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Profitability and productivity barriers and opportunities in small-scale irrigation schemes

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ABSTRACT

Irrigation development in Sub-Saharan Africa has lagged significantly behind that in other developing countries. Consequently, economic development and food security are also lagging behind. Since the mid-2000s there has been a resurgence in the willingness to invest in irrigation, and Sub-Saharan Africa has the largest potential of any developing region to benefit from it. However, to gain from new investment in irrigation without repeating past failures, it is critical to develop a business model for small-scale irrigation schemes. This article explores the barriers that such a model needs to address to be successful and the opportunities this represents for irrigators' profitability.

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Introduction

Food security has been a perennial problem in Sub-Saharan Africa (SSA), and the 2008 food-price crisis elevated this issue onto the international development agenda. Even though the increase in global food production has outpaced that of population growth over the last 50 years, food insecurity remains a major issue in SSA, as food production and demand are not spatially balanced. Reflecting this, Grafton, Williams, and Jiang (in press) stress that expanding food trade could create a more sustainable balance between food and water availability, but also argue that the projected population growth in Africa increases the concern surrounding food–water trade-offs. Hence, there remains an urgent need to increase food production in regions with food insecurity.

In the global context, irrigation accounts for 70% of water use, and the interconnected nature of economic and agricultural development means that local water management will have global impacts (Wada et al., 2016). Increasing the productivity of existing irrigated land is another way of meeting future food requirements (Grafton et al., in press). In the broader natural resources context, it is also important to recognize the increasing pressure that food demand places on soils, biodiversity and water. Agricultural development should seek to harness, restore and have an overall positive impact on ecosystems whilst improving equity and income generation and increasing food production (CGIAR, 2014).

In developing countries, the positive linkages between irrigation and agricultural productivity, income and food security are well established (de Fraiture & Giordano, 2014;

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Namara, Hope, Sarpong, De Fraiture, & Owusu, 2014; Wichelns, 2014; Xie, You, Wielgosz, & Ringler, 2014). Small-scale irrigation is recognized as a mechanism for increasing productivity and income in the rural areas of developing countries. However, this potential is often not realized, as many publicly funded systems are underperforming, run down and in serious need of maintenance and refurbishment.

Countries in SSA have failed to reap the potential benefits of irrigation, as its level of development is the lowest of any developing region (de Fraiture & Wichelns, 2010): only 4% of arable land is irrigated, compared to 47% in Asia and 18% worldwide (You et al., 2010). Hence, there is a significant potential for increasing production through investment in irrigation (Pfister, Bayer, Koehler, & Hellweg, 2011). While there was a growing reluctance among donors to invest in irrigation infrastructure in SSA during the 1980s and 1990s, a resurgence of interest took place towards the mid-2000s (World Bank, 2008). Reflecting this, Turral, Svendsen, and Faures (2010) predict that the irrigated area in SSA from 1998 to 2030 will increase by 30%, which is 5–12% more than other developing regions. There are also opportunities to improve the performance of existing irrigated areas (de Fraiture & Wichelns, 2010). It has been argued that closing crop-yield gaps would be a way to improve food security. However, Beddow, Hurley, Pardey, and Alston (2015) contend that this focus can have unintended consequences due to factors such as lack of transportation and market access.

As 30% of SSA's population is food-insecure (Pfister et al., 2011), small-scale public irrigation schemes have been the development focus (Sokile & Koppen, 2004) and account for 47% of all irrigated land (Makombe, Meinzen-Dick, Davies, & Sampath, 2001). However, private irrigation is the most rapidly expanding irrigation sector in Africa and South Asia and is often considered a more viable option (de Fraiture & Giordano, 2014).

To benefit from the increased willingness to invest in irrigation without repeating the failures of the past, it is critical to develop a business model for small-scale public irrigation schemes that is both financially and environmentally sustainable and socially equitable. This article contributes to such a business model by identifying current barriers to and opportunities for improving the productivity and profitability of small-scale public irrigation schemes. It does this by first reviewing the relevant literature and then synthesizing the main findings from a study of six small-scale irrigation schemes in SSA, which are reported more fully in this issue.

Barriers to improving productivity and profitability

The efficient and productive use of water in irrigation is critical; however, it is also multifaceted and often misunderstood. This is described and discussed in detail by Perry, Steduto, Allen, and Burt (2009), who emphasize the importance of differentiating between beneficial and non-beneficial consumptive and non-consumptive uses. FAO (2012a) differentiates between improving: (a) water-use efficiency, which aims at minimizing water losses by improving technical efficiency; and (b) water productivity and profitability, including increased yield through improvements in water, land and agronomic management practices, reduced evapotranspiration, growing higher-value crops or engaging in value-adding processes. For comprehensive definitions of on-farm and basin-scale irrigation efficiency, including the concept of economic efficiency, see Qureshi, Grafton, Kirby, and Hanjra (2011).

Considering economic efficiency also helps assess whether net returns are maximized; however, high economic efficiency does not always equate to irrigation being efficient overall

(Qureshi et al., 2011). Increasing production of commodities for which there is no market, or for which prices are so low that the expense of irrigation and other inputs cannot be justified, makes no sense.

