Transforming smallholder irrigation into profitable and self-sustaining systems in southern Africa

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Tanzania, Mozambique and Zimbabwe

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Summary

Small-scale communal irrigation schemes in Africa have not realised returns on investment. Critical to this failure is that funders, designers and managers of these schemes have not recognized them as complex socio-ecological systems with a diversity of constraints. These schemes are often under-performing and characterized by a subsistence orientation, which is compounded by poor market integration, low capacity to invest in crop production, low yields, difficulties paying for water, or lack of willingness to participate in system maintenance. The end result is unsustainable utilization of resources, failed infrastructure, inefficient use of water and land and increased conflict over access to these resources.

Conventional irrigation scheme development has focused on 'hard' technologies to improve the functionality and efficiency of infrastructure and/or irrigation application technologies. However, hard technology improvements on their own have failed to deliver sustainable schemes and improve the livelihoods of irrigation farmers (Inocencio et al., 2007): broken and decaying infrastructure is just one element of an underperforming system. While technologies that are more efficient may help improve yield, they will not necessarily improve profitability. A great many irrigation schemes are trapped in a negative cycle of infrastructure provision, unprofitable farming, lack of investment in maintenance, infrastructure degradation leading to donors subsidizing infrastructure rehabilitation (Pittock & Stirzaker, 2014; Bjornlund et al., 2017).

Transitioning these complex systems into profitable, equitable and economically sustainable schemes requires investment not only in smart technologies but also in farmers, institutions and building the value-chain network (Figure 1).

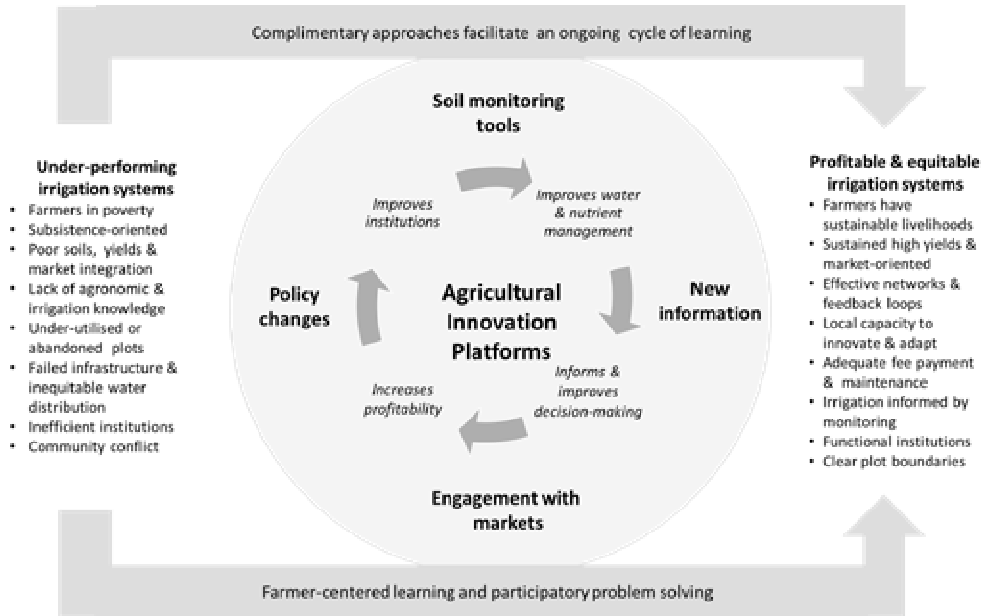

Figure 1. Transitioning under-performing small-scale irrigation schemes in Africa towards profitable and equitable irrigation systems (adapted from Pittock et al., 2018)

The project features a two-pronged approach consisting of two complementary entry points to transition small-scale irrigation schemes towards long-term sustainability (Figure 2):

- Smart water management (SWM) technologies were introduced to monitor soil moisture and nutrients and facilitate farmer learning about irrigation water management to increase yield.
- At the same time, smart water governance and learning processes, in the form of Agricultural Innovation Platforms (AIPs), were introduced to bring key stakeholders together to develop solutions to a range of challenges presenting barriers to turn increased yield into increased profitability.

In the context of SWM, it is important to understand the influence of and linkages between the two key approaches applied in this project. The soil monitoring tools represent sophisticated but simple-to-use technologies designed to support a farmer-centred learning system. These are SWM tools in the traditional sense, but the focus is on resolving the 'soft' component of the irrigation challenge by providing a means for farmers to learn about water and nutrient management, which they can use in their decision-making. The AIP is a research and development approach that draws from systems thinking and is particularly well suited to problem solving in complex systems, such as irrigation schemes. An AIP brings together stakeholders with a shared interest, builds capacity and networks, and facilitates a dialogue to identify critical barriers and appropriate hard and soft technologies to improve profitability.

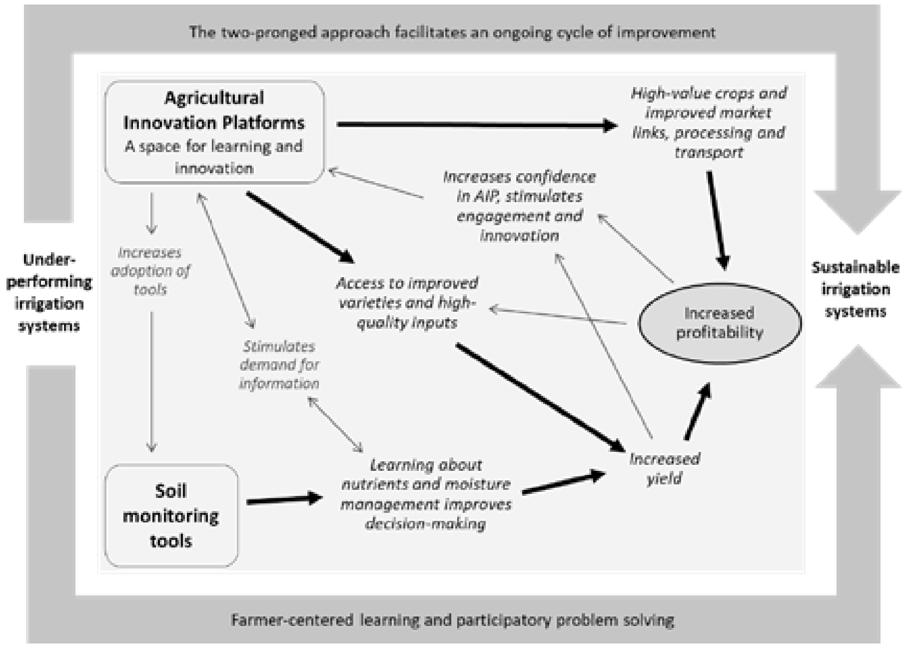

Figure 2. The two-pronged approach and how it influences profitability (Bjornlund, 2018)

Critically, there is no single solution to transitioning small-scale irrigation schemes to long-term sustainability. The AIP provides the context for the SWM technologies and identifies 'stepping stone' solutions to support ongoing learning and problem solving. Importantly, the AIP process enhances and facilitates the adoption of the learning from the SWM technologies whilst simultaneously addressing critical barriers to increasing yields and the profitability of water use[1]. In essence, the key point argued and illustrated in the chapter is that SWM technologies need to be implemented in conjunction with smart governance and learning processes (a two-pronged approach). The AIP facilitation ensures that the information generated by the tools is used to develop a deeper understanding of the water-nutrient dynamics, which allows farmers to make more informed decisions about water and nutrient management and engage in farm level experimentation., This results in critical behaviour and practice change leading to improved yields and profitability.

1. This chapter uses a simple definition of water use profitability: reduced irrigation frequency and duration of irrigation events are evidence of reduced water used. Combined with increased yield and income this is evidence of increased water use profitability.

The project outcomes described in this chapter draw mainly from a survey of project participants—a baseline survey conducted in 2014 and an end of phase one survey in 2017—as well as ongoing focus groups and field observations by the project officers working with the farmers on both elements of the two-pronged approach. Overall, the irrigators participating in this project engaged actively with the SWM technologies and the AIPs. Many farmers have experienced significant yield and income increases resulting in increased food security and prosperity. The time saved through reduced irrigation frequency has been invested in further improving yields and/or diversifying income streams: by establishing and engaging in small businesses and other non-farm income earning activities. The irrigation schemes have experienced significant water savings resulting in an increase in supply that has been especially beneficial for down-stream users and has improved reliability during periods of scarcity. The improved profitability and reliability of supply has reduced conflicts, both among irrigators and within households, and resulted in an increased willingness to engage in collective action such as system maintenance, fee payment and fence building. The outcomes presented are the preliminary analysis of the changes reported in the surveys and further evaluation of both the outcomes and the research approach are ongoing.

The research for development project described here was funded by the Australian Government through the Australian Centre for International Agricultural Research (ACIAR) and implemented in Mozambique, Tanzania and Zimbabwe. The project primarily focuses on the strategic priorities of the funding bodies and its relevance to country partners; however, it also has direct linkages to seven of the global Sustainable Development Goals (SDG) and contributes to a broad range of SDG targets

1. Context of the project

1.1 Project purpose, funding and partners

The project aims to improve the profitability of small-scale irrigation schemes. It has been developed and implemented in two phases and primarily funded by the Australian Centre for International Agricultural Research (ACIAR) (Table 1). This chapter focusses on Phase 1 of the project, which commenced in 2013 and was extended into Phase 2 in 2017.

Table 1. Project phases, timeframes, countries, expected reach and funding

Project features	Phase 1	Phase 2
ACIAR Project	FSC-2013-006	LWR-2016-137
Project title	Increasing irrigation water productivity in Mozambique, Tanzania and Zimbabwe through on-farm monitoring, adaptive management and agricultural innovation platforms	Transforming smallholder irrigation into profitable and self-sustaining systems in southern Africa
Timeframes	15 June 2013 to 14 June 2017	16 June 2017 to 15 May 2021
Countries	Mozambique, Tanzania and Zimbabwe	Mozambique, Tanzania, Zimbabwe
Schemes	6 schemes, 2,485 farmers, 1893 ha	6 original and 32 new schemes, 15,523 farmers, 6,455 ha
ACIAR funding	AU$3,416,440 (US$3,269,533[1])	AU$3,600,000 (US$2,666,400[2])
ANU[3] funding	---	AU$450,000 (US$332,550[2])
CGIAR WLE[4] funding	US$200,000	Approximately US$400,000
Total funding	US$3,469,5330	US$3,398,950

1. Based on exchange rate at 1 June 2013 (http://www.xe.com/currencytables; 2. Based on exchange rate at 1 June 2017 (http://www.xe.com/currencytables); 3. Australian National University; 4. Consultative Group for International Agricultural Research: Water, Land and Ecosystems

The research evaluates whether multi-disciplinary and learning-based adaptive approaches can solve complex socio-ecological problems and tests the following hypotheses:

1 - Widening the 'innovation space', by simultaneously addressing technological and institutional barriers, will stimulate the uptake of better farming practices;
2 - Simple monitoring of key biophysical variables can structure learning and improve decision-making towards greater crop production and water efficiency;
3 - Strengthening local institutions leads to more efficient resource use, market development, and greater gender and socio-economic equity; and
4 - Stronger local institutions create demand for more effective agricultural and water institutions at larger governance scales (Pittock & Stirzaker, 2014).

Institutions are a critical focus of the project and are defined as "the formal rules (e.g. government regulations) and informal or customary rules (e.g. types or work performed by men versus women) within a society" (Pittock et al., 2016, p. 10). The project is interested in improving institutional arrangements at several scales such as irrigator associations and government agencies to influence national and regional African policies: for example, the Comprehensive African Agricultural Development Plan (CAADP).

Whilst the Phase 1 hypotheses have yet to be fully evaluated (Pittock, forthcoming), the project was extended for four years on the strength of the positive outcomes emerging from the first phase (de Lange & Ogutu, 2016). Phase 2 investigates how the soil monitoring and AIPs can be out- and up-scaled and is briefly outlined at the end of the chapter (section 7.2).

Figure 3. Location of schemes involved in Phase 1 of the project. (© Clive Hillker, ANU)

1.1.1 Countries and collaborating partners

Key partnerships were established to work with small-scale irrigation schemes in Mozambique, Tanzania and Zimbabwe (Figure 3). Participating countries were selected based on a scoping study of nine African countries and a combination of factors: supportive national institutions; strong and relevant research capacity with good links to Australian institutions; contrasting stages of irrigation development; capacity to engage key regional African institutions; and the potential to increase food production (Pittock et al., 2013). This process established partnerships to support project development, implementation and research, and communicate outcomes to policy makers (Table 2).

The collaborating partners constitute a highly motivated team whose collective incentive is to make a difference in the lives of the small-scale farmers.

Table 2. Collaborating partners in the project

Country	Collaborating partner	Expertise/support to the project
Australia	Commissioned organization: ANU	Water governance and natural resource policy
	Key research and project partners: Commonwealth Scientific and Industrial Research Organisation, Land and Water (CSIRO)	Biophysical agricultural research, water productivity (including soil and water monitoring) and adaptive learning
	University of South Australia, Adelaide	Water policy, irrigated agriculture, socio-economic analysis, economics
Tanzania	Key research and project partners: Ardhi University, Dar es Salaam	Agricultural water management, natural resource planning, and spatial mapping
	Additional local, district or national partners: Sokoine University of Agriculture[1]	Agriculture and water catchment research
	Iringa District Council	Agricultural extension, implementation
	National Irrigation Commission, Mbeya Zonal Office	Irrigation scheme development and management, and access to and collaboration with schemes
Mozambique	Key research and project partners: Instituto Nacional de Irrigação (INIR), Direção Provincial da Agricultura, Maputo	Irrigation management (expansion and rehabilitation) & policy
	Additional local, district or national partners: Universidade Eduardo Mondlane	Agricultural research, access to and collaboration with irrigation schemes
Zimbabwe	Key research and project partners: International Crop Research Institute for the Semi-arid Tropics (ICRISAT), Bulawayo	Agricultural intensification, AIPs and value chains
	Additional local, district or national partners: Department of Irrigation, Ministry of Agriculture, Mechanization and Irrigation Development	Irrigation engineer, access to and collaboration with irrigation schemes; agricultural extension and implementation
South Africa	Key research and project partners: Food, Agriculture and Natural Resources Policy Analysis Network (FANRPAN), Pretoria	Food, agricultural and natural resources policy, governance and network analysis
	University of Pretoria, Pretoria[1]	Irrigation agronomy

1. Collaborating partners in Phase 1 only.

1.1.2 Schemes participating in the project

The selection of irrigation schemes participating in Phase 1 of the project was based on their institutional capacity, ability to improve agricultural practices, accessibility, and the level of interest in collaborating with the project. Six schemes are officially part of the project. Unfortunately, the Khanimambo scheme in Mozambique experienced significant flooding very early in the project destroying the pump and other infrastructure, which resulted in many farmers abandoning their irrigated plots. This has limited the outcomes achieved within that scheme and, hence, only five schemes are discussed in this chapter. The Magozi scheme is mostly focused on rice production and soil monitoring tools are not used in this system. However, Magozi is included in this case study as the AIP was active on this scheme and provides valuable examples of changes in yield and profitability without the use of the tools.

The location of these schemes is shown in Figure 3 and their main characteristics at project inception are shown in Table 3.

Table 3. Characteristics of irrigation schemes at project inception

	Tanzania		Mozambique	Zimbabwe	
	Kiwere	**Magozi**	**25 de Setembro**	**Mkoba**	**Silalatshani**
Year constructed[1]	2004-07	2005-07	1975	1968-69	1968-69
Location	Iringa District	Iringa District	Boane District	Gweru District	Insiza District
Farmers[2]	168	512	40	75	845
Irrigated (ha)[2]	195	939	38	10	442
Main crops[4]	Tomatoes, onions, green maize	Rice	Cabbages, tomatoes, green beans	Maize, sugar beans, leaf vegetables	Maize, wheat, sugar beans
Legal structure[1]	By-laws	By-laws	By-laws	By-laws	By-laws
Land access[1]	Inheritance, buying, renting	Inheritance buying, renting	Cooperative holds land use title	Association holds land use title	State-owned, chief allocates
Soils[4]	Sand clay varying fertility	Clay to sandy soils	Mostly fertile clay soils	Mostly infertile sandy soils	Mostly clay soils
Rainfall (mm)[4]	700	600	650-900	650-900	450-650
Main bodies governing water[1]	Basin Water Boards		Regional water authorities	Catchment Councils	
Irrigation water source and conveyance method	River, gravity canal	River, gravity canal	River, motor pump	Dam, gravity canal	Dam, gravity canal
Irrigation method	Surface flooding				

Sources: 1. Rhodes et al., 2013; 2. Zuo et al., forthcoming; 3. Bjornlund et al., forthcoming; 4. Moyo et al., 2017, de Sousa et al., 2017, van Rooyen et al., 2017; 5. Stirzaker et al., 2017; 6. In Tanzania, farmers have the legal right to private ownership but very few do so due to transaction costs.

All six schemes were constructed well before the project commenced (Table 3) and predominantly funded by government or, in some instances, donors. Irrigation associations[2] are an important component of schemes and their management and their tasks typically include ensuring water is available, water scheduling, fee collection (though fees are variable and lack clarity), organizing maintenance, information distribution, and resolving conflicts and breaches of rules and by-laws (Rhodes et al., 2014). Additional scheme information is available in Rhodes et al. (2014) and infrastructure challenges are described briefly in section 2.1.

1.2 Economic, environmental, social, technological, governance and policy context

The collective contribution of Mozambique, Tanzania and Zimbabwe to the Gross Domestic Product (GDP) of sub-Saharan Africa (SSA) is less than 5%, which is less than 2% of global GDP (Table 4). For Tanzania and Mozambique, GDP growth compares favourably to overall SSA growth; however, all three countries are categorized as low income countries (World Bank, 2017b). Poverty is a significant and ongoing problem. While extreme poverty rates have fallen for all regions of the world, SSA has experienced the highest population increase. Here, 41% of the population live in extreme poverty (half the world total), and 12% of them (47 million) reside in the three project countries (World Bank 2017a, 2017b). More than two-thirds of the population in these countries live in rural areas, where poverty rates are typically double the urban rate and agriculture is the main source of income (World Bank, 2017a, 2017b).

