Schulze, R 2004, 'A watershed approach to upgrade rainfed agriculture in water scarce regions through water systems innovations: an integrated research initiative on water for food and rural livelihoods in balance with ecosystem functions', Physics and Chemistry of the Earth, 29: 1109–18.

Rosegrant, M, Cline, SA, Li, W, Sulser, TB & Valmonte-Santos, RA 2005, Looking ahead: long-term prospects for Africa's agricultural development and food security, 2020 Discussion Paper No. 41, International Food Policy Research Institute, Washington, DC.

Senzanje, A, Boelee, E & Rusere, S 2008, 'Multiple use of water and water productivity of communal small dams in the Limpopo Basin, Zimbabwe', Irrigation Drainage Systems, 22: 225–37.

Srivastava, RC, Singhandhupe, RB & Mohanty, RK 2004, Integrated farming approach for runoff recycling systems in humid plateau areas of eastern India', Journal of Agricultural Water Management, 64(3): 197–212.

The Economist 2009, 'Rainfall and GDP, let it rain: how rainfall can affect economic growth', The Economist, http://www.economist.com/node/13432503.

The Herald 2011a, 'Turning wastelands into green belts', The Herald [New Zealand], www.herald.co.zw/index.php?option=com_content&view=article&id=16585:turning-wastelands-intogreenbelts&catid=42:features-news&Itemid=134>.

The Herald 2011b, 'Conservation farming takes root in Zaka', The Herald [New Zealand], www.herald.co.zw/index.php?option=com_content&view=article&id=16811:conservation-farming-takes-root-inzaka-&catid=47:agriculture&Itemid=139.

United Nations Human Settlements Programme (UN-HABITAT) & United Nations Environment Programme (UNEP) 2007, Limpopo Basin strategic plan for reducing vulnerability to floods and droughts, Draft for Discussion with Riparian Governments 23, United Nations Human Settlements Programme & United Nations Environment Programme, Nairobi.

van der Zaag, P, Juizo, D, Vilanculos, V, Bolding, A & Uiterweer, NP 2010, 'Does the Limpopo River Basin have sufficient water for massive irrigation development in the plains of Mozambique?', Physics and Chemistry of the Earth, 35: 832–7.

van Koppen, B, Smits, S, Moriarty, P, de Vries, FP, Mikhail, M & Boelee, E 2009, The multiple-use water services (MUS) project, Project Report PN 28, Challenge Program on Water and Food, Colombo.

Chapter 8

Integrated rainwater harvesting

Providing opportunities for wellbeing and freedom: A case study in Mpumalanga, South Africa

JAQUI GOLDIN AND GERMAINE OWEN

Introduction

The links between water and food—in particular in the study area for this study, the Ehlanzeni District Municipality (EDM) of Mpumalanga, South Africa—are critical. Farming and livestock cannot be achieved without water. Water therefore plays an important role in achieving food security. The semi-arid to arid climate of South Africa calls for better management of the country's water resources. In addition, with climate change, now more than ever careful management of the state's water resources for agricultural production in enhancing food security is critical. Koudstaal *et al.* (1992) propose that water resources should be managed as an integral part of a nation's social and economic development. Without water, there is no life, no economic production and there would be no environment at all to consider (Savenije 2002). The amount of rainfall reaching the earth is finite but all of it cannot be used and as Savenije (2002) notes that water is spread unequally in space and time and large parts of the world experience shortages during certain periods. Koudstaal *et al.* (1992, p. 279) state that: 'Water is only useful for human activities if it is available at the right time, in the proper location and if it is of satisfactory quality. If not, water is likely to be a burden rather than a resource.'

Although water is critical to food security, it is not the only determinant for food insecurity around the world. Poor agricultural practices, land inaccessibility, poor understanding and poor management of water and the relationship between

water and food security are some of the many causes that have contributed to food insecurity in the EDM and in the world at large.

The Food and Agricultural Organization (FAO), in its report *The State of Food Insecurity in the World*, focuses on the importance of reducing hunger as the explicit target of the World Food Summit (WFS) and Millennium Development Goal 1 (MDG 1), which is 'to eradicate extreme poverty and hunger', and which is an essential condition for achieving the other seven Millennium Development Goal (MDGs) (FAO 2005). The report has highlighted that the prevalence of undernourishment in sub-Saharan Africa (of which South Africa is a part) has been decreasing very slowly and even though the speed of progress improved in the 1990s, the region will have to step up the pace considerably in order to reach the MDG target. The objective for meeting MDG 1 is halving, between 1990 and 2015, the proportion of people who suffer from hunger, but if developing regions continue to reduce hunger at the current pace, they will not reach that goal. The WFS and the MDG targets can still be reached if efforts are refocused and redoubled in reducing and eliminating hunger in the rural areas where the majority of the world's hungry live (FAO 2005). Part of the refocus would be to address the issues around human wellbeing and quality of life within the context of the Capability Approach framework that is discussed in some detail below.

According to the FAO (2005) report, the world population is expected to grow by approximately two billion between the baseline period 1990–92 and 2015. Although the proportion of that larger population who are undernourished has already been reduced by half, nearly 600 million people in the developing world still suffer chronic hunger. The report states that in order to reach the WFS target of 400 million, the proportion of the population who are undernourished would need to be reduced by two-thirds and not by half.

Efforts to promote food security and environmental sustainability can often re-enforce each other (FAO 2005). Promoting environmental sustainability is one of the three objectives that integrated water resources management (IWRM)—the core water resources management paradigm within which the current project on rain water harvesting is anchored, seeks to achieve. The sustainability of ecosystems is at the centre of human existence and, without a healthy ecosystem, human needs could not be directly or indirectly satisfied. The *National Water Act* of 1998 encourages communities to become actively involved in developing and managing their water resources (Motteux *et al.* 2006). Learning about the importance of the natural environment is likely to result in proper management of the resource on which human livelihoods depend. There are obvious interdependencies between humans and the ecosystems on which they depend. When there is a healthy human environment, the health of an ecosystem is also enhanced, and vice versa (Goldin *et al.* 2008).

The capability approach (CA) is a robust theoretical framework within which this research is grounded. The Capability Approach (CA) was introduced by the Nobel Prize-winning economist Amartya Sen in the 1980s. The CA, its origin, development, critiques and application will be presented below.

The CA is the theoretical framework that is applied to inquire into the capabilities of small scale farmers in the villages under investigation. Goldin *et al.* (2008) and Goldin (2010) note that enhanced capabilities contribute not only to improved human development but also to improved management of the ecosystem. The current research suggests that with improved human capabilities, there is a likelihood that there will be better management of water resources and subsequently better crop output in the EDM, resulting in enhanced food security. But importantly, attention to human capabilities puts the focus on the eradication of poverty through achievements in human wellbeing and the quality of life.