On-farm and system efficiency need to be considered in the context of basin-scale efficiency and impacts on the environment and users downstream; efficiency at the farm scale may not result in improved basin-scale efficiency (Qureshi et al., 2011). The efficient use of water, and the complex spectrum of what this means, is an overarching issue that needs to be taken into account when overcoming barriers to productivity and profitability.

The barriers to improving farm productivity and profitability in small-scale irrigation schemes are a broad and complex mix of institutional, market, infrastructure and production issues. In the following, four categories are discussed: institutional barriers; market and supply chain barriers; infrastructure and farm equipment barriers; and production and water productivity barriers.

Institutional barriers

Adekunle, Fatunbi, Buruchara, and Nyamwaro (2013) point out that institutional barriers to improving productivity have been underestimated. Globally, there has been an increasing trend to devolve the management, ownership of and financial responsibility for irrigation systems to farmers (Turral et al., 2010). In Africa, this process of 'irrigation management transfer' has been an ongoing part of reform in government-run and farmer association irrigation systems since the mid-1980s. In most cases it has been a transfer of management rather than ownership, with government withdrawal from fee collection, conflict resolution, and operation and maintenance (Shah, van Koppen, Merrey, de Lange, & Samad, 2002). This devolution has been driven by the underperforming public irrigation sector common in SSA and elsewhere (de Fraiture & Giordano, 2014). The rationale was that water users would take over the tasks (Van Koppen, 2003) and that ongoing maintenance costs would be met through increased productivity (Shah et al., 2002). However, productivity and profitability are not the same, and higher yields do not always equate to financially viable irrigation schemes.

There is limited evidence that water user organizations have been successful in reducing poverty and improving equity (Bjornlund, 2009) or productivity (Sakaki & Koga, 2013). Others suggest that in Africa this process has even resulted in lower productivity (Van Koppen, 2003). In general, transition arrangements have not performed to their potential in developing countries (Shah et al., 2002).

Small-scale irrigation schemes face many challenges around conflict resolution, particularly in resource use between public and private irrigation and upstream and downstream users. Resolution can be hampered by unclear mandates (de Fraiture & Giordano, 2014) or the reluctance of members to deal with issues where they have conflicts of interest.

Araral (2010) argues that the rationale for water reform in developing countries has focussed on efficiency, effectiveness and fiscal sustainability rather than equity. The literature reflects a mix of inequity issues, including non-uniform and unequal plot boundaries, how well the marginalized sectors of the community are represented during the development of associations and resource allocation, and whether this sector can effectively use the participatory 'space' (Lévite & Sally, 2002; Ounvichit, Ishii, Kono, Thampratankul, & Satoh, 2008; Tankha & Fuller, 2010). In general, women in SSA are not well represented in irrigator groups

or associations, or as owners of irrigation equipment (Namara et al., 2014); these are indicators of marginalization.

Meinzen-Dick (2014) emphasizes the importance of property rights – including land, infrastructure and water – and argues that the security and robustness of property rights has a strong influence on confidence to invest, authority to manage, incentives for maintenance and efficiency, and confidence to respond to water scarcity. The link between land tenure and food security, rural livelihoods, conflicts and environmental degradation is well known (FAO, 2012b; Deininger, 2003). More specifically, land tenure is a means to generate an income and accumulate wealth, an incentive to invest and an insurance against 'shocks', and improves access to credit (Deininger, 2003). Compared to other developing regions, parts of Africa have particularly intractable land-tenure issues. There may be no formal state recognition of land under customary tenure, and the titling process can be complex and costly (Meinzen-Dick, 2014). Some farmers in developing countries have been able to attain some evidence of ownership without obtaining formal property rights; this provides some tenure security but does not allow the use of land as collateral for loans (FAO, 2010).

Market and supply chain barriers

It is increasingly recognized that small-scale farmers in Africa need to successfully participate in markets to raise agricultural income (Markelova, Meinzen-Dick, Hellin, & Dohrn, 2009). There are many barriers: supply chain complexity, food safety standards, the power of supermarkets, the need for facility upgrades, and procurement practices can all squeeze smallholders out of the market, despite their advantages of lower costs and access to family labour. Other issues are lack of information on prices and access to input and output markets and credit. In SSA, markets can be too small to absorb supply, or farmers too scattered to effectively fill demand (Sakaki & Koga, 2013). Inadequate transportation infrastructure and storage facilities are also critical economic barriers that impact a farmer's yield efficiency in low-income countries (Beddow et al., 2015). Shah et al. (2002, p. 19) argue that if farmers have access to stable, reliable markets then "much else follows", as this will improve their wealth-generation potential and livelihoods, including households' nutrition, health and education.

Infrastructure and farm equipment barriers

Shah et al. (2002) observe that, in Africa, if schemes had been designed with small-scale user group management in mind, they would have been built quite differently with respect to service delivery, fee collection, maintenance and self-management. In Zimbabwe, one of the reasons for small-scale irrigation schemes' underperformance is that many were designed as large-scale, single-unit systems and did not have the flexibility to accommodate small-scale operations (Bjornlund, 2009).