2. This is a generic term and schemes use different terminology.

Table 4. GDP, agricultural land and productivity data

	Tanzania	Mozambique	Zimbabwe	SSA	World
GDP (millions US$) and global ranking in 2016[1]	47 340 (81)	11 015 (128)	16 620 (112)	1 512 596	75 845 109
GDP (% growth, 2014-15)[2]	7.0	6.6	0.5	3.0	2.7
Population (millions, 2015) and % in extreme poverty)[1]	53.5 47	28 69	15.6 21	1001.0 41	7346.7 11
Rural population (%, 2015)[2]	68	68	68	62	46
% of total country area cultivated in 1962 (top) and 2014[3] (middle) and increase (bottom)	6.3 16.5 10.2	3.3 7.4 4.1	5.2 10.5 5.3	40 42.1 2.1[4]	36 37.5 1.5[4]
Agriculture, value added (% GDP, 2016)[5]	32	25	11	17[6] 30[7]	4
Total % of irrigation- equipped area/cultivated area[3]	3.6	2.7	5.2	4[8]	18[8]
Value of irrigated output as share of total agricultural output (%)[9]	10.0	4.8	25.9	25	---

Sources: 1. World Bank, 2017a; 2. World Bank, 2017b; 3. FAOSTAT database; 4. reference years for % cultivated area is 1961 and 2014; 5. World Bank, 2017c; 6. excludes high-income countries; 7. low income countries only; 8. You et al. 2010; 9. Svendsen et al. 2009; 10. reference year varies: Mozambique, 2008, Tanzania and Zimbabwe, 2011, and SSA, 2013

While agriculture contributes only 11% to 32% of the project countries total GDP, at least 65% of rural people are directly dependent on agriculture for their livelihood. Over the last 50 years, the percentage increase in cultivated land is more than twice the increase in SSA. Africa has low levels of agricultural productivity, which can be partly attributed to the underuse of irrigation in SSA (You et al., 2010). The area equipped for irrigation in the three project countries is on a par with SSA, whilst the value of irrigated output as share of total agricultural output varies from being the same to five times less than the SSA average (Table 4).

Development of irrigation for poverty alleviation, food security and economic productivity is a priority in Africa through plans such as the Comprehensive African Agricultural Development Plan (CAADP), which commits countries to an investment of 10% of national budgets to enhance agricultural production and a six-fold increase in the rate of irrigation expansion (Pittock & Stirzaker, 2014). These priorities underpin country-specific plans e.g. Mozambique's National Agriculture Investment Plan 2014–2018; Tanzania's Agricultural Sector Development Programme; and Zimbabwe's Agricultural Policy Framework 2012-2032 (Pittock et al., 2016). Each country has its own governance and policy arrangements for water resources management: for example, the main responsibility for development, operation and maintenance of irrigation in Tanzania is the National Irrigation Commission under the National Irrigation Act 2013. There are additional national policies and legislation for water resources management more broadly (Mdemu et al., 2017). Irrigation development varies across countries:

- In Tanzania, irrigation development has included large-scale schemes for commercial and food security purposes—with a period of state-management with paid employees—most of which performed poorly and collapsed and eventually privatised or transferred to small-scale farmers (Mdemu et al., 2017).
- Both large and small schemes are part of Mozambique's irrigation history and some large schemes are experiencing abandonment. Development halted during the civil war but resumed in the early 2000s.

- Irrigation development in Zimbabwe also encompasses large and small irrigation schemes, spanning the pre- and post-independence periods but is described as ad hoc, inconsistent and lacking a specific irrigation policy (Moyo et al., 2018).

Sub-Saharan Africa has only achieved approximately 20% of its irrigation potential (Stirzaker & Pittock, 2014) but the irrigated area is predicted to increase by 30% between 1998 and 2030 (Turral, Svendsen and Faures, 2010). Water extraction varies; in Tanzania and Mozambique the proportion of total renewable water resources withdrawn is 5.7% and 0.3%, with 78% used by agriculture (World Bank 2017b; IPFRI, 2011), and in Zimbabwe it is 21% leaving the country vulnerable to water scarcity (Stirzaker & Pittock, 2014).

Irrigation development in Africa has a history of unprofitability and underutilization. The reasons for this are outlined in section 2.1 but a critical aspect is the mismatch between objectives and expectations: that is, many systems were designed for the production of staple crops for food security, which results in higher unit costs, lower performance and unprofitable systems (Inocencio et al., 2007). The underperformance of schemes resulted in a decline in funding through the 1970s and 80s, but investment has surged again since 2000.

Large new schemes are often favoured but, while they might be cheaper to construct, smaller systems offer significant performance advantages and may have less environmental impact (Inocencio et al., 2007; Pittock & Grafton, 2014). Expansion focussed solely on large-scale schemes is misplaced and more investment is required at the community-scale (Pittock and Grafton, 2014). Hence, this project focuses on small-scale communal irrigation schemes.

These schemes are highly variable with respect to size, irrigated area, number of farmers and natural resources (as demonstrated in Table 3) but are typically characterised by:

- Households providing most of the labour and low technology use.
- Communal management through a community-elected irrigation association with shared roles and responsibilities with district/local government;
- A shared water source and supply infrastructure that is partly owned/controlled by the government and the irrigation association;
- Mixed farming activities, often focused on subsistence farming; and
- Small irrigated plots of < 1 ha with a mix of land tenure arrangements.

The World Bank (2017b) cites unemployment rates of 3%, 5% and 24% in Tanzania, Zimbabwe and Mozambique, respectively. The rate on most of the project schemes is lower or comparable with national averages except for Kiwere where the rate is much higher (15% compared the national average of 3%) (Table 5). However, low unemployment rates are misleading. First, most work is irregular or informal: for example, 84% of the SSA's labour force has irregular wages (Filmer et al, 2014), and in Zimbabwe 94% are engaged in the informal economy and the majority are classified as "working poor" (Chimhowu, 2017). Second, unemployment is higher in rural areas and there is a high dependency on agriculture with 65% of the SSA population working on family farms (Filmer et al., 2014). Households on small-scale irrigation schemes are vulnerable in relation to income due to small plot sizes and the subsistence-orientation.

There are significant poverty issues to address on the schemes; for example, income inequality in the schemes is 20-60% higher than national figures (Manero, 2017). Income options are diverse and individuals look for whatever work they can find to support themselves and their families. The proportion working on-farm varies (56% to 100%) with 25% to 52% having some off-farm work (Table 5). There is a stark contrast between households in relation to income diversification with diversified-income households having 2-4 times more income than agriculture-only households. In four of the schemes, the mean for agriculture-only income households is below the US$1.90/day that defines extreme poverty (Table 5; World Bank, 2017a). Those with lower incomes typically have: housing that is more basic, fewer assets and equipment, higher debts, smaller areas for farming, and less ability to invest in education (Rhodes et al., 2014).

Additional intra-scheme inequities have been confirmed for women, youth and tail-end users. With respect to women and decision-making, their participation is greater when they own more resources though this does not always mean that they have the final say with respect to the use of income. All-male decision-making households are associated with higher farm income while all-female decision-making households have the lowest income (Bjornlund et al., forthcoming). Research on youth work opportunities also finds issues of inequity: for example, the youngest age group (15-24) has significantly higher levels of unemployment than other youth groups and older people; and access to land is more difficult for youth from families without land and also for young women; and on some schemes there are issues relating to water access and participation in committees (Zuo et al., forthcoming). Tail-end users (those with plots at the tail-end of the water supply) not receiving adequate, timely and reliable water supply can cause conflict, which may arise due to the failure of irrigation associations to implement and manage water schedules (Mdemu et al., 2017).

Ultimately, fewer work options and lower income has broader implications than food security and impacts health, well-being and educational outcomes. Table 5 provides additional socio-economic information for each scheme.

Table 5.: Socio-economic information for each scheme

	Tanzania		**Mozambique**	**Zimbabwe**	
Socioeconomic information	**Kiwere**	**Magozi**	**25 de Setembro**	**Mkoba**	**Silalatshani**
Mean of household members[1]	6	5.5	5.3	6.8	6.4
Mean age of household head[1]	46	42	62	57	59
Mean irrigated area per household (ha)[1]	0.97	1.17	0.11	0.11	0.67
Mean annual household income (US$)[2]:					
Households with income exclusively from agriculture	607	906	1292	179	411
Households with diversified-income	1223	1754	5968	1098	940
Education (% of scheme individuals)[1]:					
Not started	2.5	11.4	9.8	7.3	6.9
Still at school	19.2	20.7	2.6	0.3	0.5
Finished schooling:					
Primary or below	60.8	58.9	54.3	52.1	52.5
Secondary of above	17.5	9.0	33.3	38.3	28.8
Unknown	0.0	0.0	0.0	2.0	11.3
Employment (% of individuals)[1, 3]:					
Working on-farm (%)	69	100	56	87	83
Working off-farm (%)[4]	31	25	47	52	46
Working away (%)[5]	7	1	14	9	3
Unemployed (%)	15	0	17	3	8

1. Zuo et al., forthcoming; 2. income exclusively from agriculture is farm income and agricultural labour; diversified income includes non-agricultural labour; regular, seasonal or self-employment; business, remittances etc; mean incomes from Manero (2017) using currency calculation for Tanzania and Mozambique based on rates on 30/6/2014 (http://www.xe.com/currencytables); 3. individuals can work both on- and off-farm; or work neither on- nor off-farm; 4. off-farm is categorized as any farm or non-farm work not on the household land; 5. work away is, living and working away from the scheme for the season).

2. The water challenge: the failure of small-scale irrigation systems

Firstly, this section outlines the environmental water challenges (e.g. salinity and over-extraction) and then outlines the contributing policy challenges (e.g. weak institutions), and the resulting challenges for the schemes, which are a mix of infrastructure and technology, institutional, and social (e.g. lack of agronomic and irrigation knowledge). The final challenge discussed relates to the complex nature of small-scale irrigation schemes and the interconnectedness of challenges and solutions.

2.1 Environmental water challenges

While irrigation faces considerable challenges to operate sustainably, expansion will take place, regardless of past failures (Stirzaker & Pittock, 2014). Globally, waterlogging and salinity affect 20-30% of irrigated land. This proportion is mirrored in Chokwe, one of Mozambique's largest schemes, where 32% of the irrigated land has been abandoned (Stirzaker & Pittock, 2014). Whilst salinity is not an issue for most of the schemes involved with this project, over-watering is common in irrigation and salinization is an ever present threat.

As population and economic growth continues, increased demand will require re-allocation of water among competing uses: such as domestic water supply, sanitation, industry, hydropower and environmental flows (Turral, Svendsen & Faures, 2010). This is particularly problematic where over-extraction is already an issue: for example, the upper Great Ruaha Basin in Tanzania is targeted for irrigation expansion but over extraction is already affecting the environment, tourism and hydropower (Pittock, 2014). Both Kiwere and Magozi are part of this basin, so there are immediate issues of competition for water resources.

Climate change will increase the uncertainty of water supply and demand (FAO, 2012). Water productivity has to improve to maintain food production. This will be challenging as farmers: i) believe more water is better than less; ii) often do not pay for water and, therefore, apply it excessively; iii) have a lack of understanding of the consequences of excessive water application; and iv) have no easy way of knowing when a crop has received enough water (Stirzaker et al., 2017). Reducing over-application of water will have positive environmental impacts by lowering transmission losses, which will minimize salinity and waterlogging and increase river flow.

2.2 Policy challenges

In general, policy challenges include: a lack of integration between agricultural, water and environmental policies (Kahinda & Masiyandima, 2014); weak water governance institutions (Shah et al.2002); perverse policy incentives (e.g. low water fees); lack of measurement and enforcement of water diversions (Pittock & Grafton, 2014); and inadequate returns on investment that discourage further funding (Inocencio et al. 2007). Another less appreciated challenge is that irrigation development—new or rehabilitation—has focussed primarily on the infrastructure and hard technology issues associated with water management, which has meant that soft issues have not been addressed. Traditionally, it has been easier to obtain funding for engineering works, while little funding has been available for soft issues such as integrating farmers into the agricultural value chain. Reasons for this include: an engineering paradigm promoted by the "hydraulic bureaucracy" (Molle et al., 2010); lack of transparency and corruption (Transparency International, 2008); expenditure rules that favour the purchase of physical items; and a lack of appreciation of the opportunities to enhance irrigation performance through investment in human capital.

Many small-scale schemes were founded on the unrealistic expectation that irrigators could manage and maintain them and that the costs of doing so would be affordable through improved yields (Shah et al., 2002; van Koppen, 2003). However, farmers frequently 'inherited' poorly constructed infrastructure that was already in decline. The subsistence-orientation of schemes—enforced in some countries by government food-security policies—traps farmers in poverty and undermines sustainability (Pittock & Stirzaker, 2014). As repeatedly reinforced in this chapter, improved crop yields do not translate to improved profitability without some focus on market integration.

2.3 Scheme challenges: infrastructure and much more

Prior to intervention, there were many challenges within the project's schemes that are specific to small-scale irrigation such as: flood damage, canal leakage (unlined canals) and siltation (lack of silt traps); inadequate water provision to plots (small intake, lack of monitoring) and scheduling difficulties; poorly defined infrastructure management and maintenance arrangements (low willingness to participate in collective actions); inadequate or non-payment of water fees; and conflict within schemes (upstream/downstream users, lack of enforcement of irrigation times) and between irrigation and other water users. More detail can be found in de Sousa et al. (2017) for Mozambique; Mdemu et al. (2017) for Tanzania; and Moyo et al. (2017) for Zimbabwe.

The adoption of new agricultural technologies is critical for improving efficiency and profitability (Wheeler et al., 2017) and, as noted, technologies associated with irrigated farming encompass both 'hard' and 'soft' options: such as irrigation infrastructure, new crops, irrigation technology, and knowledge and skills. Small-scale irrigators typically have low use of technology, rely on household labour rather than equipment, and have little or no use of artificial fertilizers and improved seeds (Rhodes et al., 2014). The traditional approach to disseminate knowledge and introduce new tools through a 'technology supply push' model of agricultural development is not appropriate in SSA. Countries that have used this approach successfully have various supportive institutional frameworks in place—such as publicly funded access to research, agri-business development, information and training, and farmers unions—but these are largely absent in SSA (Pittock and Stirzaker, 2014; Wheeler et al., 2017). Alternative farmer-centred learning systems are required that allow for experimental and adaptive learning about agronomic and irrigation practices as well as market and value chain integration (Pittock and Stirzaker, 2014).

Compounding these challenges, land tenure and land access arrangements on schemes are often unclear and access is particularly problematic for women and youth. Uncertain tenure has many implications for farmers and affects income generation, wealth accumulation, credit access, and confidence to invest and support maintenance (Deininger, 2003; Meinzen-Dick, 2014). Other barriers are similar to small-scale farming in general: for example, inequity issues such as unequal plot sizes and poor representation of disadvantaged groups; poor access to finance, inputs and equipment; low yields and profit; poor market understanding and access; lack of knowledge and little or no extension services.

The baseline surveys for this project (see section 4.1) found that the barriers for farmers included: access to knowledge, markets, equipment, transport, inputs, and finance (Bjornlund et al., 2017). This reinforced the importance of focusing attention on the soft barriers. Farmers also raised issues relating to non-functioning infrastructure and equipment during more in-depth discussions. That hard issues were raised later may reflect that the day to day challenges directly influencing each household's well-being were foremost on farmers' minds.

In summary, the underperformance of schemes affects the potential of irrigation to address poverty, food security, and improve local and national economies.

2.4 Small-scale irrigation schemes as complex systems

Small-scale irrigation schemes are complex systems with challenges and solutions that are highly interconnected. The extra level of complexity associated with managing irrigated agriculture, as opposed to dryland farming, is not fully understood and appreciated: there are new actors and interactions; there is additional infrastructure; and a new skill set is required (van Rooyen, forthcoming). In addition, the risks are higher as irrigation is labour intensive and requires expensive farm inputs. Irrigated farming reduces the time available for other income earning activities and can contribute to ongoing poverty by increasing household expenses. Farmers and households are also diverse with many households having more than one income stream—with irrigation accounting for 65% of farm income but only 42% of total household income (Bjornlund et al., forthcoming)—meaning that household decision-making is also more complex.

Schemes are not isolated systems and they have economic ties to the broader community through several sub-systems: such as farm services and other commercial suppliers, markets, and education. The diversity of sub-systems and associated agents/stakeholders is shown for the project's Zimbabwe schemes in Figure 4. Part of the complexity is that stakeholders will have different value systems and interests (Pittock & Stirzaker, 2014). Additionally, there is typically no central control within a complex system, which makes management more difficult (van Rooyen et al., 2014).

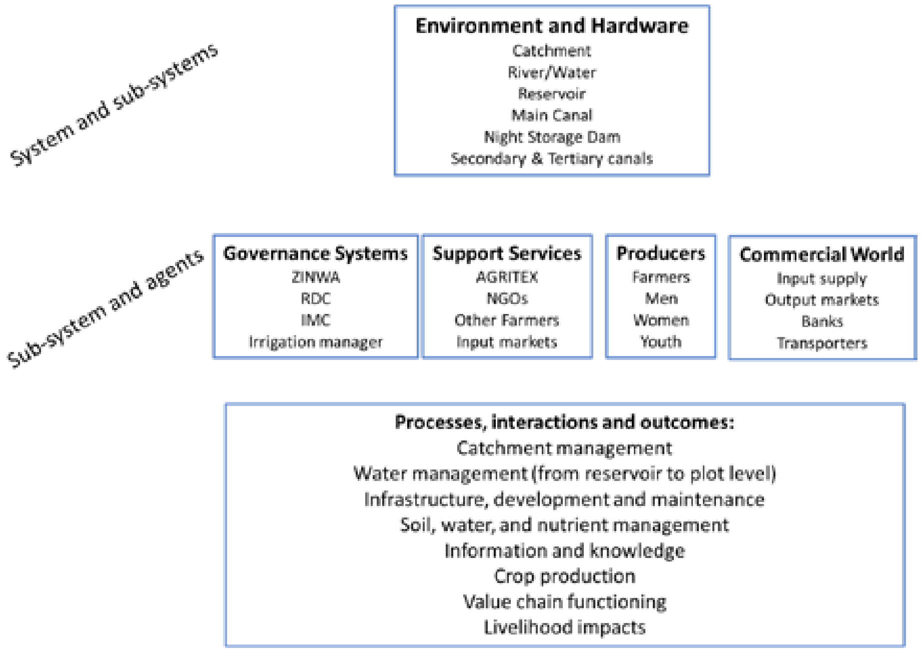

Figure 4. Example of a Zimbabwe irrigation system and its components (van Rooyen & Moyo, 2017).