Study background

The Ehlanzeni District Municipality is one of the poorest districts in Mpumalanga Province, South Africa (Goldin 2009). According to income data from the 2001 census, 67 percent of the population has no income, and 89 percent earns less than the official poverty breadline of R800 per month (Goldin 2009). The 2007 Poverty Node Survey that forms part of the Southern Africa Labour and Development Research Unit (SALDRU) Poverty Node Migration Studey, a project funded by the Mellon Foundation, estimated the unemployment rate to be as high as 76 percent (Goldin & Amde 2011). Many households rely on government grants or the unreliable cash flows from small-scale agriculture that provide some sort of livelihood (Goldin 2009). The average rainfall for the EDM is 746 mm per year, although high variations exist between communities within this district. In the context of South Africa, this makes the research area a relatively wet area, with annual rainfall above the average for South Africa for successful crop production; however, the rainfall pattern only allows for a single rain-fed cropping season per year as almost all rain falls between October and April. Water availability remains a critical constraint, particularly in the midwinter months from May to September, which are dry, thus limiting crop production (Goldin 2009).

The integrated rainwater harvesting project (IRWHP) was implemented in 2010 in the EDM of Mpumalanga Province. The IRWHP's objective is to improve output from communal food gardens through the collection, storage and management of surface run-off from precipitation and better management of soil moisture (Goldin 2009). The components of the project include: community capacity building to strengthen food security and income generation, construction of rainwater harvesting infrastructure and related technologies, development of learning resources, outreach and institutional capacity strengthening and project management and monitoring and evaluation (Goldin 2009). A baseline study—also a component of the project—has been implemented. The purpose of the project is to enhance food and water security and improve the lives of the target households by allowing for an extended cropping season. For this purpose, rainwater is being collected and stored (Goldin 2009).

Members of the EDM, mainly women but also youth and men organised themselves into groups so that they could collectively discuss common concerns that face them in their daily lives, such as food production, nutrition, community

HIV/AIDS support and income generation. These collective efforts resulted in some income being generated through a mix of food gardening, poultry enterprise and artisan activities. The groups used land that was allocated by the tribal chief to grow vegetables; however, the real problem in securing sufficient food—both for their own consumption and for income generation—is not to do with land or other issues. It is to do with not having enough water to grow their crops. Thus, securing the availability of water in order to increase food production and cash returns from food gardening is the top priority for farming groups (Goldin 2009).

Rainwater harvesting (RWH) presents a viable option for securing water availability and it is for this purpose that the IRWHP was initiated in the EDM. The project was formulated by a non-governmental organisation (NGO), Ecolink. Ecolink is a registered non-profit NGO committed to promoting sustainable environmental and social development in rural communities in Mpumalanga and Limpopo provinces. The NGO has been active in Mpumalanga Province for more than 21 years, during which time it has worked with more than 20 000 people in dozens of villages on issues related to environmental management and sustainable livelihood improvement. It has experience with interventions addressing a variety of issues including: water scarcity, food production, gender equality, HIV/AIDS, health and education (Goldin 2009). This is the first time the organisation is taking on a rain water harvesting project.

The goal of the project is to break through the food-insecurity barrier through the use of rainwater harvesting, efficient soil moisture management and appropriate organizational capacity. This is being achieved in the project area through the implementation of site-specific rainwater harvesting infrastructure. It is also being achieved by engaging the communities in improved management of rain-fed farming and soil moisture management, while empowering them through processes that promote self-esteem and facilitate access to land use rights. The idea behind the rainwater harvesting project is to improve human wellbeing and the quality of life of targeted communities.

Socio-economic landscape of Ehlanzeni District Municipality

The population of the Ehlanzeni District with access to latrines is estimated at 92 percent, with only seven percent having access to flush toilets Goldin 2009). The 2008 poverty node survey previously mentioned shows that eight percent of the population had piped water in the house, 48 percent had piped water on the stand, 36 percent fetched water from communal taps, and four percent obtained water from a tank or carried it to the dwellings (Goldin 2009). A large portion of the EDM is rural and a high percentage of households do not have access to potable water. A fundamental problem of drinking water in the area is that it is supplied intermittently—sometimes once in two weeks (Goldin 2009). This implies that consumers have to provide storage of up to half of a month's consumption. Villagers rely on a combination of sources:

- roof run-off stored in drums or tanks;

- water in communal tap stands when present (once or twice per month or *ad hoc* depending on location and municipality operational status and management approach to limiting supply for cost and resource availability reasons);
- springs and seeps—mainly adjacent to rivers;
- pools in rivers and streams when available—mainly for washing;
- borehole or tank water 'borrowed' from clinics; and
- water purchased from handcarts and vendors.

This reflects water scarcity and this profile is typical of the four rural communities where the data for this research were gathered. The lack of bulk and reticulation infrastructure in these areas has aggravated the situation (Republic of South Africa: Ehlanzeni District IDP 2009–10).

The population has identified that water is a main limiting factor for small-scale agriculture and other productive enterprises. The rainfall pattern only allows for one rain-fed cropping season per year; however, as annual precipitation in Mpumalanga Province is above the average for South Africa, rainwater harvesting presents a viable option as a low-risk and replicable way of securing water for food production. Water availability for crop production in the EDM is limited in the dry midwinter months from May to September and water stress or water scarcity in turn limits crop cultivation. Despite the wet months of October to April, cultivation of crops still presents a challenge as most of the water flows away as run-off. The limited crop productivity leaves the majority of households food insecure. There is uneven participation amongst community members in decision-making processes with some members more involved than others.

Socioeconomic description

The EDM has a population of 1 526 236 people (Statistics South Africa Community Survey 2007). The population is approximately 42 percent of the total provincial population (Mpumalanga) of 3.6 million. The population dynamics show that the district is dominated by a young population of about 38.21 percent (Statistics South Africa Community Survey 2007). According to the Statistics South Africa Community Survey, average household sizes reduced during the years 2001 to 2007. The reduction is attributed to a number of factors such as the impact of HIV/AIDS, migration, socioeconomic conditions, resources and influences of settlement patterns experienced by rural communities that were previously marginalised from mainstream socioeconomic activities of the country (Republic of South Africa: Ehlanzeni District IDP 2009–10). Almost 94.4 percent of the people of Ehlanzeni are black Africans who do not have access to sufficient services. Two-thirds of the people and more than half of the households in the Province are scattered across the rural areas of the Province (Republic of South Africa: Ehlanzeni District IDP 2009–10). The level of education shows relatively low levels of schooling in the district. Only 6.7 percent of the population has achieved a higher education and 29.5 percent have some secondary schooling (Republic of South Africa: Ehlanzeni District IDP 2009–10).

Food is vital for human growth, and its absence results in stunting, malnutrition, starvation and even death. Malnutrition alters physical and mental development, hence perpetuating poverty and reducing the productivity of societies (Gray *et al.* 2006). On a societal level, hunger and malnutrition negatively affect labour productivity and national development (Gray *et al.* 2006). Rainwater harvesting is presented as one solution to improve food production because it reduces the rate of run-off and captures water for storage during drier months. In the EDM region where the IRWHP was implemented, there are no nearby perennial streams in the vicinity of the planted gardens, while groundwater sources such as springs and old boreholes have been exploited to their full limit. This leaves RWH as the only effective option that could still be combined with and complemented by these other sources where they are feasible. The intervention will strengthen the local capacity to analyse and address issues of water scarcity in relation to food production and income-generating activities in the four targeted communities of Luphisi, Mbonisweni, Dwaleni and Mjejane. At the same time, it will demonstrate specific, locally adapted solutions that build on a combination of appropriate technology and collective action.

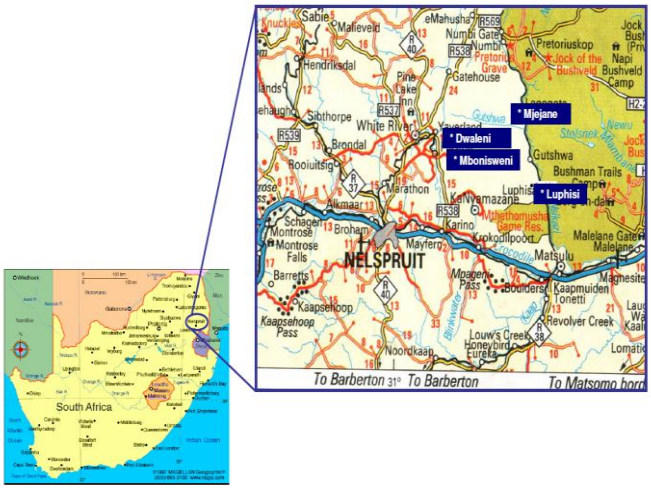
Geographical landscape of the Ehlanzeni District Municipality

Research was conducted in four rural villages: Luphisi, Dwaleni, Mjejane and Mbonisweni. These villages are located in the EDM in northern Nsikazi, in the Mpumalanga Province in the north-east of South Africa (Goldin *et al.* 2008). The EDM is bordered by Mozambique and Swaziland in the east, Gert Sibando District in the south, Mopani and Sekhukhune districts of Limpopo in the north and Nkangala District Municipality in the west (Republic of South Africa: Ehlanzeni District IDP 2009–10). The incorporation of the Bushbuckridge (Local Municipality) into Ehlanzeni has increased the total area of the EDM to approximately 27,895,47 sq km (Republic of South Africa: Ehlanzeni District IDP 2009–10).

The villages are situated in the Inkomati catchment. This was the first of the 19 water management areas (WMAs), now rationalized to 9, established in South Africa to establish a catchment management agency. The catchment is now managed by the Inkomati Catchment Management Agency (ICMA). The sub-catchments include the Sabie-Sand sub-catchment, the Crocodile sub-catchment and the Komati sub-catchment (Goldin *et al.* 2008). The Inkomati catchment is an international river catchment that includes parts of Swaziland and Mozambique (Goldin *et al.* 2008). Figure 8.1 shows the location of the study area.

As already mentioned, the average rainfall for the Ehlanzeni Municipality is 746 mm per year and the rainfall pattern only allows for a single rain-fed cropping season a year. Water availability remains a critical constraint to crop production. Figure 8.2 shows water availability and monthly evapotranspiration.

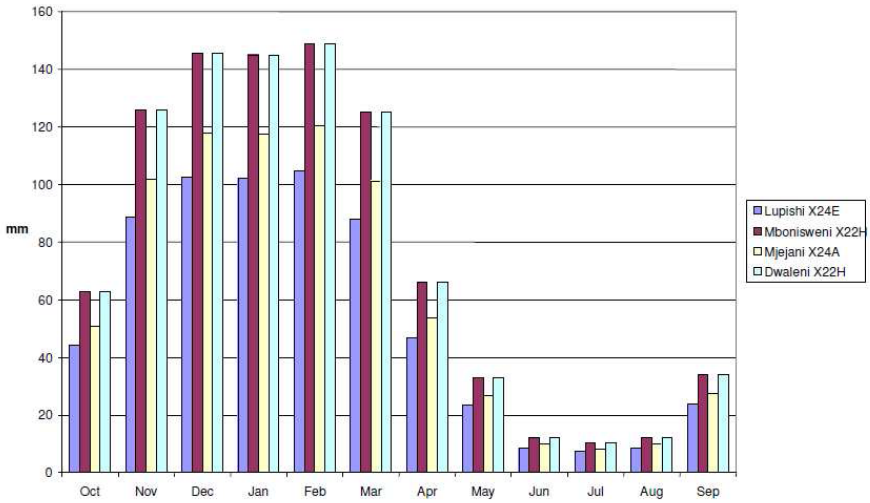
Figure 8.1 Map of the study area



Source: Goldin (2009).

Evapotranspiration is greater than rainfall. The deficit is most significant in May through September. This explains the single rain-fed cropping season per year and indicates the state of food insecurity in the villages.

Figure 8.2 Water availability in the study area



The research findings draw on the data captured from both qualitative and quantitative research conducted in the area. The qualitative data are analysed using narrative texts and discourse analysis. And the quantitative data are analysed using the statistical software *STATA*.

Introducing the Capability Approach, its foundations and development

The Capability Approach (CA) is a poverty and development framework introduced by the Nobel Prize winning economist Amartya Sen in the 1980s. It is a broad normative framework for evaluating individual wellbeing and social arrangements, policy designs and proposals about social change in society (Robeyns 2003). The CA is used in a wide range of domains, most prominently in development thinking, welfare economics, social policy and political philosophy (Robeyns 2003). It can also be used to evaluate a wide variety of aspects of people's wellbeing, inequality and poverty (Robeyns 2003). Clark (2005) also notes that the CA has emerged as the leading alternative to standard economic frameworks for thinking about poverty, inequality and human development. Sen acknowledged strong connections with Smith's (1776) analysis of necessities and living conditions and Marx's (1844) concern with human freedom and emancipation (Clark 2005).

The CA has two major concepts: 'functionings' (beings and doings) and 'capabilities' (opportunities).

The capability approach, water and development

'A focus on people's capabilities in the choice of development policies makes a profound theoretical difference, and leads to quite different policies compared to neo-liberalism and utilitarian policy prescriptions' (Robeyns 2003, p. 5). The CA is an ideal conceptual framework to assess the relationship between water and food security because of its focus on opportunity and doings and beings. The CA is applied as a framework for understanding whether and in what ways the IRWHP is able to improve aspects of human development for the communities who were targeted as beneficiaries in the Ehlanzeni District Municipality and as such it is being used primarily as an evaluative framework.

Sen (1999) posits that human development should be seen in terms of expanding substantive freedoms, where attention is given to the ends that make development important, rather than some of the means that, *inter alia*, play a prominent role in the process. Sen argues that the lack of substantive freedoms is closely related to economic poverty, which robs people of the freedom to satisfy hunger, to achieve sufficient nutrition or to enjoy clean water or sanitary facilities. For Sen (1999) development is about the expansion of human capabilities, it is about achieving freedom to be or to do what an individual values doing or being. Meaningful participation is about improved capabilities and functioning of individuals, which enable citizens to take control over their environment and to participate in decisions to improve the quality of their lives and to maintain the equilibrium of ecosystems (Goldin *et al.* 2008).

According to Sen (1999), freedoms are not only the primary ends of development, but they are also among its principal means. He suggests an understanding of the remarkable empirical connections that link freedoms of different kinds with one

another. He proposes that political freedoms (for example, free speech and elections) help to promote security and social opportunities (for example, education and health facilities) and that these freedoms facilitate economic participation. Having greater freedom to do things one has reason to value, is in itself significant for any person's overall freedom or development.