Reductionist approaches are inappropriate for understanding irrigation schemes, as it is not possible to break down the system into predictable cause and effect relationships (van Rooyen et al., 2017). Rather, these systems require adaptive management where learning and improvement is part of a real-life experiment, featuring a long-term vision, consensus making, and developing shared values (Stirzaker & Pittock, 2014)

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3. The theory behind the two-pronged approach

Support for adaptive management has coalesced as: i) the complexity of socio-ecological systems is now well recognized; ii) there is an acknowledgement of the need for linked technical and institutional solutions; and iii) cheaper monitoring is available (Pittock and Stirzaker, 2014). The two-pronged approach used in this project is particularly suited to adaptive management in complex systems and creates two feedback loops. The soil monitoring tools provide immediate feedback on several critical parameters related to irrigation management. Whereas, the advantage of an AIP is to provide a surrogate coordinating mechanism that helps the schemes establish feedback loops to critical parts of the system: for example, markets and input services.

In the past, irrigation development has focused on the provision and repair of hard technologies, such as infrastructure, with little attention to technical capacity, institutional arrangements and market linkages. Whilst infrastructure challenges are of interest to the project, they are not addressed directly through funding, rather the AIP facilitates bringing relevant partners together to find solutions to the most critical issues.

Irrigation schemes therefore will continue to fail unless successfully managed to:
- i) develop water resources within sustainable limits;
- ii) schedule water and nutrient applications to enable high crop yields;
- iii) integrate farmers into the agricultural value chain; and
- iv) introduce participatory water governance with efficient and equitable water distribution (Pittock & Stirzaker, 2014).

The project's Phase 1 theory of change is shown in Figure 5. The scale of intervention is small-scale irrigation communities (two boxes on left) and their shared resources and infrastructure. The entry point is increasing crop yields through soil monitoring and using AIPs to identify market incentives to translate increased yields into increased profitability. The challenges raised within an AIP are discussed in the context of long-term outcomes, the policy and institutional environment (top down) and the current technology, barriers and hopes of the farmers (bottom up). Information and learning from the soil monitoring intend to build capacity in the local institutions and the farmers (immediate outcomes).

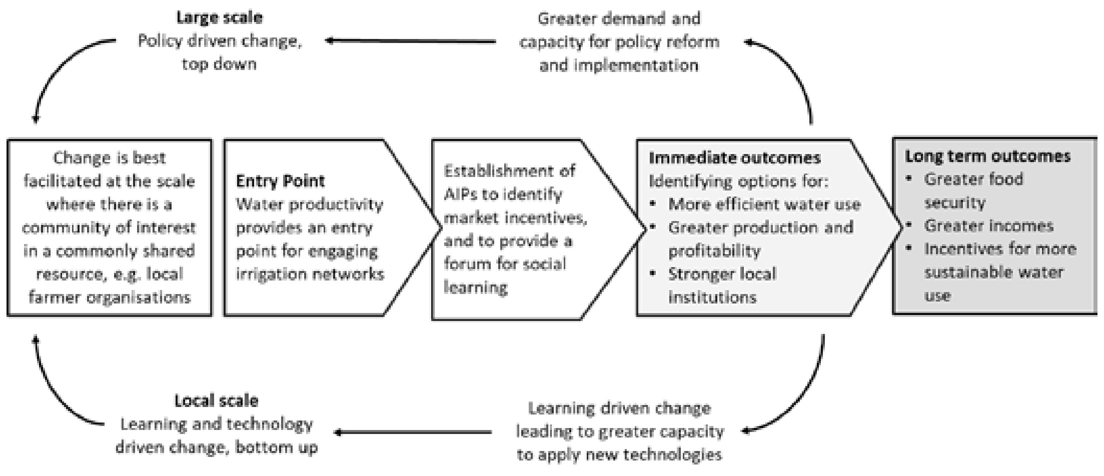

Figure 5. Project theory of change (adapted from Pittock & Stirzaker, 2014)

The approach features two critical feedback loops. An 'upward' loop of learning that fosters advocacy for improved investment of funds and reform of water licensing or pricing policy, which is stimulated as the AIP stakeholders better understand their requirements and obligations. In particular, more profitable and confident farmers put pressure on government agencies and larger businesses in the agricultural value chain to better service their needs. A second 'downward' loop represents how farmers learn about their practices and how they impact individually on profitability, and collectively on sustainability. Consequently, a virtuous cycle for improved profitability of agriculture is envisaged. The AIPs consider many constraints and, again, experience in Africa suggests that continual feeding in of information is important to stimulate and structure learning.

Phase 1 had many critical assumptions: (1) farmers are interested in adopting a business mind-set and reinvesting in their farms; (2) reliable markets can be found; (3) the value of collective effort is recognized; (4) commitment to irrigated land is maintained when rains come; and (5) efficiency improvements do not undermine equity of access to land and water.

4. The two-pronged approach to address the challenges: soil monitoring and AIPs

There is no single solution to overcoming the diversity of challenges faced by small-scale irrigation schemes to improve their profitability. Thus, problem solving and overcoming barriers is the core business of this project through the simultaneous introduction of the soil monitoring tools and the AIPs as entry points to stimulate learning and change. The tools provide a deep understanding of the water-nutrient dynamics. This allows farmers to make more informed decisions about water and nutrient management, which leads to critical changes in behaviour and practices, and results in improved yield. The AIP is a platform that facilitates the identification of challenges, their root causes and opportunities to address the challenges through context-specific measures identified by interested stakeholders. As such the AIP acts to remove the constraints that prevent farmers acting on the monitoring results and facilitates the use of and learning from the tools and translates this into increased yield and profitability. This combination is critical: earlier trialling of the FullStop device in South Africa found that interest ceased when funding ceased despite the tool being rated as easy to use and helping farmers make irrigation decisions (Stirzaker et al., 2017). Importantly, in providing these tools, it is not the intent to provide a set of solutions: farmer's livelihood choices are complex and learning from the tools will help them to apply the knowledge in their own context.

For ease of discussion, the two components of the two-pronged approach are described separately.

4.1 Soil monitoring tools

The soil monitoring tools have been developed by the Commonwealth Scientific and Industrial Research Organisation[3] (CSIRO) to stimulate farmers' learning by linking the information from the monitoring to processes that happen when water is delivered to the soil (conceptualizing the processes). The tools provide the results in the form of coloured lights, with the colours representing triggers for action. This way, the results can be easily understood by semi-literate farmers. In receiving and integrating new knowledge about soil moisture and nutrients, farmers can understand the relationships and impacts and, hence, improve crop yields and water use efficiency.

3. The development the soil monitoring tools has been supported by the South African Water Research Commission and more recently by ACIAR-funded projects.

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Traditionally, irrigation management has been taught using an engineering paradigm that uses climate, crop and soil data to provide a predicted irrigation volume to farmers. This method suffers from several issues: each variable is prone to error; application of precise volumes may not be practical (e.g. in flood irrigation systems); climate is variable; cropping patterns change; and there is a mismatch in the mental models between scientists and farmers that disrupts the transfer of knowledge (Stirzaker et al, 2017). The theoretical underpinning of the tools is that an irrigation management system for small-scale irrigators in developing countries should:

- provide people-centred and experiential learning;
- facilitate adaptive management by supporting observation, monitoring and feedback; and
- be inexpensive, robust and suitable for farmers with low literacy and numeracy: simple to use and provide the least amount of information needed for irrigation decision-making (Stirzaker et al., 2017).

4.1.1 Tool development

The design of the tools drew on a thorough understanding of the science of soil water and solute measurement techniques to determine the parameters that should be measured and how the tools should be designed to be easy to use. It is important that water, nutrients, and salt are measured together, because these factors are all inter-related and provide different insights into what is happening in the soil. Soil tension was selected for soil moisture measurement as this has the same meaning regardless of soil type and it is a measure of how hard plants must work to extract water from the soil. Nitrate was chosen for nutrient measurement as this is the major form in which soluble nitrogen is available to plants and is particularly susceptible to leaching if excess water is applied. As such, it is a lead indicator of fertility management. The third parameter is salt levels, as salinity is a common issue on irrigated land resulting in reduced yields and land degradation.

4.1.2 Description of the soil monitoring tools

Farmers received two principle devices:

- **Chameleon**™ Soil Water Sensors (Figure 6 and 7)
- **FullStop**TM Wetting Front Detector (Figure 8) supported by an electrical conductivity meter and nitrate test strips

The Chameleon is an inexpensive resistance-type sensor that measures soil tension. The technique is similar to the well-known 'Gypsum Block', except that the material inside the sensor is a highly absorbent porous media that amplifies the tension signal in the desired range. This material is encased in gypsum to buffer the sensor against variable salt levels in the soil. Three or four Chameleon sensors are included in an array, to measure the top, middle and bottom of the expected root zone. The sensors are buried permanently in the soil and connected to an 8-pin plug. The wires are colour-coded, so the farmer always knows which sensors are at which depth. Each array has a temperature sensor to allow correction of the resistance reading. This sensor includes a unique identification chip.

The Chameleon reader has an LED for each of the sensors, which can show blue, green or red, depending on the soil suction at the particular depth. The Chameleon colours are:

- **blue**, meaning that the soil layer is wet (tension is less than 20 kPa)
- **green**, meaning that soil is moist (tension is between 20-50 kPa)
- **red**, meaning that the soil layer is dry (tension is greater than 50 kPa)

A group of farmers share one Chameleon reader. The farmer inserts the sensor array plug into the reader, which displays the soil tension at each depth as blue, green or red. The reader is Wi-Fi enabled and paired with a smartphone. When the reader takes the soil water measurement it picks up the unique ID and stores the results against it. If the hotspot of the phone is on, it uploads the data to a database. If not, the data from many arrays can be stored and uploaded when the reader comes into Wi-Fi contact. In this way, the farmer sees the data in the field when recorded, but at the same time, the process records the entire season's colour pattern online. Farmers can access this pattern through their phone, but they also record the data in their field books.

Colour provides a common language about a plant's ability to extract moisture from the soil. Importantly, because the sensors measure soil tension, calibration is not required and the 'language' is independent of soil type: however, soil type will influence how quickly the colour changes from blue to green to red. Information on water availability enables farmers to avoid water stress, waterlogging and fertilizer leaching and learn about the value of rainfall. Farmers receive information to make better irrigation decisions and understand the seasonal progression of crop root depth and moisture needs in the soil profile.

Figure 6. Chameleon™ soil moisture sensors and reader (Photo: VIA Farm website)
Figure 7. Farmer demonstrating the use of the Chameleon reader at Kiwere scheme

The second device is the FullStop, which enables the measurement of soil nitrate and salt levels. The funnel-shaped devices are buried at approximately one third and two-thirds of the expected depth of the crop's root system (Figure 8). As water moves down the soil profile and reaches the wetting front detector, it is funnelled into one or both of the devices depending on three factors: amount of water applied, soil type and initial soil moisture. When sufficient moisture enters the device the indicator above the surface rises. The indicator is magnetically latched in the up position to tell the farmer that a soil water sample has been captured. This water sample is then extracted (using a rubber tube and syringe) and tested for nitrates (using colour test strips) and salinity (using a modified electrical conductivity meter that also uses colour through lights). The team is in the process of developing an automated version of the FullStop that works in a similar manner to the Chameleon sensor.

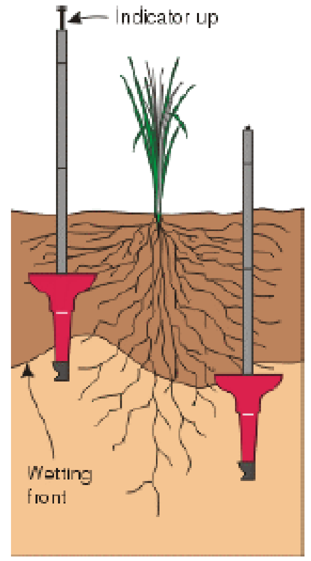

Figure 8. Placement of two FullStop devices (Photo: VIA Farm website)

4.1.3 Deployment of the technology

The FullStop was developed in the early 2000s and commercialized in 2004 (Stirzaker, 2003; Stirzaker et al., 2010); it was introduced into Tanzania, Mozambique and Zimbabwe by this project. The Chameleon was first installed on the Kiwere irrigation scheme as part of this project in mid-2014. By 2015, both tools had been provided to five irrigation schemes (not at Magozi as flooded rice production does not require these tools). Tools were deployed on 100 plots across the five schemes (20 on each) with each scheme also receiving two readers.
Field officers were trained in how to install the tools and work with the farmers to take measurements. Each farmer provided with the tools had two FullStop devices and an array of three of four sensors buried at different depths, depending on the crop (Table 6). The number of sensors and depth of deployment varies with the crop. Initially, three or four sensors were used but the final Chameleon model uses three sensors.

Table 6. Irrigation method, crops monitoring and placement depths of FullStop and Chameleon sensors on schemes (Stirzaker, et al, 2017, p. 792)

Scheme	Irrigation method	Crops monitored	Wetting front depths (cm)	Chameleon depths (cm)
Kiwere	Gravity flood	Tomatoes	20, 50	20, 30, 40, 50
Silalatshani	Gravity flood	Maize	20, 40	15, 30, 45, 60
Mkoba	Gravity flood	Maize	20, 40	15, 30, 45, 60
25 de Setembro (Boane)	Pump flood	Maize, cabbage	20, 40	15, 30, 45, 60

The field staff explained to the farmers what the colours meant, when and how to extract water from the FullStop, and how to analyse the water sample for nitrate and salt. It was then the farmer's decision how to act on the monitoring information. The reason for this approach was to remain faithful to the project philosophy—that although there may be an optimum colour pattern from a scientific standpoint, the optimum for a particular farmer may be quite different. Each farmer's management options are context-dependent, they have different appetites for risk and they face a unique set of constraints within which to optimize their business. The colour patterns simply tell the farmers the outcome of their current management and it is up to them to learn their way to a better outcome as their experience and expertise evolves. The output from the tools structures this experiential learning process.

The farmers using the tools maintain a detailed record in their field books of the readings from the tools as well as farm inputs, yield and the prices received for their crops. The installation on the schemes was designed to ensure representation of plots with a different location on the water delivery system: upstream, middle and downstream plots.

Initially, field staff took the readings once or twice a week, and nitrate and salt status were recorded when the FullStop indicator had risen. The farmers recorded the readings directly, if they were present when readings were taken, or the results were communicated to them via mobile phone. Farmers recorded the readings in their field books for their own ongoing record-keeping and learning. The field staff communicated the data to the research team.

Three early issues necessitated a change to this process: i) the cost of employing people to take the readings, record data and enter it into databases; ii) data validity, transcription and quality issues through consolidation of the data across farmers, schemes and countries; and iii) farmers sometimes moved sensors to different crops or plots mixing sensor locations. For these reasons the team abandoned the manual reading system and developed the digital Wi-Fi based version described in the section above. Some additional training was required but it removes human error and facilitates fixing data problems sooner. It also removes the at times lengthy delay from field recording to sharing data with the team. This change did not affect the farmers' access to the data.

In addition to weekly or bi-weekly discussions between the project staff and farmers about the monitoring data, 20 Kiwere farmers were interviewed at the end of the first cropping season in February 2015, about their experience of using the tools. Several months later, ten farmers participated in a focus group to discuss their experiences in more detail and some of these results are summarised in section 4.2.1. The farmers who were provided with the tools continued to use them throughout Phase 1 and into Phase 2.

4.1.4 Uses and users of the data

The key component of the improved monitoring system is the storing, uploading and reporting of data to a platform hosted by the Virtual Water Academy (VIA platform), which was introduced in 2016 (www.via.farm). Field staff upload the FullStop data manually at the time of collection and additional data—such as farm inputs, yield, crop prices and gross margins—are uploaded at the end of each season based on farmers' field books. The VIA platform has been designed for analysis and reporting at various scales, which is being explored further as part of the up- and out-scaling in Phase 2 (section 7.2). Of most relevance to the farmers, is the seasonal, daily or weekly patterns of soil moisture that show the wetting and drying of the soils, rooting depth, and how well irrigation or rainfall refills the soil (Figure 9). Farmers can access this data from their field books, but it is also available graphically on the VIA platform. However, farmers are currently still relying on their field books for learning and sharing with other farmers as reported in section 5.1.

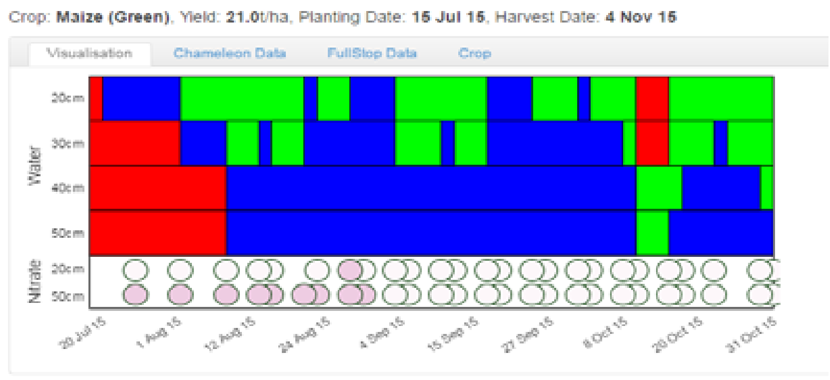

Figure 9. Seasonal pattern of soil moisture and nitrate for a maize crop on Kiwere

Figure 9 provides an example of a seasonal pattern—showing soil moisture at four depths and nitrate at two depths—available through the VIA platform, and the knowledge that can be gained from its interpretation. The soil is dry at the start of the season and the profile fills with water as irrigation water is applied or rainfall is received. The soil is too wet when all depths show blue and nutrient leaching is likely to occur. The soil is too dry when red is shown. In this example, most root activity is in the 0-30 cm zone, but nitrate is mostly available below 20cm and is leached below 50cm about half way through the season.

The design of the data system should allow different users to access data for different purposes. Farmers need their own copy of all data: so they can increase their knowledge and make their own decisions about their farming practices and conduct end-of-season evaluations. The seasonal patterns across farmers and schemes will be of interest to other stakeholders such as extension officers, local government and irrigation departments. With appropriate placement of tools on the schemes, the results can also be used to evaluate systemic management issues such as over irrigation at the top end of the canal/scheme and water scarcity at the bottom end of the canal/scheme (Pittock & Stirzaker, 2014). The platform can also support benchmarking of performance, identification of better practice and prioritization of interventions (Stirzaker et al., 2017).

4.2 Agricultural Innovation Platforms (AIPs)

AIPs are defined as forums "established to foster interaction among a group of relevant stakeholders around a shared interest" (Makini et al., 2013, p. 2) and dialogue is facilitated amongst a diversity of stakeholders to identify synergies between different components of the system (Homann-Kee Tui et al., 2013). These platforms have been widely used in Africa in a diversity of farming contexts—for example, seed, maize, honey and livestock production (Makini et al., 2013)—and the Forum for Agricultural Research in Africa has advocated their use as the preferred approach to research for development (Schut et al., 2017).