Anand (2007, cited in Goldin *et al.* 2008) notes that the CA has been only recently applied to the water sector; however, it is a useful development framework within which to reflect on the extent of achievements in the water sector (Goldin *et al.* 2008; Goldin 2013). The multidimensional poverty approach, with particular reference to Sen's (1993, 1999) CA, embraces notions of development that pay particular attention to the expansion of human capabilities (Goldin *et al.* 2008, Goldin 2013). According to Goldin *et al.* (2008), the expansion of human capabilities is built on principles of social justice and equity, which include the just allocation of resources. The multidimensional approach encourages an expanded set of poverty indicators that is of great importance to the water sector because it brings to the fore vital capabilities and functionings that are necessary for human systems to be capable of managing the ecosystems on which they depend (Goldin 2013). In her paper entitled 'From Vagueness to Precision, raising the volume on social issues for the water sector' Goldin's (2013) focus is on isolating measurement indicators that tap into constructs such as self-esteem, understanding, affiliation and so forth. Our focus in this paper is on self-esteem, trust, agency, and empowerment as measurements of wellbeing and achievements of quality of life.

Goldin (2010, p. 3), in her article in the *Review of Radical Political Economics*, makes the links between knowledge, agency and shame explicit, and argues that 'unequal relations of power and knowledge restrict agency, jeopardize the building of trust and may perpetuate feelings of shame'. The author goes on to state that, 'where there is an unequal distribution of resources and knowledge to gain access to those resources, there is also social exclusion that can create vicious cycles that entrench feelings of unworthiness, embarrassment—and shame' (Goldin 2010, p. 3). Smith (1776, cited in Goldin *et al.* 2008) has reflected on the right of people to appear in public without shame. Shame is something a person carries around inside his/her head that makes that person feel bad about him or herself (Goldin 2010). Goldin (2010, p. 7) claims that 'shame does not sit comfortably with dignity, pride and self-esteem, which are important attributes of social justice and anticipated outcomes of the equitable distribution of resources'—such as water.

Having introduced the ideas of capability (opportunity) and functioning (doings and beings), let us consider whether and in what ways this framework helps us evaluate the success—or lack thereof, of the rain water harvesting project in Mpumalanga. We will take evidence from one small scale farmer, Gogo, as much of what Gogo says in the extracts below, has been expressed in different but somewhat similar words in interviews with small scale farmers in the four villages where the projects were implemented. Importantly, these selected extracts reflect the 'soft' achievements that are so critically important when considering

how technologically and appropriate low cost infrastructure, built within the context of the rain water harvesting, can improve the quality of life and bring more freedom (wellbeing) to farmers.

> *Everything goes slow, but it will be fine. In this world we live in you have to wake up and work to fill up your stomach. When you are lying down what will you eat? You'll just lie down and die. How we met to start this project? It's been a while since we started working in the garden. We were tired of not eating so we decided to go to our own place. From the beginning we didn't have water. Where we are now was a forest and we destroyed it. We would hire tractors to take the trees away. We decided to buy a fence because we knew that we were not lazy (Gogo, interview Luphisi 2011)*

The extract above depicts hope (opportunity) and the building of social capital or social cohesion (opportunity) which allowed the Vukani Farmer Group of which Gogo is a member, to position themselves favorably for projects such as the rain water harvesting project. Prior to the project the women had hope that they would succeed:

> *Now we don't need summer or the rain we just go ahead and plant. We are not lazy at all, we like to work , the problem is water. If we had water there would be a lot of trucks coming to take vegetables to orphanages and hospitals.*
>
> *It's the rain that is killing us, because we can't plant without the rain. When it rains we only get a little bit of water. We fetch water with a bucket, and we use it even for the next day.That's what hurts us really. It hurts. Now that is different because we fetch water from the dam.*

An earthdam of 1000m^3 was built in Luphisi and Mbonisweni. In Dwaleni the rain water harvesting technology was based on guttering from the rooftop of the local abbatoir and in Mjejane, a rock was used to harvest the rain water.

> *We have to raise these issues in the meeting. When you plant, whatever grows, grows for you – not for other people. I'd never take my bag and go and pick something from your garden (um-m). Everyone has to pick from his or her own garden. Other people just go to other people's gardens and sometimes you are not there to watch them. For example, I have to go somewhere, and when I'm not at home some people can see.*

There is trust (opportunity) that is generated as women work together and learn what works and does not work.

> *It (the meetings) helps a lot because when we sit down and give each other advice. One will say which way should we take, and one will say, maybe the short way. Or whenever we have our meetings we sit under this tree. We give each other advice whenever there is a problem. I'll keep quite now – someone else talk.*

Figure 8.3 Earth dam (1000 m^3) in Luphisi. A similar technology was used in Mbonisweni

Again a sense of pride and self-esteem (opportunity) at what has been achieved.

> *What has brought us together is water. We were really suffering before. We used to try get water from the river, and when the river dried up, we stayed at home. Until today as you came and told us to stand up and do it for ourselves we succeeded (saphumelela).*

Or again

> *They decided that we should have a book and register the garden. So we took two people to go and register the plot. We had to get a certificate for our garden. We have registered our garden, now we plough freely. Even the chief knows about us. Even the counsellor.*

Again, the farmers had to learn what works and what does not work. This is also a male dominated environment and women are not used to registering a pot or getting a certificate for their garden.

> *We really get inspired. We can even take the little we plant home to eat with our kids. We get mealies and nuts. Working together as women has helped us a lot. It helps us physically because our bodies are always weak, but working everyday makes us fit.*

The rain water harvesting brought farmers together around a common project and in the end it has increased food security. The storage of water in the earthdam has provided not only material but also mental security. Gogo reflects on the time prior to the earth dam:

> *When we started ploughing there was a little water near that banana tree. We dug and dug then we would fetch water with buckets. Within a few days the water was finished. Then we decided to go to that big river, we get water from January, February, around April, the water finishes. Our wish was for the chief to help us. If the chief could help us we could plant the whole year. What we do now, we plant only in summer, in winter we rest, then we start again in summer.*
>
> *We don't lose hope in our garden, we like it a lot. We didn't have anything to eat with our porridge (pap) we couldn't even get r20 for us to buy at school… We tried everything, even now our kids are at university because of these arms.*

During the preparation phase of the project the women had a sense of achievement and pride (opportunity) that is reflected in the extracts below:

> *Before we bought the fence, a reverend came and asked us what we were doing, we told him that we were ploughing but we don't have the fence, we use woods to fence our garden. This white person came back again with the fence. We were so happy we nearly died, some of us got high blood pressure. As the women that we are, we were so happy. Two men came and looked at what we were doing and thought it was a joke and they left.*
>
> *I can see that things are going well, there are people from all over coming here. We were really suffering. This year has been a blessing we reaped mealies and nuts. Even the vegetables we are planting we can now eat. If that water there doesn't finish, we will eat our vegetables.*

Prior to the design of the dam there was a consultative process where the women were invited to give their input and share their knowledge and to learn in the process:

> *…we told him that the water goes down the river. We told him that you can't control this water, and he said I can. Then we told him to do it. He said to us you have to gather your friends around so that I can see you. Then I will try and help you with the water. Do you think we can stop the water from going to the river? How can we block it from going to the river? We wondered how he was going to do it. He came back the next day. We wanted to see the kind of dam that he was going to build, because, we built our own dams and the water just vanishes. I promise you, the year we will get water, we will deliver vegetables to schools hospitals and orphanages. We must learn to plant this way, how to setup a vegetable bed and how to plant seeds and how to build the dam so that the water will not vanish and go down the river.*

The above extract shows determination and empowerment (opportunity) for women to be part of the solution.