This project uses AIPs for the first time with irrigation schemes as they are particularly well-suited to simultaneously address multiple barriers, which in the scheme context are the technological, capacity and institutional challenges that are constraining adoption and profitability. The forums provide a space for learning and experimentation and generating adaptive capacity (Boogard et al., 2013) through:

- Empowering stakeholders and creating a platform where they can be active decision-makers for their own future.
- Fostering paradigm shifts amongst service providers, farmers and other stakeholders to transition from subsistence agriculture to farming practices that are more market-oriented and profitable.

- Building local capacity to innovate and analyse challenges and opportunities, reduce risk and increase income.
- Improving communication and networks between stakeholders along the value chain, and between farmers and water supply/management institutions/organisations.
- Enhancing participant's capacity for self-organization, representation and communication.
- Fostering greater respect and elevated status for farmers from government and private sector employees.

4.2.1 Setting up the AIPs: initial stakeholder selection and facilitator engagement

In this project, information was collected on each scheme to better understand the specific agricultural systems, demographics, context and challenges faced by each scheme. From this information, an initial identification was made of stakeholders that should be involved in the AIP process, either from the value chain or other relevant systems.

This was a critical exercise as the strength and success of AIPs are underpinned by the networks and connections established. Many and strong connections lead to better opportunities and solutions. The structure of an innovation platform allows for three tiers of participation from a diversity of stakeholders. With this in mind, the AIP organizers make an initial broad and careful consideration of the stakeholders and whether they are core (with continuous participation), secondary (with regular participation) or peripheral (with occasional participation) and, hence, the likely extent of their participation.

In this project, the stakeholders identified were all individuals who understood their own challenges well and could identify options to improve the efficiency of the production-to-market system. Country teams specifically considered farmers who were innovative, active and disseminators of knowledge and information (van Rooyen et al., 2014). Additional participants typically included district government, other government representatives (agriculture, water, irrigation, social welfare, youth and rural development), extension officers, private sector businesses (e.g. finance, agriculture and inputs, and produce markets), NGO representatives and scientists. In some instances, relationships needed to be built with some stakeholders to engage them in the AIP process and to ensure they attended.

Another critical aspect of the pre-implementation phase was the engagement of suitable facilitators who were then trained and mentored throughout the AIP process. The role of the facilitator is crucial, and requires a fundamental understanding of local systems, norms and cultures. Their role is to guide the diverse stakeholders through the process, uphold transparency and be aware of gender and power relations within and outside the AIP (van Rooyen et al., 2013). The facilitator must work innovatively to support inclusivity, ensure the inclusion of each stakeholder's voice, facilitate discussion of all contributions, and entertain all suggestions. A keen ear for detail and quick analytical skills are required to assess statements and provide space for the participants to discuss and reach agreements. Facilitating the group to respect and appreciate all contributions was paramount to success. Throughout the AIP, especially in the beginning, it is critical to accentuate that there is value in failure and that these experiences are important elements of success. The major role of the facilitator is to manage the process in a way that provides space for evaluation and learning, and engenders a real sense of ownership by the stakeholders: ultimately, the overall goal is to establish local capacity to innovate and self-organize.

4.2.2 The four-stage AIP process

The AIP process consists of four core stages. Each stage is not necessarily one specific meeting and several meetings may take place within each stage.

Stage 1: AIP inception and stakeholder identification

The AIP inception meeting brings the stakeholders together and they are introduced to the AIP process. This step is important to gain commitment from the diverse range of stakeholders and enables additional stakeholders to be identified. It is beneficial to have a high-profile agricultural/irrigation person to champion the AIP and welcome people to the process. In this stage, participants articulate their interest, and clarify their role and responsibilities for developing new and improved ways of doing business.

Stage 2: Identification of system constraints

Reflecting that it is human nature for individuals to want to express their problems, this stage allows many opportunities for the articulation of challenges. While this serves to set the scene for the following stages, the interconnectedness of the problems, their relationships and the feedback mechanisms between them also become apparent. For example, limited access to inputs leads to poor yields, which results in poor returns. Similarly, poor markets lead to low income and reduced incentives to invest in inputs. Participants are divided into groups (farmers, technical support staff, private sector and government) to: list and prioritize challenges and opportunities; determine the root cause of each challenge; and identify solutions and critical partners. Table 7 demonstrates that there can be multiple causes and solutions requiring the involvement of many partners.

Table 7. The challenge of low prices for rice in the Magozi scheme (van Rooyen et al., 2017)

Challenge	Root causes	Solution	Partners who can assist
Low price of rice	Lack of a joint market for farmers to sell rice	Farmers have to organize themselves and sell their rice collectively	Farmers
	Flooding the market with small quantities of different varieties	Store rice in a warehouse while waiting for better prices	Iringa District Council
	High transportation costs	Grow varieties that are in high demand	Financial institutions e.g. as non-governmental organizations, Member of Parliament
	Selling paddy instead of rice	Acquire and install rice hulling machines	Ministry of Agriculture, Food Security and Cooperatives
	Imported rice from abroad sold at low prices compared to domestic rice prices	Adopt expert advice on growing, processing and marketing	Savings and Credit Cooperative Society
		Advocate that the government give priority to locally produced rice before permitting imports	Private investors (rice hullers).

Adequate time to discuss challenges is important, as participants may not be able to move to the next stage if they have not done so. During this stage, the facilitator prompts the groups to think comprehensively to ensure that: i) known significant challenges are discussed; and ii) the stakeholders move beyond a generic articulation of a challenge and its cause. Participants were asked to repeatedly consider the 'why' question to analyse and identify the root causes and viable potential solutions. Finally, the groups reunite to discuss, clarify and confirm their findings and identify who will implement the solutions.

Stage 3: Visioning

Central to the success of the AIP process is developing a common vision of where the participants see the system in five years. Participants work in their groups to develop pictures of the current and future state of the irrigation scheme and their community. The facilitator has an important role in stimulating the forward thinking, as this can be difficult for people that have not been able to 'dream' about a different future. The desired future picture (Figure 10) expresses what stakeholders perceive to be achievable within a five-year period, but is not limited by whether a clear pathway towards the vision is available. The pictures show the scheme layout and important local infrastructure: for example, houses and other buildings, plot and crop arrangements, irrigation infrastructure, shops and local markets. The visioning process places farmers aspirations in context and the support services and private sector can adjust their strategies to accommodate them.

In stage two, it is not uncommon that hard technological interventions are identified as a quick-fix to an issue and many projects stop the diagnostic process there. However, the visioning exercise should help bring the 'people' issues to the surface and this stage often illustrates the systemic challenges. For example, while improved agronomic practices may increase yields they do not increase income if markets are not functioning, storage is not available, or if there is no transportation to take produce to markets.

Finally, the facilitator asks participants to develop a narrative of how they envisage their scheme can move from the present to the future situation. This is helpful as it allows the AIP's stakeholders to think in terms of process and not only the technological interventions. This facilitates the development of a contextual environment so that the scheme can best utilize technological and policy interventions.

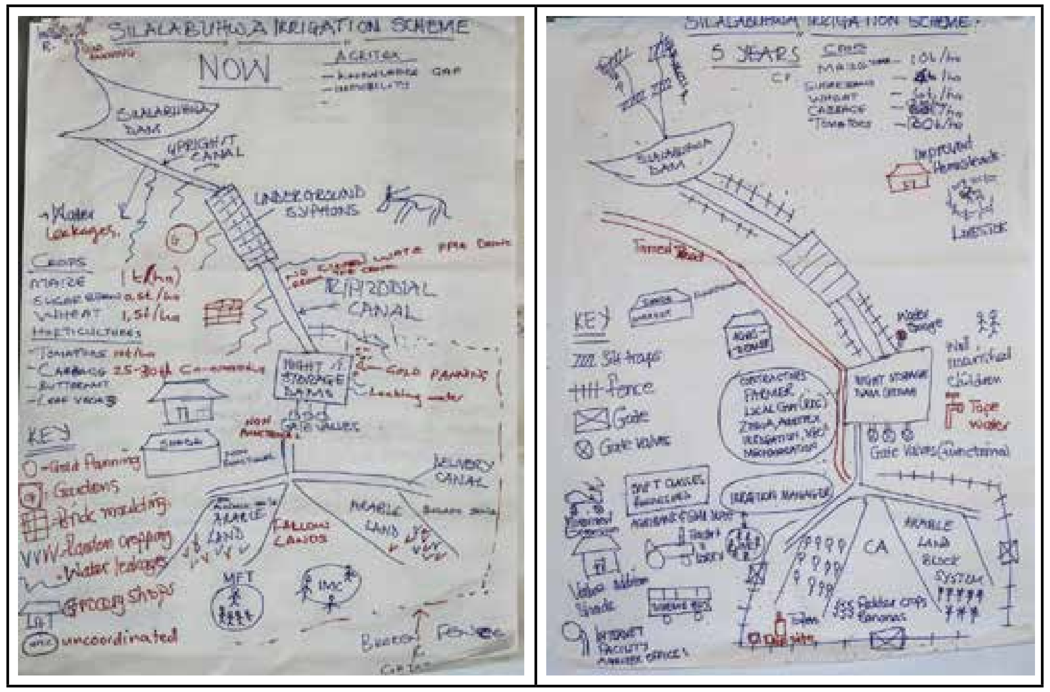

Figure 10. Examples of the current situation (*left*) and desired situation (*right*) produced from the visioning exercise in Silalatshani, Zimbabwe (van Rooyen et al., 2017)

Stage 4: Innovation process
Stages 1 to 3 identify critical issues that need immediate attention and potential strategies (with accompanying actions and resourcing requirements) that help the scheme transition to the future state. One element of innovation is that stakeholders are brought together who, whilst they might have engaged with one another previously, have never discussed common problems or identified improved business strategies. The resulting solutions and innovations draw from the diversity of knowledge and perspectives of the participants. They are tested by the stakeholders themselves, and adapted and placed into the local context to improve system efficiency to benefit all stakeholders.

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The diversity of stakeholders allows for the emergence of different solutions, opportunities and activities that support the transition process. Some activities may be within the control of the AIP stakeholders to implement, while others are larger system challenges associated with policy, infrastructure, markets and knowledge needs. The stakeholders discuss the challenges to determine what can be addressed by the AIP and associated organizations and the appropriate sequence of activities. In some cases, issues may need resolving before priority activities can be implemented. Care is taken to structure activities in such a way that incentives for behavioural changes are clear and direct. Importantly, this stage results in shared ownership of a holistic set of solutions achievable in a realistic period. The project management team may deal with higher-level interventions—those beyond the control of the AIP stakeholders—or they may be set aside if participation and commitment is required beyond the reach of the project.

Now the innovations are implemented, which is an iterative process of testing, evaluating, learning and adjusting. Depending on the activity, sub-groups of stakeholders will focus on individual tasks, resolve challenges and test innovations. Stakeholders may not need or be able to participate in all meetings either because they are unavailable or their expertise is not required. Most of the actual innovation process takes place outside the AIP meetings. Groups report back on their activities and the AIP meetings enable progress to be tracked to sustain momentum, maintain transparency to foster trust in the process, and allow stakeholders to learn and adapt from the experience. Examples of AIP outcomes are described later in section 5.2.

The AIP meetings continue as coordinating and monitoring forums for as long as is required. Initially, the AIP serves as a catalyst, bringing people and organizations together into an informal network (Figure 11). Over time, the relationships and network between stakeholders strengthens and becomes formalized. There are no fixed rules about how long an AIP should last. Once the networks are formed, the role of the AIP should become redundant or evolve to address the next set of challenges, which may include working with new stakeholders and some stakeholders discontinuing. Ideally, the network becomes independent of the AIP and a self-sustaining institution is formed.

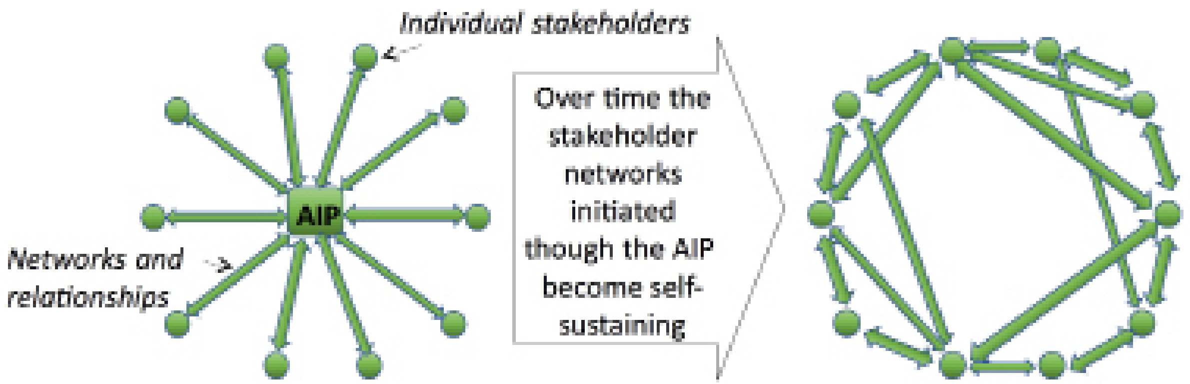


Figure 11. Developing functional networks (van Rooyen & Moyo, 2017)

The rules and process of an AIP can vary from one system to the next. For example, the facilitator's affiliations varied across the three countries and enabled the project to deploy a different facilitation model for each of the three project countries:

- independent facilitator, Tanzania
- government-led facilitation, Mozambique
- researcher-led facilitation, Zimbabwe (Pittock & Stirzaker, 2014)

In Tanzania, a researcher-led model replaced the independent facilitator in the second year of the project. The replacement was necessary after realizing that the independent facilitator perceived the AIP as a one-off event rather than an ongoing process that required a broader understanding of the project, farmers and other participating stakeholders. The facilitator is critical in the AIP process: consistency and longevity are, therefore, essential.

4.3 Key enabling components

The ACIAR, ANU and CGIAR WLE financial contributions (Table 1) have been a central enabling component with both the Australian and national research partners and the collaborating local organizations providing significant in-kind support in the form of salaries for researchers and field officers (Table 2). The management structure of the project comprises project leadership by ANU and a coordinating team of seven researchers from ANU, Australian and African collaborating partners. The coordinating team collectively bring together multi-disciplinary expertise and a robust collegiate spirit, which has been one of the key strengths of the project. The mid-term review of the project highlighted that the integration of technical and social disciplines into a cohesive research team has made a major contribution to the successful and synergistic implementation of the soil monitoring tools and the integrating role of the AIPs (de Lange & Ogutu, 2016). Capacity building within the country teams has been an important component of the project with research and facilitation skills improving through training in: multiple aspects of data collection and analysis; report and academic writing; gross-margin analysis, focus group and AIP workshop facilitation; and conference presentations.

Significant effort has been invested in establishing and maintaining partnerships, which has been essential for all stages of the project: inception, implementation, reporting and evaluation. During the application process the country representatives and their networks were vital in identifying organizations, districts and schemes that could be involved. Hence, the project links with many regional and national partners who facilitate local collaboration, support implementation, provide solutions to challenges and undertake research. The collaborating stakeholders welcomed the project from the outset, provided all the necessary support and access, and have embraced the learnings.

A three-day annual workshop is hosted on a rotational basis by the countries participating in the project, in which the entire research team and the country partners from the host country participate. This allows for extensive cross-country sharing of activities and discussion of lessons learned and future directions.

This participatory approach has been a significant enabling component and a deliberate position has been taken to have an approach that contrasts with previous top-down irrigation refurbishment projects that have focussed solely on hard solutions such as equipment and infrastructure. From the outset, it was clear that the focus would be on soft skills to empower farmers and stakeholders; to help them learn about irrigation and nutrient management and overcome their most important problems. There was some initial scepticism from farmers and other stakeholders, but this changed very quickly as early successes emerged: for example, the immediate benefit of the tools helped build trust with the researchers and the longer-term processes of the AIPs. Farmers, irrigation associations, extension officers and other stakeholders soon embraced the project's approach and their enthusiasm to be part of Phase 2 illustrates this.

5. Achievements and results

Considerable quantitative and qualitative data has been collected throughout Phase 1, including:

- Household surveys of the six schemes: a baseline survey of 402 households (de Sousa, et al., 2015; Moyo et al., 2015; Mziray, et al., 2015); and a Phase 1 end-of-project (Phase 1 EOP) survey of 266 households in 2017 (Moyo, et al., 2018; Cheveia et. al, 2018, Mdemu et. al, 2018). As part of the 2017 survey households were asked to consider how various things (e.g. income and yields) had changed because of the tools and AIP.
- Interviews and field visits as part of a mid-term project review by independent reviewers, which formed the basis for the project receiving extended funding (de Lange & Ogutu, 2016).
- Qualitative data from focus groups discussing: emerging issues and outcomes, and specific focus groups on soil monitoring tools, gender or youth issues.
- Observations by project staff.
- 10-20 farmers in each scheme having the tools have maintained detailed records of tool monitoring, crop choices, input, irrigation rounds, yields and prices paid.

The achievements and outcomes outlined in this section (Tables 8 to 17 and Figures 12 to 15) draw predominantly from the 2017 Phase 1 EOP surveys unless otherwise stated. It should also be noted that at the time of writing this chapter the Phase 1 EOP data was not yet fully validated, integrated across schemes and countries and analysed. Similarly, farmers' field books were not fully analysed. Analysis is ongoing, and many academic publications are at different stages of production or review.

First, outcomes related to the soil monitoring tools and the AIPs are outlined in sections 5.1 and 5.2. There are many 'flow-on' outcomes from the tools and AIP approach and these are outlined in subsequent sections, which for ease of discussion are presented as on-farm, household, gender and decision-making, and scheme outcomes (sections 5.3 to 5.6). As the outcomes are highly connected, it is hoped that readers will accept the need for some cross-referencing between the sub-sections. It is acknowledged that macro-economic factors and other local developments might also influence results. However, based on our observation in the regions and countries this has not been the case in any important way, and no attempt has been made to control for these aspects in this chapter.

Where possible, it is highlighted if outcomes are a result of the soil monitoring tools or the AIP. However, the synergistic nature of the two approaches means that, it is neither realistic nor desirable to attribute outcomes to one approach or the other and additional evaluation will be undertaken as part of Phase 2 (see section 7.3). In general, the soil monitoring tools increased crop yield and the AIPs turned this into increased profitability by facilitating better market access and introducing better varieties and new more valuable crops (Figure 2). Also, the AIP facilitated the adoption and learning from the tools which resulted in changes to farmers practices. Finally, the AIP facilitated access to better quality seed and other farm inputs as well as agronomic advice. All contribute to increasing profitability. The relationships are more complex, but it is unlikely that farmers would have been able to fully capitalise on the learning generated by the monitoring tools without the AIPs facilitating solutions to other barriers.

The section on outcomes concludes by making observations on the longer-term impacts of the project and the unexpected outcomes that have occurred (sections 5.7 and 5.8). Critically, this case study illustrates the importance of considering the context within which any new SWM technology is introduced, and the institutions and processes that are needed to ensure that the technology is adopted and properly used. Without it, SMW technology might remain on the shelf with little real impact.

5.1 Engagement with and learning from soil monitoring tools

Observations by project staff found that farmers were starting to learn from the tools and were reducing their irrigation within a few months of the tools being deployed. Additionally, farmers requested that the Chameleon reader be kept on the scheme as they wanted to take readings more frequently than the project had initially allowed (Stirzaker et al., 2017). Together with farmers asking for their own reader and other farmers asking for more sensors, this shows that the soil monitoring is valued.

Of the households surveyed, between 24% and 68% had the Chameleon and FullStop devices installed on their plots (Table 8). Despite the tools not being deployed on all household plots, the level of awareness of the tools is very high, with between 89% and 100% of households surveyed aware that some farmers have the tools. Further, of the households that know about the tools, more than two-thirds know what the tools measure and what this information is used for, and a similar proportion are aware of the changes being made because of the tools. More households report making a change from their use of the Chameleon sensors compared to the FullStop with the changes made varying across the schemes. Where households report that they have made a change based on the tools, the majority report an increase in yield and 43% to 94% report an increase in income. Whilst these figures vary significantly between the tools and across the schemes, they are very positive results.

Table 8. Engagement, awareness and changes made associated with the monitoring tools

	Tanzania[1]	Mozambique	Zimbabwe	
	Kiwere	25 de Setembro	Mkoba	Silalatshani
Households interviewed (n)	100	28	54	84
Households with soil monitoring tools (%)	42	68	35	24
Households aware of the tools (%)	92	100	96	89
Households that know about the tools (%):				
Are aware of changes farmers have made because of the tools	73	96	87	73
Know what tools measure and what they are used for	72	93	86	70
Households that are aware of the tools have made changes because of their learning from (%)				
The Chameleon	50	93	54	55
The FullStop:	48	68	37	26
Households that changed practice and also increased yields (%)	93	83	86	77
Households that changed practice and also increased income (%)	94	80	43	55

1. Magozi is not reported in this table as soil monitoring tools are not used on this scheme.

Farmers have learnt about the complexities of the movement of water and nutrients through the soil profile and examples of this new knowledge are shown in Figure 12. Farmers have been able to correctly interpret the Chameleon colours: for example, by reducing irrigation when blue is recorded at all depths. In some cases, the observations of one farmer—that nitrate strips show white (indicating no nitrate in the Fullstop water sample) when the Chameleon shows blue (moisture is present in the soil)—have led to the learning that overwatering leaches the fertilizer to below the root zone. In response, this farmer reduced their irrigation frequency and found that the crop's new growth was more lush and green. Knowledge about over-irrigation and the relationship to a quick drop in nitrate levels spread quickly throughout one scheme, which then led to a widespread reduction in irrigation frequency. This resulted in downstream farmers reporting that more water was available within a short period of time of tool deployment (Stirzaker et al., 2017).

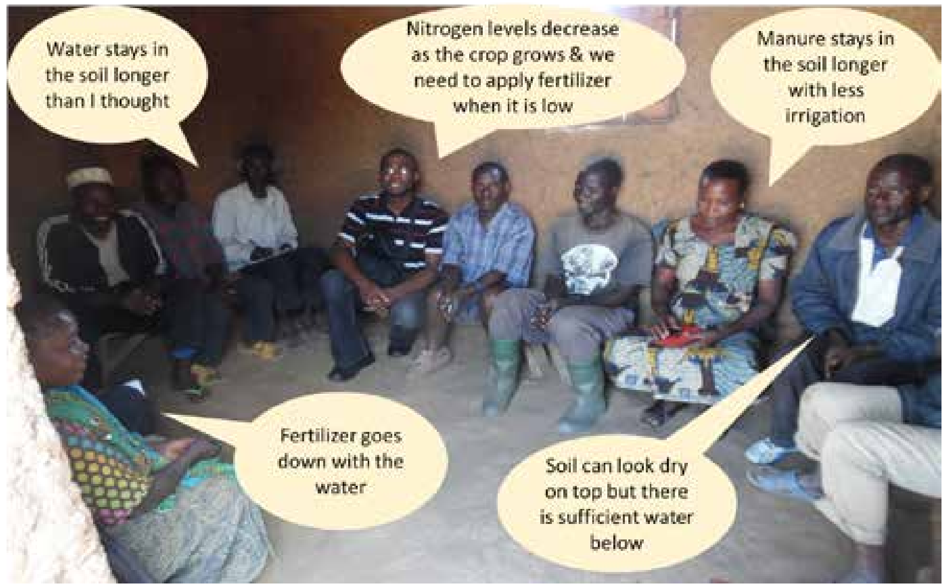


Figure 12. Examples of increased understanding of complex scientific phenomena from Kiwere focus group discussion (Stirzaker, et al., 2017). Photo courtesy of Ikenna Mbakwe

Importantly, it is the combining of data from the two separate monitoring tools that has stimulated understanding and change (Stirzaker et al., 2017). The spread of knowledge and change is also a critical outcome for the project with implications for future tool deployment: for example on the Zimbabwe schemes, 35% and 24% of farmers had the Chameleon (Table 8) with half or more of households aware of the tools changing their frequency of irrigation (Table 9). As noted earlier, the learning from the tools is ongoing. Farmers using the tools in Phase 1 are continuing to use the tools in Phase 2: they are refining irrigation management, and are continuing to learn about the difference between organic and chemical fertilizer management.

5.2 AIPs outcomes

Across the schemes the AIPs have facilitated a shared vision amongst those with an interest in making the schemes more successful and valuable relationships have been built (de Lange & Ogutu, 2016). Alongside facilitating the learning generated from the tools, the AIP processes have systematically addressed many critical barriers that were negatively impacting yield and profitability, which has augmented the learning gained from the soil monitoring tools and enabled this to be translated into other outcomes.

The following briefly lists the range of AIP outcomes (van Rooyen et al., 2017):

- Capacity building – consolidating the learning from the soil monitoring tools, empowerment and relationship building through the actual AIP process, farm record keeping, gross margin calculations, demonstration plots, and visits to other schemes.
- Plot management - changed agronomic practices including crop diversification, plot levelling, manure management (see also section 5.3).
- Input supplies - collective negotiation with input suppliers, and ensuring supply of good quality seed and fertilizer.
- Financial - linking farmers to finance institutions to access credit, and addressing water payment arrears.
- Markets and marketing - identification of high-value crops and buyers for these crops, market research committees to liaise with local agri-dealers, and new storage facilities.

- Scheme maintenance – dam wall, canal and fence maintenance; canal lining, replacing broken equipment; and installing new infrastructure.
- Governance – participatory scheme mapping, revision of irrigation association constitution, scheme-scale business planning, audits of plot ownership, re-allocation of unused plots to youth.

In many cases, the solutions require a significant amount of work, which was evidenced earlier in Table 7 where multiple root causes, solutions and partners are associated with improving rice prices. AIP activities sometimes addressed several challenges simultaneously (reflected in the dot point list above). For this reason, the following examples from each country are provided in some depth so that readers can gain an appreciation of the diversity and context-specific nature of solutions and the extent of work required.

In Tanzania, the project has facilitated a participatory mapping process within the two schemes (Figure 13). During the AIP process for Magozi and Kiwere schemes, it was identified that the size of the irrigation schemes was estimated and farmers did not know the exact sizes of their plots, which is important as this is linked to the water fee owed by each farmer. It was, therefore, agreed that the schemes should be mapped as individual plots due to the importance of this information for planning and decision-making. An important component of this process was to walk all plot boundaries within the scheme with the neighbouring farmers and use a Global Positioning System (GPS) to document the coordinates along the boundaries. The resulting community mapping and database of the schemes records: plot boundaries, ownership status, mobile phone number, sizes of plots, irrigation canal networks, farm access roads and drainage networks. Several benefits have resulted from the mapping: i) the information supports the issuing of customary certificates of land occupancy by government agencies, which farmers can use to access finance; ii) farmer's trust in the fairness of area-based water use fees has increased; and iii) communication within the schemes has improved. Further, these benefits have contributed to increased participation in scheme maintenance and willingness to pay fees (Table 15). The maps are proudly displayed and used as a communication tool when the scheme hosts visitors.

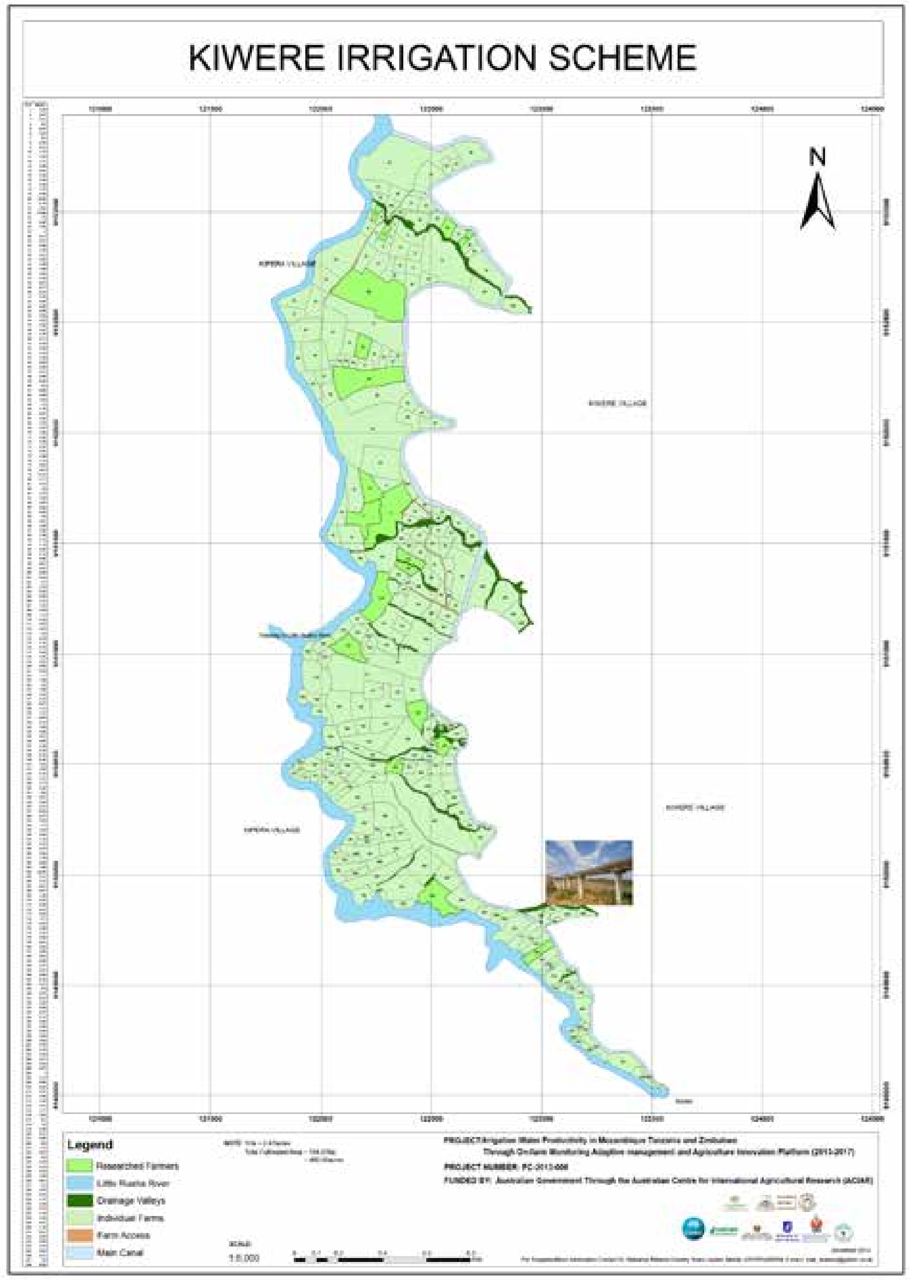


Figure 13. Scheme mapping in Tanzania

In Tanzania, the AIP process has also been instrumental in facilitating that the scheme's irrigation associations developed business plans. The associations are also proactively revising their constitutions to reflect better practice: as a result of agreement gained through the AIP and the learning gained from a visit to the Igomelo scheme in Mbeya, which was facilitated by the AIP. During this visit, farmers and leaders from Kiwere and Magozi learnt that the Igomelo scheme had: higher annual and seasonal water fees; greater enforcement of payment of water fees; higher levels of institutional organization; and a physical irrigation association office. As these outcomes were a direct result of Igomelo's constitution, the Kiwere and Magozi leaders were encouraged to urgently revise their constitutions.

In Zimbabwe, the AIPs have been very active in facilitating farmer integration into the value-chain. At the Silalatshani Scheme, the AIP facilitated the resolution to two far-reaching policy issues. The AIP helped negotiate a solution to a longstanding conflict with the local water authority, Zimbabwe National Water Authority (ZINWA). The conflict related to the size of an outstanding water bill, which had arisen during a period when Zimbabwe was experiencing hyperinflation and multiple exchange rates were in use during the transition from the Zimbabwe to the US dollar. The uncertainty over this water debt was a critical issue standing in the way of potential project success and was one of the major reasons for irrigated plots being idle at the commencement of the project. Additionally, the water fee had been based on a business model that depended on full use of the scheme and profitable farming businesses, neither of which were the case (van Rooyen et al., 2017). The negotiation resulted in a more realistic debt level and a repayment schedule that the farmers were able to agree on and have subsequently started to repay. This has resulted in an increased willingness of farmers to farm and invest in the irrigated plots.

The AIP at Silalatshani also brought stakeholders to a common understanding that land ownership was a major issue. At the second AIP meeting it became evident that a considerable number of absentee landowners were not utilizing their land. The Department of Agricultural, Technical and Extension Services (AGRITEX) indicated that the scheme was supposed to have 849 plot holders, but their registers indicated less than 300 landowners or users. At the meeting it was agreed that this needed to be resolved by the district leadership (District Administrator (DA), Chief of the Rural District Council and AGRITEX) who subsequently suggested that a plot ownership audit be conducted. The project team initially thought that these issues would be difficult to solve; however, there are strong indications that the AIP process has resulted in this policy issue being addressed. The DA and the local Chief have since held two meetings with the irrigators, discussing absentee landowners and trying to map a way forward. The project acknowledges that dealing with land tenure issues is complex in Zimbabwe, but starting the process to address some of the linked tenure issues should yield considerable economic and social impacts.

In Mozambique, the 25 de Setembro scheme has an ageing farmer population and many are therefore no longer able to manage their plots, which poses a threat to the scheme's economic and social sustainability. The farmers identified this problem during the AIP meeting. After some discussion with the district's extension services, farmers decided that, when allocating unused plots the relatives of the owners should be offered the plot first, before inviting people from outside the scheme. Unused plots have since been reallocated and approximately 17 young women and men have become involved in irrigated farming. The cooperative has elected a young farmer as vice-president, which shows that members have recognized the value of giving responsibility to young farmers.

The AIP process at the 25 de Setembro identified that the lack of a business plan made it difficult for farmers to obtain and manage a bank loan. Farmers lacked the necessary skills to develop such a plan and neither banks nor local authorities were providing this training. In order to overcome this problem, as part of the AIP process the French Agricultural Research Centre for International Development (CIRAD) was asked if it could provide business plan training, which was subsequently delivered to both farmers and extension officers. This training also included workshops with farmers to learn how to compute gross-margins for their crops.

CASE STUDIES
TRANSFORMING SMALLHOLDER IRRIGATION INTO PROFITABLE AND SELF-SUSTAINING SYSTEMS IN SOUTHERN AFRICA

5.3 On-farm outcomes

In this section the focus is on household's perception of changes over a four-year period for irrigation practices, yield, crop choices and prices received. Importantly, a key underpinning of this project is that households and schemes need to realise yield and profitability improvements in order for irrigation—a more expensive farming system compared to dryland farming—to be sustainable in the longer-term. Encouragingly, there are signs of improvement. However, the results also demonstrate the different starting points and journeys towards improvement: such that, irrigation on schemes may increase as infrastructure issues are overcome. There is additional discussion in the section on longer-term impacts (5.7) that acknowledges the importance of water savings with respect to environmental challenges at higher scales of interest.

Farmers have used the soil monitoring tools to make changes to the frequency or duration of irrigation events and for surveyed households: i) 50%-88% have changed their irrigation frequency; ii) the interval between irrigation events has increased by 1.4 days on Kiwere and between 4 to 9 days on the other schemes; iii) between 3 and 19 hours has been saved per irrigation event; and iv) the duration of irrigation events has been reduced by 1 to 2.4 hours (Table 9).

Table 9. Irrigation outcomes from using the monitoring tools

	Tanzania[1]	Mozambique	Zimbabwe	
Changes by households	**Kiwere**	**25 de Setembro**	**Mkoba**	**Silalatshani**
Have changed frequency %)	63	88	50	54
Interval between irrigation events has increased (days)	1.4	4	8	9
Time saved per irrigation cycle (mean hours)	19	8	4	3
Have changed number hours irrigating (%)	53	81	43	32
Mean reduction in irrigation (hrs/cycle)	2.4	2	1	2

1. Magozi is not reported in this table as soil monitoring tools are not used on this scheme
Sources: Moyo, et al, 2018; Mdemu et al., 2018; Cheveia, et al., 2018.

The reduction in irrigation is important for two reasons. Firstly, it reduces nutrient leaching, which increases the available nutrient pool and contributes to improvements in yield without additional cost to the household. Whilst salinity is only an issue in isolated pockets on some schemes, reduced irrigation is a preventative measure. There are also signs that the monitoring and AIP activities have collectively increased yields, though this is highly variable depending on the scheme and crop. Between 43% and 81% of households report an increase in yield of more than 25% for their main irrigated crop (Crop 1) and between 33% and 73% for their second and third main crops (Table 10). Interestingly, the proportion of surveyed households reporting an increased yield for their three main crops is consistently lower for Magozi, which is the scheme that does not use the soil monitoring tools and, potentially, reinforces the importance of the combination of tools plus AIP.