Conclusion

The CA is a helpful framework to apply to the water sector where participation is seen to be the core principle in IWRM. As can be seen from the extracts above, a

number of intangible goods, such as pride, self-esteem and trust are reflected and these represent opportunities for women to engage and gain agency in their lives around issues of water and food. Participation is difficult where there is shame, lack of agency and trust, and social exclusion. Sen (1999, p. 19) states that 'an agent is someone who acts and brings about change'. Sen (1985, p. 203) defines human agency as 'what a person is free to do and achieve in pursuit of whatever goals or values he or she regards as important'. We have seen from the extracts above that the small scale farmers have been able to pursue the goals that were important – getting and retaining water for food. When there is lack of agency, people are unable to influence decisions that affect their everyday living (Goldin 2010). Ibrahim and Alkire (2007, p. 11) state that 'the opposite of a person with agency is someone who is coerced, oppressed, or passive', and thus their opportunities and access to public goods are likely to be restricted.

Gogo, the farmer whose voice is captured here, is not coerced, oppressed or passive and her story is one of hope and opportunity. The rain water harvesting project has helped women to be or do what they wanted to be or do and as such they have been able to achieve valuable functioinings (beings and doings). These achievements might not have been captured if the development framework had only focused on the hardware. It is quality of life and improved wellbeing that is well reflected using the capability approach as a development framework. This framework is multi-dimensional, reflecting the many dimensions of human wellbeing. No single dimension can be deemed more valuable than another as, being a multi-dimensional framework, we see that many attributes matter at the same time (e.g. self-esteem, hope, dignity). As Sen states in an interview with Robeyns in 2010, the preferred route for a policy maker and/or donor is to measure the norm, but this is not a good reason to discard what is relevant to a quality of life even if it is evasive and difficult to measure. Goldin (2013) reminds us that it is helpful to remember that methodologists in the 80s and 90s struggled with the 'vague' concept of social capital but the concept is now mainstreamed and well recognized within development discourse, albeit sometimes too thinly measured. What is crucial is not simply the construction of the 1000 m^3 earth dam, nor the in-field harvesting and soil conservation technologies, the vetiver grass to improve soil contours or/and mulching, that together boost the value of crop per drop. There are hybrids of emotion and intangible assets that are connectors for technological innovation and vice versa.

As Robeyns (2003) reminds us, 'a focus on people's capabilities in the choice of development policies makes a profound theoretical difference, and leads to quite different policies compared to neo-liberalism and utilitarian policy prescriptions'. There are two ways that this different theoretical approach may gain influence. The first is that we can recognize that there are connectors that make it possible for technological innovation to root – we know that the uptake of technology in developing country contexts is very often jeopardized because of governance and institutional arrangements, operation and maintenance. Therefore, if we want the technology to be accepted, there needs to be a scaffold in place that supports people and their everyday experiences around technology. The second point is

that wellbeing cannot be measured only in terms of tangible gains and that feelings of pride, hope, trust and self-esteem – for instance – are good for society. They have positive spinoffs in terms of combatting crime, health and other symptoms of deep poverty. Achievements in these domains are just as important as material gains. This does not mean that the material gains are unimportant but rather that a focus only on material gains limits our attempts to uproot poverty and improve human lives. The implications for policy and planning is that, in recognizing opportunity and the importance of agency and wellbeing, we acknowledge a process that must rooted alongside technological interventions. This process takes time and requires matching budgets. The gains in intangible goods are less visible but no less important. This brings us to the third point and that is to do with measurement. What we measure is what we get. If we only measure achievements in terms of technology (earth dams, guttering, volumes of water stored) we will miss the intangible gains. If our measurement focus is simply on the technological gains we may well jeopardise capabilities or opportunities for people to be or do what they would chose to be or do. The measurement of intangible gains requires deliberate commitment if there are to be achievement in the quality of life and human wellbeing alongside our technical achievements.

References

Anand, P. B. (2007). Capability, sustainability, and collective action: An examination

Clark, D. A. (2005). The capability approach: Its development, critiques and recent advances. *Global Poverty Research Group, 3*

Food and Agriculture Organization, (2005) The State of Food Insecurity in the World: Eradicating world hunger-key to achieving the Millennium Development Goals. Retrieved on 6th October 2010. From www.fao.org/icatalog/inter-e.htm.

Goldin, J. & Amde, W. (2011). Provincial Migration Report for Limpopo and Mpumalanga Province: Poverty Node SALDRU, University of Cape Town (forthcoming).

Goldin, J. (2005). Trust and transformation in the Water Sector in South Africa, Unpublished Doctoral Thesis, (University of Cape Town Department of Political Studies).

Goldin, J. (2009). Integrated Water Harvesting Project Mpumalanga, South Africa. Retrieved on 5th April 2010 from www.africanwaterfacility.org/ fileadmin/uploads/awf/projects-activities/44%20%20South%20Africa%20%20 Ecolink%20Integrated%20Water%20Harvesting%20Project%20FINAL.pdf.

Goldin, J. (2011). From Vagueness to Precision: raising the volume on social issues for the water sector. Paper presented on panel entitled 'Water Struggles: right to water, justice, and changing hydro-social worlds' at the 9th International Conference for the European Society for Ecological Economics, Istanbul.

Goldin, J. A. (2010). Water policy in South Africa: Trust and knowledge as obstacles to reform. *Review of Radical Political Economics, 42*(2), 195.

Goldin, J., Rutherford, R., & Schoch, D. (2008). The place where the sun rises: An application of IWRM at the village level. *International Journal of Water Resources Development, 24*(3), 345-356.

Gray, *et al.* (2006), Stunted growth is associated with physical indicators of malnutrition but not food insecurity among rural school children in Honduras. *Nutrition Research*, *26*(11), 549-555.

Ibrahim, S., & Alkire, S. (2007). Agency and empowerment: A proposal for internationally comparable indicators. *Oxford Development Studies, 35*(4), 379.

Koudstaal, R., Rijsberman, F. R., & Savenije, H. (1992). Water and sustainable development. *Natural Resources Forum, 16*(4) 277-290.

Marx, K. (1844), *Economic and Philosophic Manuscript* (English Translation), London: Lawrence and Wishart, 1977.

Motteux, N., Rowntree, K. & Fargher, J. (2006). Participation in Integrated Water Resources Management in South Africa, Quick Reference Guide. Water Research Commission Report No. TT 258/06.