Table 10. Yield increase during the four years of project implementation

	Tanzania		Mozambique	Zimbabwe	
(% households unless otherwise stated)	**Kiwere**	**Magozi**	**25 de Setembro**	**Mkoba**	**Silalatshani**
Yield of three main[1] irrigated crops					
Crop 1	Tomato	Rice	Green maize	Grain maize	Grain maize
Households growing (%)	62	100	79	78	96
Households with the crop having an increase in production of 25% or more (%)	62	43	77	81	71
Crop 2	Green maize	Grain maize	Cow pea	Wheat	Wheat
Households growing (%)	59	15	36	28	64
Households with the crop having an increase in production of 25% or more (%)	57	33	66	73	58
Crop 3	Grain maize	Soybean	Tomato	Sugar beans	Sugar beans
Households growing (%)	34	3	32	57	62
Households with the crop having an increase in production of 25% or more (%)	55	33	75	59	70

1. The three main single crops listed are those with the highest proportion of households growing the crop.
Sources: Moyo, et al, 2018; Mdemu et al., 2018; Cheveia, et al., 2018.

The existence of barriers to purchase inputs is well-known, but 50% to 68% of the households surveyed believe it is now easier to purchase inputs (Table 11). Additionally, 18% to 60% report they are growing new crops. However, there has been variable success across the schemes in realizing higher prices for crops: overall, 9% to 58% of surveyed households report that prices for their crops have increased with 8% to 90% reporting improved prices for their main crop. Whilst in many cases a high proportion of the households on the Zimbabwean schemes report improvements in yield this has only translated into higher prices received for a smaller proportion of households. Part of the explanation for some farmers not receiving increased prices for their crops is the type of crop being grown. For example, in Zimbabwe, many households are still growing staple crops that receive lower prices, despite Zimbabwean extension officers calculating negative gross margins for irrigated maize. Post-harvest losses are also significant with 60%, 98% and 63% of households growing grain maize losing between one fifth to a third of their crop in Zimbabwe, Tanzanian and Mozambique, respectively (Moyo, et al, 2018; Mdemu et al., 2018; Cheveia, et al., 2018.). The inter-connections between influencing factors are complex.

Table 11. Changes to crops, range of inputs and prices received

	Tanzania		Mozambique	Zimbabwe	
On-farm outcomes over four years (% households)	**Kiwere**	**Magozi**	**25 de Setembro**	**Mkoba**	**Silalatshani**
Growing new crops	23	47	18	41	60
Household rating that the price for their crops has increased	58	41	46	9	19
Change in range of inputs has made purchase easier	64	50	50	55	68
Price received for three main irrigated crops[1]:					
Crop 1	Green maize	Rice	Green maize	Grain maize	Grain maize
Households growing (%)	59	100	79	78	96
Households with this crop receiving increased prices (%)	74	33	90	28	18
Crop 2	Tomato	Grain maize	Tomato	Sugar beans	Wheat
Households growing (%)	61	15	32	57	64
Households with this crop receiving increased prices (%)	38	56	25	17	6
Crop 3	Grain maize	Tomato	Cow pea	Wheat	Sugar beans
Households growing (%)	34	2	36	28	62
Households with this crop receiving increased prices (%)	61	0	84	17	22

1. The three main single crops listed are those with the highest proportion of households growing the crop.
Sources: Moyo, et al, 2018; Mdemu et al., 2018; Cheveia, et al., 2018.

5.4 Household outcomes

It was anticipated that the combination of the tools and AIP would stimulate farmers' demand for information and the survey data supports this expectation with more than 70% of households reporting an increase in their information needs and that their range of sources has increased (Table 12).

Table 12. Changes in information needs, sources and advice (% households)

	Tanzania		Mozambique	Zimbabwe	
	Kiwere	**Magozi**	**25 de Setembro**	**Mkoba**	**Silalatshani**
Information needs have increased	77	89	74	74	81
Range of information sources has increased	77	89	76	83	89
Getting better agricultural advice	97	96	96	91	95

Sources: Moyo, et al, 2018; Mdemu et al., 2018; Cheveia, et al., 2018.

Additionally, more than 90% of households report an improvement in obtaining agricultural advice (Table 12), which has important implications for government extension services. Whilst farmers have greater self-reliance due to the information from the monitoring tools, their demand for additional technical support from extension services has also been stimulated. The extension staff involved in the project report that their work has become more rewarding as they are providing information demanded and used by farmers, which they believe has led to better socio-economic outcomes.

Encouragingly, households surveyed are reporting changes in their income sources and improvements in income. As has occurred in the past, it is possible to improve yields but this can often result in farming households being worse off if demand and/or other market arrangements are not addressed. As the tools and AIPs are endeavouring to stimulate change on many aspects, it is a positive outcome that some household are reporting income improvements after a relatively short period of time. On the majority of schemes, between almost half and two-thirds of households report that their source of income has changed. For households where income sources have changed, small businesses or off-farm work are the main new sources in Tanzania; the provision of farm labour in Mozambique; and, for Zimbabwe, the sources appear evenly spread across the options, including remittances. With respect to increases in income there is scope for further improvement and, as noted earlier, the majority of farmers are not receiving increased prices for their crops due to a continuing focus on staple crops.

Table 13. Changes to household's income and income sources

	Tanzania		Mozambique	Zimbabwe	
Outcomes (% households)	**Kiwere**	**Magozi**	**25 de Setembro**	**Mkoba**	**Silalatshani**
Income sources have changed	66	63	11	48	44
New sources					
Providing farm labour	14	21	67	46	35
Small business or off-farm work	67	61	33	31	30
Remittances[1]	12	19	--	39	46
Farm income is now better	67	53	83	41	21
Off-farm income is now better	55	39	60	47	49

1. Remittances are transfers of money to the household usually from migrant household members
Sources: Moyo, et al, 2018; Mdemu et al., 2018; Cheveia, et al., 2018.

Between 39% and 60% of households, report that their off-farm income has improved, and on all schemes bar one more than 40% of households surveyed report improved farm income. The findings illustrate the complex livelihood strategies of farming households who are combining income earning from irrigation, dryland farming and livestock with off-farm activities. This balancing act influences how land, labour and monetary capital are used. Hence, it is not possible to explore decisions related to irrigation isolated from other livelihood strategies (Bjornlund et al. forthcoming). Off-farm income and having more time is clearly critical and focus group discussions with young farmers show that they are starting new businesses: for example, hair salons, and bread and brick making. There is a symbiotic relationship between farm and off-farm income, with income from one or the other source used to support the household's basic needs, establish or maintain a small business, or pay for farm inputs (Zuo et al., forthcoming). The increased time commitment to off-farm work could reflect two important outcomes. First, the increased yield and income enables the hiring of non-family labour allowing family members to increase their engagement in potentially better paid off-farm work to further diversify their income stream and reduce their reliance on farm income. Second, the reduced time commitment to irrigation has allowed some family members to engage in off-farm work with similar effects.

In general, households report that they are spending more time (including time saved irrigating) on a range of activities (Table 14). Whilst this varies across the schemes, spending more time on farming activities (irrigation plots, dryland plots and livestock) and home improvements appears to be particularly important. More time spent on farming—for example, weeding to reduce competition for nutrients and water—can bring immediate improvements to yield.

In some schemes, a third to a half of households use their time saved on household chores (Table 13). This is particularly beneficial to women as they shoulder the majority of household duties, which are likely to include small livestock and vegetable production on the home garden. Also, many at Kiwere and Mkoba use more time diversifying their income stream. These are important results as they indicate that the combination of the tools and the AIP has increased profitability and hence increased farmers' willingness to invest both time and money in scheme maintenance and irrigation. That fewer households at de Setembro report spending more time on scheme maintenance, probably reflects that the canals were lined and gates improved, which was facilitated by the AIP process. In general, this has reduced the need for farmers to undertake maintenance during this period; the lining reduces the time it takes for water to reach the farmers gate and allows the system to supply sufficient water for irrigation.

Table 14. Household's use of time and extra income

	Tanzania		Mozambique	Zimbabwe	
Outcomes (% households)	**Kiwere**	**Magozi**	**25 de Setembro**	**Mkoba**	**Silalatshani**
Are now spending more time on:					
Irrigation plot	46	37	15	41	49
Irrigation/scheme maintenance	34	28	7	19	34
Dryland farming	32	15	5	37	29
Livestock	29	21	21	26	31
Home improvements	38	42	39	28	28
Off-farm income earning activities	21	17	0	34	18
Time saved on irrigation through monitoring tools is used for[1]:					
Resting, family time or family works	25	--[2]	4	30	27
Farm management (crops, ridge/land preparation, improvements, dryland)	37	--	44	30	46
Fishing	--	--	4	--	--
Household chores	--	--	22	52	38
Infrastructure maintenance	--	--	13	15	9
Small business[3]	27	--	13	22	2
Livestock management	2	--	30	11	13
School	--	--	--	0	2
Farming plot that was not cultivated	8	--	--	--	--
Carpentry	--	--	4	--	--
Nutrition garden project	--	--	13	--	--
Are now spending more money on:					
Irrigation and farm inputs	73	65	61	64	65
Irrigation/scheme maintenance	31	49	18	28	48
Education	49	42	61	68	55
Food	62	54	72	50	36
Farm implements	66	65	46	35	31
Home	64	64	64	56	36
Are now spending more money on inputs:					
Chemical fertilizer	77	57	93	68	55
Insecticide	68	56	100	27	14
Herbicide	67	57	67	27	14
Manure	42	0	50	19	5
Water fees for irrigation	34	40	83	2	41
Non-family labour	73	81	81	22	32
Equipment	54	74	68	21	20
Seeds	68	64	92	66	44
Post-harvest management	53	74	88	11	3
Households indicating they have extra income spend this on:					
Food	45	71	50	73	60
Education	57	54	36	67	71
Health	39	53	25	10	4
Farm input	54	28	25	53	67
Investment in home	45	38	18	27	15
Investment in farm	39	44	14	30	27

1. Open question; 2. there is no data for Magozi as soil monitoring tools are not used on this scheme; 3. reported as 'other business' on Kiwere.
Sources: Moyo, et al, 2018; Mdemu et al., 2018; Cheveia, et al., 2018.

In general, the majority of households spend more money on a mix of expenses, with irrigation and farm inputs (61%-73%), education (42%-68%) and food (36%-72%) of particular importance (Table 14). With respect to spending on critical inputs, the majority of farmers are reporting increases in spending on farm inputs, with chemical fertilizer, herbicides and seeds of most importance. This at first may not seem to be a desirable outcome: but, again, the starting point is important and the nutrient status of soils is low with animal manure often in short supply and farmers previously unable to afford chemical fertilizer. Farmers know that fertilizer, herbicides and better seeds will make a difference but they can only purchase these inputs when incomes are improved. Reflecting this, farm input is one of the areas in which farmers spend most of their increased income. Additionally, they need to be confident before they make the investment that their increased spending will result in improved profitability: the AIP helps remove the barriers that impact profitability.

The households that specifically reported they had more income are spending this extra income on food, education and farm inputs. It is clear that household know what their priorities are and they are investing in: the farm to increase crop production and future income; food to improve household nutrition; and education of their household to underpin future income and livelihoods.

Ultimately, what is anticipated is that improvements in income will bring about broader improvements for the households. And there are signs that households are experiencing real and tangible improvements to household food-security and well-being (Table 15). Approximately two-thirds of surveyed households report improved food security. Households' health and capacity to pay for education have also improved, though this has varied significantly across the schemes: 42%-75% and 31%-61% of households, respectively.

Table 15. Household perceptions on well-being

	Tanzania		Mozambique	Zimbabwe	
Outcomes (% households)	**Kiwere**	**Magozi**	**25 de Setembro**	**Mkoba**	**Silalatshani**
Household food security is better	70	58	67	64	66
Family members health is better	75	75	61	42	62
Capacity to pay for education is better	59	58	61	31	37

Sources: Moyo, et al, 2018; Mdemu et al., 2018; Cheveia, et al., 2018.

Collectively, the benefits of improved income and more time have also led to a reduction in household conflict in 44% to 89% of households surveyed (Figure 14).

5.5 Gender and decision-making outcomes

While the project did not focus specifically on gender issues, there has been an influence on gender roles across schemes. Qualitative data suggest women predominantly adopted the high-value crops. Hence, women's contribution to household finances has increased significantly, which should increase their influence both within households and the broader community. Even in Tanzania (the most male-dominated of the three countries) observations, qualitative data and anecdotal evidence suggest that women have increased their presence and influence within the schemes. Households surveyed have observed changes in gender roles, and in Tanzanian and Zimbabwe, they represent more than three-quarters of households (Table 16). In Zimbabwe, the main changes reported are that women are now more involved in physical work (50% and 61% of those reporting changes in the two schemes), men are now involved in household chores (41% and 27%), and there is more gender equality in leadership (34% and 36%). The greater involvement in physical work may be due to more men working in urban areas resulting in women having little choice but to do more physical work.

In Tanzania, the two main changes are that men and women now jointly perform the work (23% and 30%) and women have decision-making rights (20% and 27%). The main changes reported in 25 de Setembro are that women are now more involved in physical work (50%) and there is more gender equality in leadership (40%).

In Tanzania, the number of households where men alone make decisions has dropped by between 11% and 25% (depending on scheme and type of decision) with the shift mostly to joint decision-making and a smaller shift for decisions on spending income (between 7% and 18%) compared to decisions relating to resources (Mdemu et al., 2018). While decision making within the household in Tanzania has shifted from being all male-dominated, men still dominate activities away from the home, such as accessing information and participating in farming-related meetings. In Zimbabwe, the farmers are predominantly women. The decision-making structure varies between female and male-headed households. In female-headed households, women make the majority of decisions, and no households report men as the decision-maker, but about 15% report joint decision-making (Moyo et al., 2017). This reflects that there is either no husband or the husband is working away. In male-headed households, women still predominantly make decisions (except for large livestock) or they are joint, with the man being the sole decision-maker in only about 20% of households. In de Setembro, households report little or no change for resource allocation decisions with women being the more dominant decision-makers. With respect to income the decision-making is more even with women becoming more dominant with respect to off-farm work decisions and men more dominant with respect to salaries (Cheveia et al., 2018).

Table 16. Change in gender roles and decision-making

	Tanzania		Mozambique	Zimbabwe	
Outcomes (% households)	**Kiwere**	**Magozi**	**25 de Setembro**	**Mkoba**	**Silalatshani**
Households observing change in gender roles	79	91	36	82	79
Main changes reported[1]:					
Women are now involved in physical work	--	--	50	50	61
Men now involved household chores	--	--	10	41	27
Gender equality on leadership	--	--	40	34	36
Men and women jointly perform the job /involved in all cropping tasks	29	33	20	--	--
Women participate in irrigation farming	19	18	--	--	--
Participation of women in different income generating activities	19	13	--	--	--
Women currently have rights in making decisions	25	30	--	--	--

1. Options differed across the countries. 'Main' is where more than 12% of households reported the change.
Sources: Moyo, et al, 2018; Mdemu et al., 2018; Cheveia, et al., 2018.

5.6 Scheme-scale outcomes

Improvements in income and confidence have translated into scheme-scale outcomes: almost all households surveyed are participating more in scheme maintenance; there is greater willingness to pay for water (more than 64% on all schemes and all of the Tanzanian households); more than two-thirds are more able to pay for water; and 70% or more perceive water allocation to be fairer (Table 17). These are critical achievements as lack of maintenance and fee payment have, historically, contributed to the degradation of irrigation schemes. Importantly, the findings related to 'willingness' reflect qualitative findings and anecdotal data that actual participation and fee payment is increasing.

Table 17. Household perceptions on scheme maintenance and water payment and allocation

	Tanzania		Mozambique	Zimbabwe	
Outcomes (% households)	**Kiwere**	**Magozi**	**25 de Setembro**	**Mkoba**	**Silalatshani**
Participating more in scheme maintenance	100	99	89	87	91
More willing to pay for water	100	100	64	76	69
More able to pay for water	98	99	79	79	69
Perceive process of water allocation & use to be fairer	79	87	86	70	75

Sources: Moyo, et al, 2018; Mdemu et al., 2018; Cheveia, et al., 2018.

These changes also reflect households' willingness to engage in collective action, which can be directly related to the activities of the project. The reduction in irrigation frequency and length of an irrigation round has significantly reduced water use. As a result, more water is available for tail-end users, which has resulted in a significant reduction in conflict between irrigators: particularly for both Tanzanian schemes and Mkoba in Zimbabwe where more than half of the farmers surveyed report decreased conflict (Figure 14).

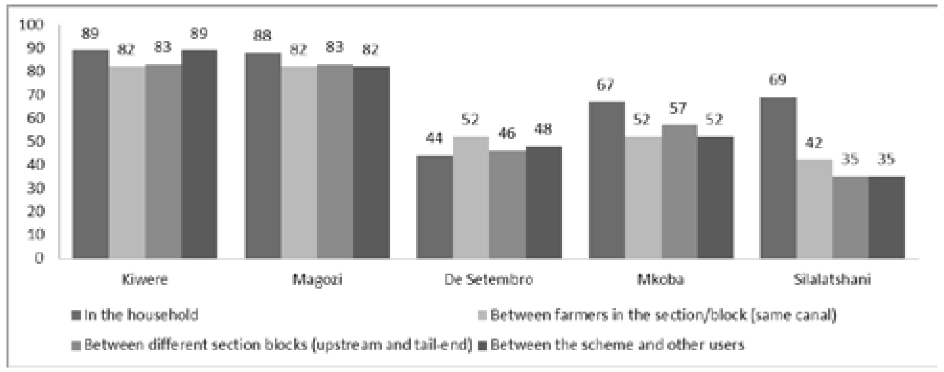


Figure 14. Percentage of farmers reporting decreased conflict over a four-year project period
Sources: Moyo, et al, 2018; Mdemu et al., 2018; Cheveia, et al., 2018.