Republic of South Africa, (2009) Ehlanzeni District Integrated Development Plan 2009/2010

Robeyns, I. (2003). The capability approach: An interdisciplinary introduction. *Papier Écrit Pour Le "Training Course» Précédant La 3e Conférence Internationale Sur l'approche Par Les Capabilités, Pavie, Italie, Septembre,*

Savenije, H. H. G. (2002). Why water is not an ordinary economic good, or why the girl is special. *Physics and Chemistry of the Earth, Parts A/B/C, 27*(11-22), 741-744.

Sen, A. (1985). Well-being, agency and freedom: The Dewey lectures 1984. *The Journal of Philosophy, 82*(4), 169-221.

Sen, A. (1999). *Development as freedom* Oxford University Press.

Sen, A. (2005). Human rights and capabilities. *Journal of Human Development, 6*(2), 151-166.

Sen, A., & Nussbaum, M. (1993). Capability and well-being. *The Quality of Life, 453*

Smith, A. (1776). An inquiry into the nature and causes of the wealth of nations. cannan, edwin (ed.), 1976.

Chapter 9

Future directions for water and agriculture in southern Africa

JAMIE PITTOCK AND R QUENTIN GRAFTON

The multiple and cross-disciplinary perspectives presented in the preceding chapters offer new and African insights into the challenges of increasing food production and supporting sustainable agriculture. Fresh thinking and practical guidance are needed to help address the question of how to raise domestic food production and reduce poverty while sustainably managing water resources and the environment. In this, the concluding chapter, we provide our own views as editors about the nature of the food and water security challenges in southern Africa. Based on our experiences both in and beyond Africa, we suggest possible ways forward to link food and water security.

The status of water and agriculture

An estimated one in three people in Africa goes hungry and this is the region with the largest proportion of people living in poverty. To reduce rural poverty Africa needs a productivity boost in terms of its agricultural production. One way to raise food production is with irrigation, as it can remove an important constraint and has the potential to greatly increase crop yields. Despite its potential, irrigation is underdeveloped in sub-Saharan Africa while many existing irrigation systems perform well below expectations, primarily due to technical, governance and water security challenges (Stirzaker & Pittock, this volume).

Current projections indicate that the area of land equipped for large-scale irrigation will increase rapidly in the near term, primarily through the intervention of multilateral donors. To appreciate the potential, just ten percent of the land that could be irrigated is irrigated. Not only can irrigation increase crop yields it also can assist farmers adapt to climate variability and climate change as

substantial parts of southern Africa are expected to become drier in the coming decades. Irrigation may also offer opportunities to enhance existing domestic water delivery to supply household food gardens.

At the small or micro scale, the use of small, motorised pumps to exploit shallow groundwater offers an opportunity, if practised sustainably (Stirzaker & Pittock, this volume), to raise food production. Groundwater pumping can assist farmers who traditionally grow rain-fed crops. The great benefit of sustainable groundwater extraction is that it responds much more slowly than surface waters to drought and is, therefore, a buffer against climate variability. Groundwater, in comparison with surface-water extraction, is available over a much larger spatial area, and if used sustainably provides opportunities for farmers to diversify their livelihood strategies without the social dislocation and landownership problems that frequently confront new surface-water schemes.

Policy clarity

How then should governments, donors and civil society approach these opportunities for improved food production through irrigation? The unfolding Comprehensive African Agricultural Development Plan (CAADP) process is valuable because it focuses government attention and funds on rural development. Nevertheless, transforming these aspirations into on-ground actions is a huge challenge (Sullivan & Pittock, this volume).

African governments are currently embarking on a massive expansion in irrigation without fully addressing the reasons why many previous irrigation schemes have been unsuccessful. It is essential that the mistakes of the past irrigation expansion of the 1960s to 1980s are not repeated, where low profitability did not allow the ongoing investment in infrastructure and the associated institutions that govern equitable and sustainable use (Stirzaker & Pittock, this volume). Contributors to this volume suggest that the national and Africa-wide contributions to CAADP need to be better defined and policy responses should focus on:

- irrigation and food security objectives,
- integration of agriculture and water sustainability, and
- effective capacity building and governance.

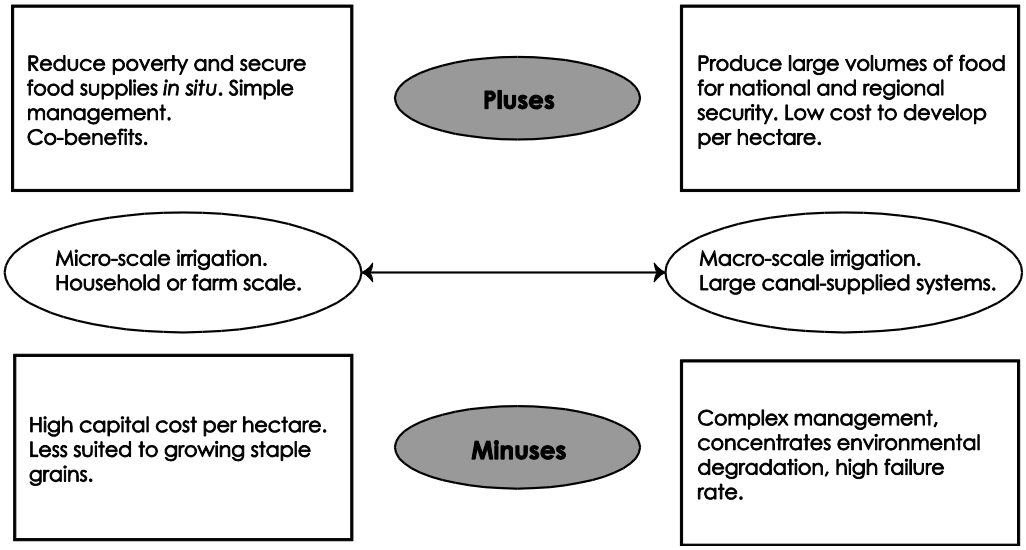
What kind of irrigation and food security?

Dryland agricultural production relies on transpiration of rainfall, known as ‘green water’. Irrigated agriculture involves the capture, storage and supply of water from aquifers, rivers and storages, referred to here as ‘blue water’ (Falkenmark & Rockstrom 2006). Waste or ‘grey’ water may also be reused in agricultural production.

Irrigation systems are varied in scale and in the application of technology, which has implications for food security and poverty reduction; Figure 9.1 illustrates this spectrum. Lankford (2009) classifies irrigation into four types of technologies:

small-scale technologically simple systems, small-scale smallholder-owned canal systems, pressurised irrigation systems built as donor or government-sponsored smallholder schemes, and rehabilitated or newly built large-scale canal systems as externally funded smallholder schemes.

Figure 9.1 Spectrum of irrigation scale and technology versus policy objectives



Small-scale irrigation

At the smallest scale there is the capture and storage of water around a home for application to a household garden. A modest increase in domestic supply to water a garden is often advocated as a cost-effective first step up the 'water ladder' (van Koppen *et al.* 2009). At the individual farm scale, rainwater may be collected in small dams or tanks, pumped from shallow groundwater or diverted from local schemes. At these individual scales the institutional complexity in managing the water supply is low and this water access may have many co-benefits in improving social status and providing water for uses such as drinking, bathing and washing (Goldin & Owen, this volume), which are not considered in agricultural economic assessments of deployment of these technologies.

Small-scale technologies may boost water supplies where people live across the landscape and, thus, increase local food security and reduce poverty. For example, treadle pumps may assist (Lankford 2009), but a wide range of technologies is available (Kahinda & Masiyandima, this volume; Makurira, this volume). A biophysical analysis of the potential extent of conservation agriculture and rainwater harvesting for poverty reduction shows that there are extensive opportunities to reduce poverty in southern Africa by deploying these approaches and measures (Kahinda & Masiyandima, this volume).

While small-scale technologies could play key roles by improving the incomes and the resilience of livelihoods of the poor in regions subject to climatic variability and change, they are also criticised as very expensive per hectare of

irrigated land, less suited to production of staple grain crops and suboptimal steps to adoption of more effective technologies (Lankford 2009). Makurira (this volume), after surveying rainwater harvesting practices in Mozambique, South Africa and Zimbabwe, identifies knowledge of the opportunities and the high upfront capital cost as major barriers for many farmers in adopting these small-scale rainwater harvesting and irrigation technologies.

Small-scale irrigation may reduce the impacts on the environment and ecosystem services because these schemes entail lower transmission losses and, in their application across the landscape, they distribute and minimise impacts like salinity and river-flow reduction. Nonetheless, any diversion of water from ecosystems for farming can have environmental impacts, as recognised in South Africa in the regulation of stream-flow reduction activities. Pollard *et al.* (this volume) detail the challenges in governing irrigation water use to maximise the benefits for people and to minimise the impacts on the environment. In particular, there are trade-offs between explicit or de-facto uses of water, including between plantation forestry, canal irrigation, rainwater harvesting and biodiversity conservation. Analysis by Pollard *et al.* (this volume) highlights the gap between national laws and other policies versus on-ground implementation, as they argue for strengthening local water governance institutions through social learning and adaptive management.

Medium- and large-scale irrigation

At a medium scale, irrigation schemes based on pumping groundwater or village-scale surface-water systems have the advantages of modest institutional complexity and some potential for dispersal across the landscape. This has possible benefits by reducing environmental impacts while contributing to enhanced food production.

The largest commercial scales of irrigation involve large canal systems commanding thousands of hectares with water often supplied from regulated rivers. Such schemes are the cheapest per hectare to construct and can supply large volumes of food to markets, yet they often fail (Stirzaker and Pittock, this volume). Reasons for these failures include: an inability to link produce to profitable markets required to underwrite operating costs; deployment of technologies for which there is insufficient local expertise to readily maintain them; unreliable energy supplies to operate key equipment; organisational complexity and failure; and a build-up of waterlogging or salinity that is difficult to manage at these large scales. Further, such large-scale schemes are restricted to limited suitable geographic locations (You *et al.* 2011) and, thus, will not directly reduce poverty or increase food security in regions of a country that are physically unsuitable for such development. Finally, while opportunities to expand irrigation are suggested on the basis of general, regional statistics, there are real costs from large-scale diversions that include the loss of ecosystem services and also livelihoods.

Food security

Food security is defined by the Food and Agriculture Organization as 'when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life' (CWFS 2012). Elements considered in food security programs extend beyond increased production to cover such elements as nutritional quality, transport and market access, as well as purchasing capacity. While these are important, in this volume we have focused on questions of supply from irrigated agriculture.

Assessing food security in southern Africa, Bogale *et al.* (this volume) consider whether the challenges of high population growth and low agricultural productivity can be overcome to meet development goals for reducing hunger and poverty. Measures they assess for facilitating sustainable livelihoods among the people and nations of sub-Saharan Africa include increased investment in agriculture, sustainable land and water management processes, and drought-resistant crop varieties.

Irrigation for food security as part of poverty reduction through subsistence agriculture at a local scale requires an emphasis on technologies that may be applied at smaller scales in a broader range of localities where people live. Pollard *et al.* (this volume) point out that the status and societal value of smallholder agriculture differ by context because such farming can be viewed as a safety net for the resource poor, who are seen as low-status members of society, or as part of the solution to sustaining growth as well as delivering reasonably equitable development. In contrast, production of staples to secure food supplies and lower food prices at a national or regional scale suggests an emphasis on irrigation technologies that can be applied at key locations at a large scale.

As an example of donor-country views, the Australian International Food Security Centre observes that 'Australia is supporting African efforts to improve food security by boosting long-term agricultural productivity and building resilience, while meeting the immediate needs of vulnerable people when humanitarian crises occur'.[9] Similarly, AusAID states that:

> *Australia's approach to food security is centred on increasing the availability of food through production and improving trade, while also increasing the poor's ability to access food. Australia has prioritised three pillars to improve outcomes in food security:*
>
> - *Lifting agricultural productivity through agricultural research and development*
> - *Improving rural livelihoods by strengthening markets and market access*

[9] <http://aciar.gov.au/aifsc/food-security-and-why-it-matters> (accessed 15 November 2012).

- *Building community resilience by supporting the establishment and improvement of social protection programs.*[10]

Governments and other organisations need to decide what scale and type of irrigation technologies need investment, which depends on the type of food security desired, and the model they favour for poverty reduction. Lankford (2009) suggests that there is not a single, correct answer, but rather deployment of a mix of irrigation technologies is desirable to meet different needs in different biophysical and societal circumstances. Nevertheless, government sponsorship of large-scale irrigation schemes appears to be the default setting. It would appear that the promotion of smaller-scale technologies is a greater challenge given the difficulty of providing government support for a larger number of scattered interventions. Further, governments struggle to combine sectoral policy interests, such as domestic water supply and sanitation, with water for agriculture in order to justify the higher capital costs of small-scale schemes. The power of the 'hydraulic bureaucracy' that is supportive of 'think big' engineering and political rewards also favours large-scale irrigation schemes (Molle *et al.* 2010) and is often assisted by the power of larger and more commercial operators to increase their resource access compared with subsistence farmers (Pollard *et al.*, this volume).

In our view, the food security programs of African governments and donors would be enhanced by greater clarity on the types of security they seek so that limited resources can be focused on the types of irrigation technologies and places for their deployment that can best meet these objectives. If *in-situ*, small-scale irrigation and rainwater harvesting are required then governments will need to redouble their support to overcome barriers such as knowledge, capital costs and resistance from the hydraulic bureaucracy. This must be coupled with better integration of agricultural and water institutions and governance because adoption of technology is insufficient to resolve Africa's food security challenges.

Integration of agricultural and water institutions

Greater water productivity or 'crop per drop' is a priority in many regions of Africa where water is scarce or fully exploited and where there are competing users. This is illustrated by the conflicts between water for irrigation and for hydropower in the Great Ruaha River of Tanzania (Pittock, this volume). Irrigation in Africa is only one-third as productive per unit area as that of Asia and there is an order of magnitude difference between frontier and poor practices in crop production when the water supply, irrigation management and agronomy are all optimised (Stirzaker & Pittock, this volume). While there is widespread recognition that greater water productivity is required, perverse incentives abound in terms of water for conservation in southern Africa.