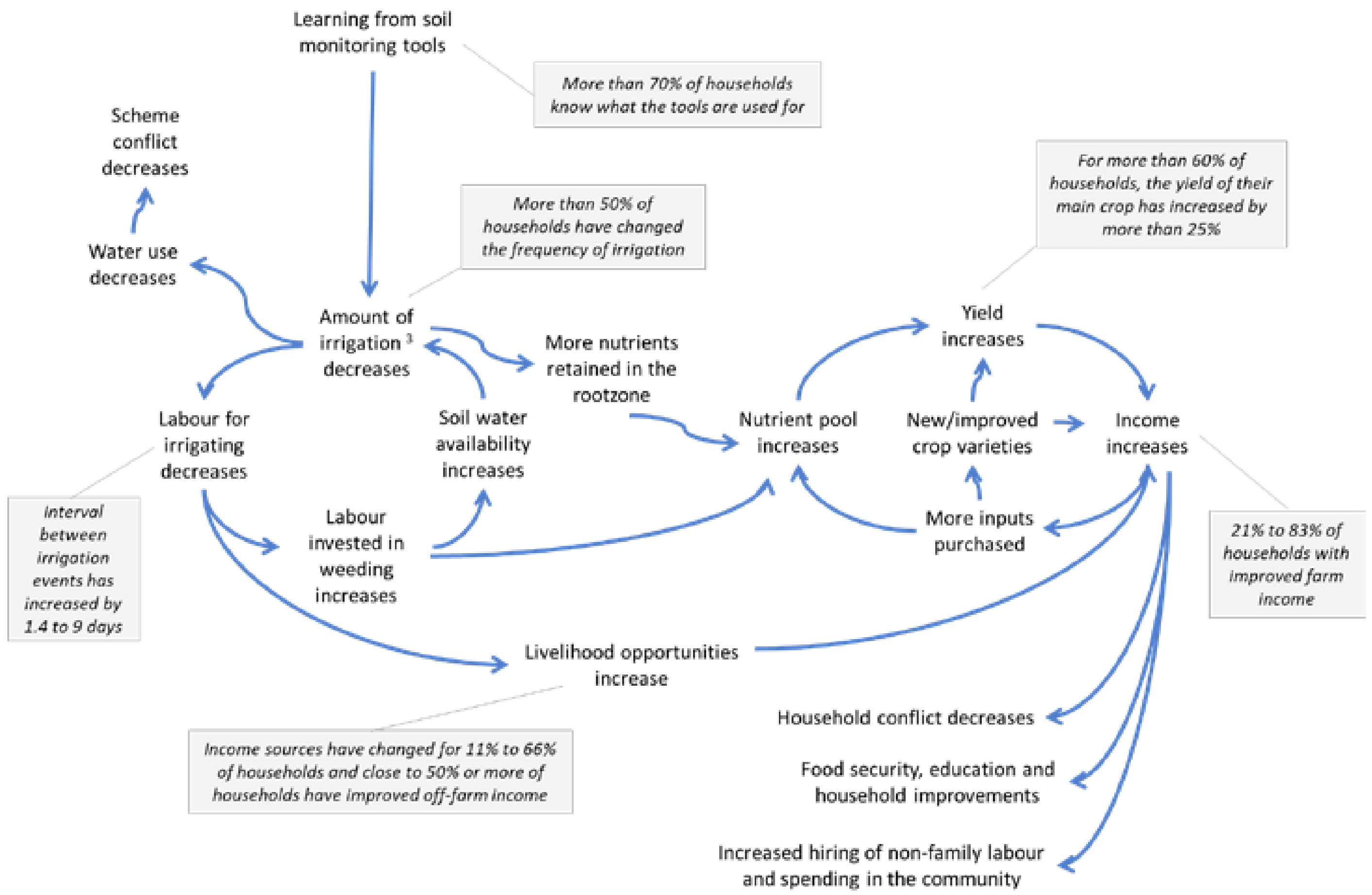
Apart from scheme maintenance and fee payment, farmers report other important examples of collective actions: in Silalatshani for example, farmers agreed to pay an additional $3 per month to erect a fence around the irrigation blocks to protect against damage from livestock (as identified in their AIP visioning exercise) and the scheme has now purchased the fencing materials. There are several examples of collective bargaining with produce buyers. In Tanzania, farmers have initiated road maintenance, set land aside for a scheme office and agreed to pay for the office construction. In Mozambique, the farmers at 25 de Setembro have agreed on standard prices for the more important crops such as green maize and cabbage, so they no longer accept the price offered by buyers.

At all schemes, some previously unused land is now utilized: 11% of households on both schemes in Zimbabwe; between 20% and 43% in Tanzania; and 25% in de Setembro report bringing unused land back into production. This change is likely to be a result of the increased profitability of farming. There is also anecdotal evidence from all countries that family members are coming back because of increased profitability. This may be due to specific project outcomes such as improved water supply to tail-end users (Tanzania); re-allocation of unused plots to youth (de Setembro); reallocation of plots and increased confidence in irrigation due to the resolution of the previous water bill (Silalatshani). Land utilization has therefore increased from less than 30% to near 100%. That only 11% of households on the Zimbabwe schemes report bringing land back into production reflects an under-reporting in the end of project survey. The baseline survey found that only 20% of plots were farmed and today almost all land is used. This under-reporting is probably due to the current policy focus of giving underutilized land to deserving farmers; hence many did not want to admit that they previously had some land that was unused.

5.7 Longer-term impacts

Importantly, the early outcomes of the project have provided the research team with a better understanding of the complex relationships between the factors that influence improvement in small-scale irrigation schemes, which will be further enhanced as additional research is undertaken in Phase 2. Figure 15 shows a model of the influence of key factors and the cycle of change as initiated by the AIPs and the soil monitoring tools: i) through their learning from monitoring tools, farmers have reduced their irrigation frequencies and duration because they can see that their crops do not use as much water as they previously thought and that excessive irrigation results in leaching of nitrates below the root zone; ii) reduced labour required for irrigating means more labour for weeding (which flows through to increases in the nutrient pool and yield) and more time for alternative livelihood opportunities; iii) improvements in yield are further enhanced by increased income and households' ability to purchase more inputs and improved crop varieties. As a result, households involved in Phase 1 of the project and those surveyed have reported significant increases in household income, an improvement in food security and health, and an increased ability to pay for children's education, water fees, and farm inputs.

Figure 15. Influence model of key changes initiated by monitoring tools and AIPs[1] with selected outcomes[2] (adapted from van Rooyen and Moyo, 2017)



Notes: 1. The AIPs influence is not shown in the diagram but includes facilitating improved access to inputs and markets and enhancing learning from the tools; 2. Outcomes from the 2017 Phase 1 EOP survey for Kiwere, 25 de Setembro, Mkoba and Silalatshani; 3. An aggregate term representing frequency, length of time, and/or volume.

Whilst, the longer-term impacts are more difficult to assess at this early stage, the model suggests that households have entered a beneficial and self-reinforcing cycle of development, which will lead to further positive impacts in the long-term. Better management of the nutrient and moisture pool will continue to increase yield; higher yields of higher value crops with improved market integration will increase income; and more income will facilitate investment in more and better farm inputs and implements. Increased spending on food, education and health, results in better educated youth who have improved chances of obtaining off-farm work or successfully transitioning to urban jobs. This development will ease the current pressure on household finances, which are supporting young people who are struggling to gain secure and decent employment (Zou et al, forthcoming). Additionally, the increased intensification of irrigation has resulted in increased use of non-family labour (Table 13) and the increased willingness to pay the water fees has resulted in increased hiring of labour for system maintenance and scheme improvements. Both of these outcomes have provided off-farm jobs for both land-holding and non-land-holding households. This cycle of development should continue as long as the external conditions remain the same or improve.

Farmers regularly monitoring their soil and nutrients is step one and a relatively easy 'win'. In the future, success would see far greater use of the information: patterns of one farmer over time, benchmarking across the scheme, comparisons among schemes and even countries, and other aggregations of the datasets. Encouragingly, there are some early signs of this occurring and the value of the monitoring information has been recognized beyond the farmers on the irrigation scheme, which is essential for the building of a wider learning system that surrounds small-scale irrigation schemes. Learning has spread to extension officers, managers of irrigation schemes and senior irrigation bureaucrats and the value of the information at different scales is becoming recognized (Table 17).

Table 17. Scales of interest in the tools and decision-making opportunity (Stirzaker et al., 2017, p. 799)

Scale	Interest	Opportunity
Farmer	Crop yield	Avoid crop water stress and nitrate leaching
Extension worker	Demonstrate good practice	Demonstrate clear links between irrigation and fertiliser management and data from monitoring tools and crop yield and quality outcomes
Water user association	Equity of water distribution, increased scheme production and hence income	Feedback as to whether different parts of a scheme obtain water when required. More fees paid to maintain the system
Regional government manager	Rehabilitation of schemes	Identification of schemes with infrastructure contributing to poor water distribution
Government agency	Stewardship of common resources	Demonstration of learning systems to achieve best practice

The results have shown that reduced water use by head-end farmers has had immediate benefits for tail-end users by increasing downstream supply. Also, that reduced nutrient leaching has immediate benefits for the farmers: with 43% to 81% of households reporting a 25% or more increase in yields for their main crop. There is also scope for water savings to spread to farmers within the existing schemes. If the current outcome of increased yields (between 43% to 81% across schemes report increases of 25% or more for households' main crop) can be out-scaled, there will be ongoing and long-term improvements in the performance of small scale irrigation schemes and the well-being of the households and communities that depend on them.

This project has documented widespread over-irrigation in all three countries suggesting that there are relatively simple interventions to increase water use efficiency, reduce nutrient leaching and increase crop yield (Stirzaker et al., 2017). While it is very difficult to calculate exact gains, increasing the footprint of this impact will have significant reductions in water use, and increases in yields and incomes at region and nationals scale.

Understanding the environmental and sustainability impacts of the project's approach is complex. Considering agriculture more broadly, the project helps reduce the amount of natural resources used in terms of land, water and fertiliser per unit of food produced. This is a goal of sustainable development policies and a sound demonstration of agricultural intensification. More efficient water use is reducing the leaching of nutrients from irrigated fields into the broader environment; a very positive outcome.

Importantly, the project does not address Jevon's paradox, namely, that by making irrigation more profitable through more efficient water use it is likely that there will be added incentive to expand irrigation beyond the existing schemes with negative environmental impacts. Each country makes its own societal choice of how to allocate any 'spare' land and water resources; including expanding irrigation or improving other environmental and socio-economic activities. Capping water extraction for agriculture can be challenging in countries where governance is weak. In the three countries involved in this project, government policies currently favour the expansion of irrigated agriculture. This project may therefore contribute to improved decision making in that regard.

5.8 Unexpected or unanticipated impacts

The two-pronged approach had at least three early and very important unanticipated impacts. First, labour saving from using the tools enabled households to invest their time in other activities. Second, the reduction in irrigation events resulted in increased reliability of supply, especially for tail-end users. This has significantly reduced the level of conflicts between irrigators, and is reflected in a willingness to participate in collective action. Third, increased profitability has resulted in the hiring of non-family members (Table 13) with significant flow-on effects in the community.

The project has been more successful than anticipated and created demand for the soil monitoring tools that has proven hard to meet. The testing of the Chameleon in farmers' fields has identified several problems, resulting in new design elements, greater reliability, and cheaper manufacture and data collation. However, the exorbitant importation fees charged by African governments for this type of agricultural equipment remain problematic.

The national partners in the project are now mainstreaming many of the project learnings. For example, the National Irrigation Institute in Mozambique incorporated many ideas from the project in new regulations for more effective irrigation associations. In the Insiza District of Zimbabwe, the AGRITEX extension staff are transferring better practices and market opportunities from the scheme involved in the project to others schemes within their jurisdiction.

6. Links to the Sustainable Development Goals

The project was developed to link primarily with the strategic priorities of the funding bodies and to be relevant to each country partner. However, the project activities contribute directly to seven of the global Sustainable Development Goals and a broad range of the associated targets: section 6.1 briefly describes how activities link to the targets, which are listed in Table 16. Indirect project linkages are outlined in section 6.2.

6.1 Direct project contribution

Target 1.4

The project helps identify and improve the institutions that reinforce inequity with particular interest in gender, youth and tail-end users and a focus on social capital, access to natural resources, economic well-being, and agency in decision-making. Additionally, farmers have direct use and control of appropriate technology.

Target 1.5

The purpose of irrigation technology is to reduce vulnerability of crop production from weather variability, but these benefits require functioning irrigation schemes. Increased understanding of sustainable resource use; enhanced individual and community capacity (knowledge, empowerment and agency); reduced conflict has fostered collaboration, strong networks and increased willingness for collective action; and income and crop diversification.

Target 1b

Communicating and advocating for policy change is facilitated through government partners in the project and regional African policy partners (e.g. FANRAPAN) and will be accelerated in Phase 2. Policy messages are also communicated through academic papers, FANRAPAN workshops and conferences with a policy focus.

Target 2.3

New crops and markets, and increased yields have increased farmer's incomes. Women in particular are growing higher value crops and young farmers have gained access to land in some schemes. Land tenures have been clarified in a number of schemes through mapping, reallocation of abandoned plots and issuing of certificates. More efficient water use has improved reliability of access for tail-end farmers.

Target 2.4

Farmers have: increased awareness of sustainable irrigation practices; changed practices to reduce water use and improve fertilizer management; and an increased appetite for more information.

Target 5.5

Women's incomes have increased and there have been increases in joint decision-making and also in female decision-making. Household conflict has reduced.

Targets 6.3 and 6.4

Farmers have improved understanding of fertilizer run-off and leaching and have changed their irrigation and fertilizer practices. Farmers have improved water use efficiency and water productivity.

Targets 8.1 – 8.6

Household incomes have increased and income and crop diversification changes have been made. Reductions in irrigation time have been used to improve crop management, establish new small business or undertake labouring for other farmers. There has been an increase in youth farming in the schemes.

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Target 10.1

Virtually all farmers in these schemes would be in the bottom 40% for income. Farmers in the schemes have reported increased incomes.

Target 10.2

See targets 1.4, 1.5 and 5.5

Target 10.3

See targets 5.5 and 8.1-8.6. Phase 2 has greater focus on disadvantaged groups: women, youth and tail-end users.

Targets 16.6 and 16.7

Irrigation associations have been strengthened through the project and new rules are being negotiated. Reduced conflict has been reported in households, within the scheme and between the scheme and other users.

6.2 Indirect project contribution

There are additional indirect links to goals 2, 4 and 5. The monitoring and AIP process are indirectly improving agricultural and extension services. Farmers have been stimulated to acquire more information from a range of sources. There is also evidence that the increased household income has increased household investment in farm input and system maintenance. The AIP also indirectly provides better market information, access and integration. The tools and the AIP are aimed at improving yield and profitability: however, the pathway to achieve this necessitates increased knowledge and skills about agriculture and business management. This will equip farmers for improved farm management and resilience.

The project has increased farmers' incomes and there are examples of farmers, including women farmers, using this income to send their children to school and even university. The project also directly supports a small number of research scholarships. Technology is a critical aspect of this project and whilst its specific use is to improve water use efficiency resulting in more profitable irrigation schemes, the project also seeks to empower farmers through greater knowledge, including women and youth. Women in the project have reported enhanced participation in decision-making and also a reduction in household conflict due to the increased household income.

Table 16. Direct project linkages to global Sustainable Development Goals4 and targets

Sustainable Development Goals and Targets	
SDG 1: Towards zero poverty **End poverty in all forms everywhere**	
1.4	By 2030, ensure that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources, as well as access to basic services, ownership and control over land and other forms of property, inheritance, natural resources, appropriate new technology and financial services, including microfinance
1.5	By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters.
1b	Create sound policy frameworks at the national, regional and international levels, based on pro-poor and gender-sensitive development strategies, to support accelerated investment in poverty eradication actions.

4. Based on the list in the Report of the Inter-Agency and Expert Group on Sustainable Development Goal Indicators (E/CN.3/2017/2), Annex III, March 2017.

SDG 2: Towards zero hunger **End hunger, achieve food security and improved nutrients and promote sustainable agriculture**	
2.3	By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment.
2.4	By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality.
SDG 5: Gender equality **Achieve gender equality and empower all women and girls**	
5.5	Ensure women’s full and effective participation and equal opportunities for leadership at all levels of decision-making in political, economic and public life
SDG 6: Water for all **Ensure availability and sustainable management of water and sanitation for all**	
6.3	By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally
6.4	By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity
SDG 8: Sustainable economic growth **Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all**	
8.1	Sustain per capita economic growth in accordance with national circumstances and, in particular, at least 7 per cent gross domestic product growth per annum in the least development countries
8.2	Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value added and labour-intensive sectors
8.3	Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalization and growth of micro small- and medium-sized enterprises, including through access to financial services
8.4	Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-Year Framework of Programmes on Sustainable Consumption and Production, with developed countries taking the lead
8.5	By 2030, achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value
8.6	By 2020, substantially reduce the proportion of youth not in employment, education or training
SDG 10: Climate change action **Take urgent action to combat climate change and its impacts**	
10.1	By 2030, progressively achieve and sustain income growth of the bottom 40 per cent of the population at a rate higher than the national average
10.2	By 2030, empower and promote the social, economic and political inclusion of all, irrespective of age, sex, disability, race, ethnicity, origin, religion or economic or other status
10.3	Ensure equal opportunity and reduce inequalities of outcome, including by eliminating discriminatory laws, policies and practices and promoting appropriate legislation, policies and action in this regard.
SDG16: Partnerships for the Goals **Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels**	
16.6	Develop effective, accountable and transparent institutions at all levels
16.7	Ensure responsive, inclusive, participatory and representative decision-making at all levels

7. Lessons learned

During project implementation, the team learned many critical lessons about how to facilitate the process of change towards profitable and sustainable small-scale communal irrigation systems.

Lesson 1: Complex socio-ecological systems require multiple interventions.

Small scale-irrigation schemes are complex systems that require many physical and institutional elements to work well for schemes to be sustainable. Multiple interventions are, therefore, needed to transform irrigation systems to a more sustainable and profitable state; thus, contributing to poverty reduction, food security and economic growth. The soil monitoring tools and AIP constitute two broad interventions with the AIP facilitating multiple context-specific solutions to challenges.

Lesson 2: Invest in institutions and human capacities

Substantial investment in institutions and human capacity is essential for irrigation schemes to thrive. This requires a paradigm shift from irrigation development that only focusses on water infrastructure.

Lesson 3: Never forget profitability

It is delusional to think that small-scale irrigation can be sustainable in the medium to long term if schemes remain dependent on government subsidies that have political objectives of poverty reduction and food security. Schemes must be profitable, and this often means growing high-value rather than staple food crops. A paradigm shift is needed from subsistence farming to commercial farming. Farmers must focus on generating profit, which provides them with the financial means to secure their food supply as well as their families health and education.

Lesson 4: Draw on local knowledge

A purely ‘top-down’ technocratic approach to governing small-scale irrigation schemes results in failures. Irrigation agencies need to draw on the different kinds of knowledge held by farmers and foster the capacities of farmer organisations to enhance their self-reliance and profitability. The concept of subsidiarity is important: devolving to farming communities clearly defined responsibilities and opportunities for self-governance.

Lesson 5: Choose entry points to achieve early positive outcomes

Previous experiences with implementing AIPs in Africa, shows that they are only successful if there is a focussed entry point (Pittock and Stirzaker, 2014). One entry point for this project was soil monitoring, which has helped farmers to understand the root causes of low yields. And farmers’ adoption of learning from the tools was swift. The second entry point was the AIP, which facilitated learning from the tools, identified priority barriers and solutions, and achieved early positive results. As irrigators have a mix of farming operations—including dryland and livestock managed as a joint enterprise—there should be broad consideration of entry points: for example, addressing the significant crop and livestock losses could be valuable entry points to provide ‘quick gains’.

Lesson 6: Allow extension officers' roles to evolve

AIPs work well when they continuously receive information to stimulate and structure learning. Encouraging involvement of stakeholders along the value chain stimulates new connections and options for solutions: facilitation is key to their success. There is potential for the role of extension officers in Africa to evolve from a 'command and control' approach that is failing, into a facilitation role that is more rewarding and effective.

Lesson 7: Irrigation decision-making must be understood within the context of diverse livelihood strategies

Farmers' main concern is how to feed their household and educate their children. To achieve this, each household pursues diverse and complex income generating strategies. They combine income and food production from dryland farming, irrigation and livestock with off-farm income from activities such as small businesses and farm labouring. Households' irrigation decision-making, and how they allocate their land, water, labour and financial resources are subject to this complexity.

Lesson 8: Address the issue of small plot size

Complex livelihood strategies are, in part, a consequence of the small size of irrigated plots, which mean that farm households cannot support themselves from irrigation alone. When allocating their scarce land, labour and financial resources, households must consider how best to use these resources from the perspective of total household income. This inevitably results in suboptimal use of irrigation water and land.

Lesson 9: Foster collective thinking to identify opportunities based on a common vision and priorities

Farmers' main constraints are those that influence their income earning capabilities. Such as, access to: markets for quality inputs and selling produce; knowledge about what to grow and how to grow it; transport to take produce to markets; farm implements to ensure optimal timing of fieldwork; finance to ensure ability to purchase quality inputs; and storage to retain produce until prices are best. Whilst this confirms existing literature on the plethora of constraints common to all small-scale farmers, the lesson relates to providing supportive mechanisms, such as the AIP, that enables collective identification of problems and opportunities, agreement on a common vision, and prioritization of interventions: collective thinking to overcome barriers.

Lesson 10: Address soft and hard issues simultaneously

While the soft access issues in Lesson 9 are foremost on farmers mind, hard issues—such as infrastructure and reliability of water supply—are also critical and can be principal barriers to change (see Lesson 11), or will become urgent once farmers experience that it is profitable to maximize the use of land and water. Hence, it is critical to work on both at the same time.

Lesson 11: Identify and resolve the 'deal breakers'

It is critical to identify the key issues within each irrigation scheme that might be deal breakers. These are issues that, if not resolved, will prevent or negate all other efforts. For example, the unsettled ZINWA water bill in the Silalatshani scheme in Zimbabwe and the leaking infrastructure in 25 de Setembro in Mozambique

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Lesson 12: Understand the flow-on effect

Learning spread widely within the schemes (evidence of social learning) and practices changed faster than expected, which contrasts with African adoption of soil water monitoring equipment, in general. The number of farmers who changed behaviour and adopted new practices based on learning from the soil monitoring tools far exceeds the number of farmers who had the tools deployed in their plots. For example, 24% of Silalatshani households surveyed had the tools, but up to 73% had changed their irrigation practices. This has important implications for future interventions; as it shows that the flow-on effect within a community can be substantial and this needs to be understood to maximize both the return on investment in the equipment and the anticipated 'reach' of the learning.

Lesson 13: Demonstrate benefits to create willingness to pay for tools (SWM technology)

In the early stages of the project, farmers were reluctant to say how much they were willing to pay for the tools. By the end of Phase 1, the value of the tools had been recognized and most households indicated a willingness to pay.[5] Farmers who currently have the Chameleon arrays want more of them to use in different locations and crops and some would like their own Chameleon reader to take readings more frequently.

Given, the current approximate hardware cost of US$40 for a Chameleon array and US$115 for the reader, the survey results show that 38% to 94% of households would be prepared to pay the amount required for four households to share an array and 78-94% of households would be prepared to pay the cost of 10 households sharing a reader. The flow-on effect suggests that such sharing might be the most cost-effective deployment option. Given that some farmers want their own tools, despite the demonstrated flow-on effect, this raises an interesting question around how many farmers actually need the tools. There is more to be learnt about how trust in a technology is developed and spread.

Lessons 14: Understand the public and private benefits of the tools and apportion the cost accordingly

The data generated by the Chameleon arrays and readers and uploaded to the Virtual Irrigation Academy has value at several levels: private, scheme, Basin and National as well as for future research. This database collates a wealth of information about water use across different locations and crops (such as crop yield and gross margins), which is currently only available as estimates. For the first time, this system will aggregate data based on plot level data. This raises important questions about how much the farmers, who will only receive the private benefits, should pay for tools that generate data that provides additional public benefits. Hence, Phase 2 aims to develop different business models for how farmers can access the tools and how other institutions such as government and donors can contribute to the cost in exchange for access to the data.

Lesson 15: Irrigation learning systems must be self-sustaining

Despite the positive outcomes, the distribution of free equipment and use of external capacity to implement AIPs do not guarantee longevity of use and continuing impact. That farmers have expressed a willingness to pay for the tools, is confirmation of the positive outcomes that they have experienced and an important first step. However, for the learning system to be successful in the longer term, farmers need to take their learning from the tools to a deeper level (e.g. exploring the seasonal patterns), the learning from the tools and AIP needs to spread beyond the project schemes, and institutional arrangements and networks (i.e. AIP or equiv-

5. During the Phase 1 EOP survey, at least 80% of households surveyed expressed willingness to make a payment of US$5 or more for a Chameleon array and between 12% and 35% of households are willing to pay US$40. Similarly, 78% to 94% of households are willing to pay US$10 for weekly access to a reader.

alent institution) need to become self-sustaining. Phase 2 will explore models of access to the tools and how farmers and organizations can implement the two-pronged approach without external support.

Lesson 16: Inflexible water supply constrains farmers' ability to benefit from the two-pronged approach

Farmer have used the monitoring data and improved their irrigation practices: however, they may still be constrained in fully utilizing the learning due to water systems that have fixed delivery schedules. It is critical that new water delivery systems are developed to provide flexible scheduling that meets individual irrigators' needs. Only then can farmers use the tools to make irrigation decisions that maximize yield and profitability.

Lesson 17: Recognize women as early adopters of high-value crops and the linkage to empowerment

As part of the complexity of households' income earning strategies, many adult men contribute by working off-farm. Collaboration of spouses around decision-making at a distance is, therefore, critical. Additionally, an important lesson from the project is that women are the predominant adopters of higher value crops, which has increased their contribution to household income and strengthened their position in the household and within their communities. There has, therefore, been a shift towards joint decision-making within households and women are more engaged in decision-making and more vocal in meetings. The end-of-project survey revealed several changes related to gender roles and the balance of decision-making. This is important for several reasons: i) traditional gender roles do not change quickly; ii) increased decision-making has linkages to empowerment and equity; and iii) women's greater involvement in decision-making, including use of income, has beneficial linkages to household well-being.

Lesson 18: Understand the role of irrigated farming in youth livelihood options

The likely pace of structural adjustment is such that farming will remain an important income source for several decades. Policies that recognize and facilitate the improved profitability of irrigation schemes are, thus, acting to improve the livelihood options for the burgeoning youth population. The role of irrigated farming in this regard is multi-faceted: profitable irrigation provides direct employment (on family farms or labour for others), supports the establishment and growth of household enterprises and also enables families to provide a better education for their children. Policies that seek to improve irrigated farming should be augmented by policies that support local business development, which allows young people to stay in their community and also contributes to rural development. With respect to education, there is an interesting dynamic: educated youth are more likely to gain wage employment and transition to city living, yet irrigated farming stands to benefit from more educated and entrepreneurial youth. However, not all youth can or will remain in rural areas and some migration to cities is inevitable.

Lesson 19: Recognize the potential role of youth

As small-scale irrigation households experience increased profitability, there are signs that household members, including young people, are returning to the village and engaging in irrigated farming. Increased profitability partly overcomes the issue of the unattractiveness of farming, but the increased involvement of young people also creates an opportunity to foster scheme resilience. There is no future for small-scale irrigation if youth are not engaged: schemes need to gain new ideas and address inter-generational transfer. For this to happen, schemes need to encourage youth engagement by overcoming youth-specific constraints—such as facilitating access to land and participation in scheme decision-making forums— to foster their involvement and harness their energy. Additionally, increasing the involvement of young women may be the most effective way of increasing women farmers' empowerment in the longer-term.

Lesson 20: Understand the value proposition of the two-pronged approach

In terms of private benefit, farmers have learned to appreciate the tools and are, therefore, willing to pay for the arrays and reader. Considering only the time saved, it becomes clear why the tools make a difference to farmers. Farmers from 25 de Setembro, Mkoba and Silalatshani have changed from irrigating once a week to once a fortnight, which potentially releases 16 days per year for a household member to engage in other income generating activities.[6] In terms of benefit at the scheme-scale, more land is under production and, if all else is equal, this must translate to increased crop production for the scheme. The increased participation in collective action, such as payment of fees and willingness to participate in scheme maintenance, also has significant scheme level benefits with respect to long-term sustainability.

At the scale of public investment in irrigation development, the lessons from this project suggest that investment in the two-pronged approach is critical to secure a return on investment in irrigation infrastructure. Currently, nearly all money invested in irrigation development goes into infrastructure and many schemes are struggling to be viable. Future research should investigate what proportion of investment in irrigation development should be allocated to building a learning system to enable the infrastructure to be used successfully for the long-term.

8. Additional information and next steps

8.1 Recommendations for those wanting to implement a similar project

The project approach of context-specific learning and innovation has been trialled successfully in Phase 1 and can benefit new or existing small-scale irrigation schemes. Those developing new schemes need to be aware of the history of irrigation development and the detrimental impacts (socially, environmentally and economically) that can result from scheme dysfunctionality. There is benefit also for smallholder private irrigation where irrigators draw from a common pool resource that needs collective awareness and management to avoid over-exploitation and degradation of the resource.

There are some fundamental underpinnings of the two-pronged approach that should be considered by those wanting to implement a similar approach:

i) There is considerable depth to the rationale and theory that underpins the project and its success. Essentially, a new paradigm of adaptive management for research for development is being tested and promoted. Those seeking to implement a similar approach should gain a full appreciation of the project's 'why'.

ii) Together, the complementary approaches of soil monitoring tools and AIPs are fostering two farmer-centred learning loops that address different barriers to overcoming challenges to improving yields and profitability. Those wanting to implement a similar project should resist the temptation to cherry-pick elements of the project as a cost-cutting measure. This is the 'what' of the project.

6. Assuming two 16 week irrigation seasons per year and an average 8.5 hours saved per irrigation event, means that households have approximately 16 days per year (at 8 hours/day) that they can use for other activities.

iii) Farmer empowerment, community knowledge and relationship building and stakeholder-led innovation—a bottom up approach and 'how' this project works—is central to this project but might take more time to implement. A top-down approach will not yield the individual, scheme and community resilience outcomes that can result from stakeholder participation, ownership and direction.
iv) What if …? Notwithstanding the above points, there is scope for experimentation as no two irrigation schemes are the same: farmers, natural resources, institutions and market systems will differ. Linked with the ethos of a research project, there is always more to learn and improve through application in new contexts.

In addition to the practical on-ground benefits, it is hoped that the research findings will influence and stimulate other research for development proponents interested in farmer-centred learning, innovation platforms, multiple and complementary interventions, and equity.

8.2 Out- and up-scaling in Phase 2

On the strength of the outcomes reported in the mid-term review of Phase 1 (de Lange & Ogutu, 2016), the project received funding for a four-year Phase 2, which commenced in 2017. Importantly, Phase 1 determined that there is an appetite for out- and up-scaling of the soil monitoring tools and AIPs. In general, the objective of Phase 2 is to develop ways of spreading the learning and impact of the project more widely and testing how the two-pronged approach can become sustainable with a minimum of external resources. Ongoing research is essential to evaluate whether the approach is widely replicable in developing countries and to develop irrigation policy options for governments and multilateral agencies. Central to Phase 2 is determining how the two-pronged approach of AIPs and soil monitoring tools can be:

- Scaled up to enable innovation at higher political scales using five district and three national-scale AIPs. It is anticipated that district AIPs will develop a critical mass of capacity that will last beyond the project's timeframes. Also, national case studies will test the transferability to new districts as well as innovative partnerships for agri-food systems.
- Scaled out to 32 or more new irrigation schemes by establishing new AIPs or by more cost effectively replicating innovations for implementation on schemes with similar circumstances (agricultural, markets and stakeholders). The project will test how best to spread the learnings and associated behavioural changes from the existing AIPs to surrounding schemes and determine how large an area an existing AIP can cover.

The project will continue to work closely with the ACIAR project that is developing the VIA platform. The production of the tools has moved from Australia to a facility in Pretoria, which will enable cheaper production and more effective shipping to ensure sufficient tools to support the out-scaling. Phase 2 will test different business models to sustain the production and spread of the tools—for example, public sector pays, private sector pays, finance, co-payment—with a consideration for how the options might hamper take-up or create inequity of access. The project will also explore how the data—such as estimates of soil fertility, water consumption, water efficiency and yield—that is aggregated by VIA can be used by irrigator associations and governments to improve scheme performance: for example, identification of under- and well-performing irrigation plots and schemes; prioritization of places for intervention; and enhancement of agronomic practices to maximize crop yields. The VIA project already operates in other countries, in addition to Mozambique, Tanzania and Zimbabwe, and will also be used as an entry point to engage new countries in the use of AIPs.

Several successful Phase 1 AIP innovations will be given greater focus in Phase 2. The Tanzanian project team will extend the participatory plot-level mapping produced in Tanzania by out-scaling it to other schemes and in other countries and work with local agencies to produce certificates of customary land occupation (or their equivalent), which can be used to qualify for access to micro-finance. The value of this mapping and its use in clarifying boundaries to reduce conflict, improve fee collection and enhance governance will be assessed. The Zimbabwe team will work through the AIP and with irrigator associations, and the departments responsible for them, to: i) revise their constitutions and strengthen their roles and ability to enforce the constitutional rules; and ii) clarify the issues of ownership of and responsibility for irrigation infrastructure such as dams and off-takes to the canals that supply individual plots. Negotiations are taking place with the Zimbabwe government to spread the use of the two-pronged approach at a large scale, including the large-scale training of irrigation extension workers in the existing irrigation-training centre. In Mozambique, as the out-scaling takes place and moves further away from Maputo, it is expected that there will be more women and young people who have agriculture as their main source of income and who have loans with micro-banks. It will be important to promote business plan training for more farmers to improve and guarantee the sustainability of their farming activities.

Across the project, farmer record keeping will receive greater emphasis. Farmers, who have the tools, will use a refined version of the farmer field-book to record seasonal data; the farm household, their land and livestock; cropping program; readings from the monitoring tools; and farm activities including the purchase of inputs, fieldwork, harvest, and prices obtained. Farmers will fill out the final section of the field book during an end of season workshop, where farmers will compute yield and gross margins and discuss learning from using the tools and market integration during the season.

Phase 2 will have a stronger focus on disadvantaged groups such as women, youth and tail-end users. The aim will be to provide guidance on how to reduce inequity by examining how institutions enable or limit access to natural resources, economic well-being, agency in decision-making and the building of social capital. For example, the project will investigate whether plot-level mapping is an opportunity to assist with the re-allocation of plots to increase equity. Similarly, the project will examine water saving opportunities and their potential to improve equitable water sharing. Some opportunities need to be more visible but discussed sensitively according to the local context.

A challenge related to out-scaling is the cost of data collection. Hence, at the end of Phase 2 the project will only comprehensively survey the households there were part of Phase 1 to allow an analysis of change over eight years. Based on the baseline and end-of-project surveys, the research team has chosen a smaller set of indicators to support adaptive management and track positive changes, perverse impacts, and identify new opportunities. The national teams will discuss these indicators with existing and new schemes so that the irrigation communities agree to help measure progress towards the desired state of the scheme.

The projected impacts for Phase 2 are ambitious and a sufficient number of stakeholders at scheme, district and national scale need to be motivated to ensure that the project succeeds. Thus, a key assumption for engagement is that the incentives for participation can be communicated successfully and are sufficiently motivating. Additional assumptions and challenges associated with out- and up-scaling include:

- There is a known appetite, and therefore some pressure, to out-scale quickly to benefit more farmers. However, this needs to be balanced by having sufficient depth of intervention to produce robust research findings.
- Irrigation schemes will fall into one of two assessment categories for AIP out-scaling in terms of their similarity with Phase 1 schemes: those that are similar can be drawn into existing AIPs, whereas others may require new, resource-intensive AIPs to be established.

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- Uncertainty of whether there is sufficient commonality of barriers and opportunities at district scale to derive common solutions across several schemes.
- A bottom-up and facilitation for empowerment approach has underpinned the success of Phase 1 AIPs. As up-scaling occurs, there may be a temptation for the district-scale AIPs that are based on government agencies to direct rather than facilitate change (Pittock et al., 2016).

As with all development projects working with natural resources, there are the inevitable risks associated with seasonal variations and climate change.

8.3 Further information and research

A 'how to' (Pittock et al., 2018) guide is available, which summarizes the approach and knowledge gained through the project. The guide provides practical advice to farming leaders, community organizations and government officers on interventions for sustainable and profitable irrigation. Overall, the guide will help ensure that public or private investment in the rehabilitation or development of new small-scale irrigation schemes is used to best effect.

This chapter has been limited in the research that can be communicated. Key findings from the initial 2014 baseline survey are reported in a special issue of the International Journal of Water Resources Development (Volume 33, Number 5, 2017), which have been further communicated during two special sessions at the World Water Congress in Cancun in May 2017 and at the Stockholm Water Week in September 2017. Research is ongoing and additional in-depth analysis will be available in the future: for example:

- Separate Phase 1 End-of-project surveys reports for Tanzania, Mozambique and Zimbabwe;
- Country-specific academic papers on adoption and impact of soil monitoring tools on yield and profitability of irrigation farmers; and
- Cross-cutting papers on the soil monitoring tools (e.g. beneficiaries, willingness to pay) and the project's theory of change.

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