A number of factors contribute to inefficient water use in African agriculture. Water diversions are rarely measured and licence limits are rarely enforced. Due to the risk of power for pumps failing or other problems in scheduling there is

[10] www.ausaid.gov.au/aidissues/foodsecurity/Pages/home.aspx, accessed 15 November 2012.

every reason for African farmers to apply as much water as they can, when they can. Water fees are usually very low and as they are not proportional to the volume consumed there is no incentive to use less.

There is growing recognition internationally that tradeable water entitlements establish market-based incentives for more efficient water use, and opportunities for water to flow to higher-value uses offer the potential to increase employment and economic output without increasing environmental impacts (Grafton *et al.* 2011). Yet most southern African countries currently lack the requisite water accounting, entitlement laws and other institutional capacities that are the basis for such water markets, and have a cultural reluctance to consider such water market mechanisms.

We contend that irrigation schemes only work efficiently under a complex set of conditions that includes effective institutions in government and society for managing land, water and energy resources. Consequently, to enhance production sustainably there is a need for ongoing learning and adaptation of all the players and for them to ask the appropriate questions when implementing decisions and in terms of data collection and learning from past experiences (Stirzaker & Pittock, this volume).

Effective capacity building and governance

Almost all of the contributors identify people rather than technology as the primary challenge and opportunity: the software not the hardware, institutions rather than engineering. To enhance food security in southern Africa, Bogale *et al.* (this volume) recommend sustainable land and water management processes as one of three key interventions. Mwenge Kahinda and Masiyandima (this volume) and also Makurira (this volume) argue that the benefits to be gained from small-scale rainwater harvesting and irrigation systems are being overlooked as government agricultural programs focus on large, commercial-scale agriculture.

From a sociological perspective, Goldin and Owen (this volume) advocate application of a 'capability approach' in the water sector to reinforce participation, which is a core principle of integrated water resources management (IWRM) (GWP 2000). They promote the fostering of a number of intangible goods, such as pride, self-esteem and trust, as these provide opportunities for the poor, women and other disadvantaged groups to engage and show agency in managing their water and food stress. In contrast, they say that participation is difficult where there is shame, lack of agency and trust, and social exclusion.

Pollard *et al.* (this volume) argue that agricultural practice cannot proceed in a vacuum, and should be referenced against important contextual factors of which three of the most important are water, land and governance. Despite the risk of capture by well-resourced commercial water users, they advocate for IWRM to support the transformation to more sustainable modes of agricultural production. Pollard *et al.* (this volume) also declare that the priorities for intervention are mainly in the realm of governance, with the principal improvement required not in terms of what is done, but rather the way it is done. The water and agricultural

governance measures that Pollard *et al.* promote, among others, include: enhanced communication between managers at every level; joint priority setting, feedback loops and reflexive learning within the relevant sectors; and a stronger focus on strategic adaptive management. In their work in the Incomati River Basin in South Africa, Pollard *et al.* (this volume) stress the importance of developing these capacities and institutions at the scales of catchment management areas and sub-national governments if national laws and other policies are to be well implemented.

Stirzaker and Pittock (this volume) argue that a 'bottom-up' technology push coupled with a 'top-down' organisational reform is necessary if irrigation is to be more productive, equitable and sustainable. They call for a focus on the lack of incentives for more productive use of water in agriculture to evaluate how greater investment in social learning and adaptive management can contribute to more sustainable irrigation farming. To improve production from medium to large-scale irrigation schemes, they propose the local irrigation scheme or community as the scale of intervention so as to capture the interests of the community in terms of the shared resource and infrastructure and the financial interests of farmers in terms of irrigation. They recommend enhancing local institutions to reinforce social capital and support equitable development.

Their focus is on measuring irrigation scheme performance with requisite simplicity as a catalyst for a community-based social learning and adaptive management process. In turn, the information from the monitoring and subsequent learning fosters the intermediate outcome of building capacity in local institutions and the skills of farmers. Further, they contend that most progress will be made when local communities have the agency to initiate their own reforms to improve irrigation scheme productivity, sustainability and equity because empowered communities are better able to identify and adopt appropriate technologies and demand more practical, supportive policies from government agencies and their programs.

Conclusions

The varied approaches proposed in this volume by Mwenge Kahinda and Masiyandima, Pollard *et al.*, Makurira, Goldin and Owen, and Stirzaker and Pittock are a challenge to business-as-usual irrigation development in southern Africa. While their views all support the need to grow more food, they argue that governments should be much more explicit in defining their food security goals and explaining how their programs will help achieve these objectives. Several authors urge support for small-scale and decentralised rainwater harvesting and irrigation because they empower the most disadvantaged people and have many livelihood co-benefits.

A key finding is the integration of governance of water and of agriculture and to make more explicit decisions on trade-offs across competing uses. We note that the 'information deficit' model of agricultural extension is insufficient, and stress the importance of building the capacities of local communities and governance

agencies to make their own decisions through social learning and adaptive management. The effectiveness of 'top-down' governance is questioned when there are no effective institutions at more local scales to ensure that there is demand for the government programs and that they are responsive to local needs.

A new approach to sustainable management of water for agricultural development and poverty reduction in Africa is required. We contend that the sole focus of many African governments and multilateral agencies on expansion of large irrigation schemes is misplaced. Greater investment in training people and establishing institutions, particularly at the community scale, is required. Successful examples and case studies presented in this volume need to be built on to achieve widespread benefits.

There are no simple solutions for increasing agricultural production, enhancing food security and sustaining fresh water, but it is clear that business as usual must change. The diverse perspectives here do not offer all the solutions. Nevertheless, they can assist and can go some way to promoting food and water security in southern Africa.

References

Committee on World Food Security (CWFS) 2012, Committee on World Food Security, Food and Agriculture Organization, Rome.

Falkenmark, M. and J. Rockstrom (2006), 'The new blue and green water paradigm: Breaking new ground for water resources planning and management', *Journal of Water Resources Planning and Management*, 132(3): 129-132.

Global Water Partnership (GWP) 2000, *Integrated water resources management*, TAC Background Papers No. 4, Global Water Partnership, Stockholm.

Grafton, RQ, Libecap, G, McGlennon, S, Landry, C & O'Brien, B 2011, 'An integrated assessment of water markets: a cross-country comparison', *Review of Environmental Economics and Policy*, doi: 10.1093/reep/rer002.

Lankford, B 2009, 'Viewpoint—the right irrigation? Policy directions for agricultural water management in sub-Saharan Africa', *Water Alternatives*, 2(3): 476–80.

Molle, F, Mollinga, PP & Wester, P 2010, 'Hydraulic bureaucracies: flows of water, flows of power', *Water Alternatives*, 2(3): 328–49.

van Koppen, B, Smits, S, Moriarty, P, Penning de Vries, F, Mikhail, M & Boelee, E 2009, *Climbing the Water Ladder: Multiple-use water services for poverty reduction*, IRC International Water and Sanitation Centre and International Water Management Institute, [TP series; no. 52], The Hague.

You, L, Ringler, C, Wood-Sichra, U, Robertson, R, Wood, S, Zhu, T & Sun, Y 2011, 'What is the irrigation potential for Africa? A combined biophysical and socioeconomic approach', *Food Policy*, 36(6): 770–82, doi: http://dx.doi.org/10.1016/j.foodpol.2011.09.001.

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