Infrastructure barriers for small-scale irrigation schemes include dilapidated water supply systems, poor construction quality and lack of resources to maintain infrastructure (de Fraiture, Kouali, Sally, & Kabre, 2014).

Whilst small-scale irrigation technologies are used by farmers, more than 80% of these are manual devices (Giordano, de Fraiture, Weight, & van der Bliek, 2012). It is recognized that investment in small-scale equipment, such as power tillers, can bring income returns,

but lack of affordability and availability present difficulties for irrigators (Giordano & de Fraiture, 2014). As labour is not factored in, manual systems can appear to be low-cost alternatives. With women representing a significant portion of agricultural labour (54% in SSA and 64% in southern Asia), the issue of balancing fieldwork with households' needs must be considered (Faures, Svendsen, & Turral, 2007). The availability of low-cost implements for irrigation and other fieldwork would be a major improvement.

Production and water productivity barriers

Walters and Groninger (2014) argue that crop productivity improvements should encompass irrigation technologies, field production, management practices and capacity building. Without this focus, economic growth in rural areas will not be attained even if water supply issues are being addressed.

In Africa, there is evidence of over-application of water in smallholder schemes as water is supplied on a roster basis, so if a farmer receives water on a weekly roster they will irrigate whether water is required or not. More flexible scheduling mechanisms are needed, as is greater understanding of watering requirements and the impacts of over-watering (Samakande, Senzanje, & Manzungu, 2004).

Kahinda, Rockström, Taigbenu, and Dimes (2007) found that irrigation helped stabilize crop yield but emphasized that nutrient management was also needed, as well as knowledge to identify the critical stages in the growing cycle when water shortage most affects yield. Throughout Africa, smallholder farming systems suffer from negative nutrient balance for nitrogen and phosphorous, which affects crop production (Roy, Misra, Lesschen, & Smalling, 2003). Stirzaker, Mbakwe, and Mziray (2017) further argue the case for farmer learning around soil moisture and nutrient measurements and the impact of over-irrigation on nutrient leaching.

Crop choice is another important aspect of the viability of small-scale irrigation schemes. In Zimbabwe, low-value subsistence crops are often grown by poorer farmers, and it is only when their own needs are met and their income is secure that they consider higher-value crops (Robinson, Mathew, & Proudfoot, 2004). Perceptions of risk associated with these crops are strong; hence, it is the more affluent farmers who adopt higher-value crops and realize increased income. These risks are amplified by unreliable markets and farmers' lack of understanding of consumer preferences (Twomlow, Love, & Walker, 2008).

Globally, a decline in state-funded extension services and training, and input subsidies, has created problems for farmers, and obtaining appropriate inputs has been identified as a major productivity barrier (Markelova et al., 2009). In Zimbabwe, the adoption of new practices has been limited by a range of social and economic issues, especially in labour-deficient households such as those affected by AIDS (Twomlow et al., 2008). The issue of extension services is covered in more detail by Wheeler, Zuo, Bjornlund, Mdemu, and van Rooyen (2017).

The small plot sizes of 0.1–0.5 ha, so prevalent in small-scale irrigation schemes, effectively prevent famers from producing a significant surplus; hence irrigation is only marginally profitable compared to other economic opportunities in urban centres (Venot, de Fraiture, & Acheampong, 2012). Small plot sizes mean that irrigators have to depend on several sources of income, including animal husbandry, fishing or urban work (Shah et al., 2002).

Opportunities to improve water productivity and profitability

For small-scale irrigation to be sustainable, development needs to reduce external investment as much as possible, match the economic capacity of the community and be self-supported by farmers (Sakaki & Koga, 2013). Progress is most likely to occur when local communities have the agency to initiate their own reforms to improve irrigation-scheme productivity, sustainability and equity, because empowered communities are better able to identify and adopt appropriate technologies and demand more practical, supportive policies from government agencies.

Private schemes, such as rainwater harvesting and wells, are promoted as they: (1) require less investment and support as they are driven and financed by farmers; (2) have improved crop yields through timely irrigation; (3) use minimal and easier-to-manage technology; (4) have avoided sustainability issues apparent in public systems; and (5) allow a gradual shift to commercial farming (de Fraiture & Giordano, 2014; Malik, Giordano, & Sharma, 2014; Sakaki & Koga, 2013)

In Africa, the objective of many small public schemes is food security, as opposed to market integration, which is needed to support reinvestment in the system (Moyo et al., 2017). There are few market linkages, and hence little or no reinvestment in maintenance or infrastructure. The focus on food security fundamentally influences profitability.

Some suggest an amalgamation of public and private schemes, merging modern and traditional arrangements, as a pathway for reforming small-scale irrigation institutional arrangements (McCartney, Lankford, & Mahoo, 2007). This allows the positives of local decision making and leadership to merge with the need to manage increasingly competing uses and inequity issues associated with water allocation. Where over-allocation is a concern, some suggest that this can be resolved and successfully managed through social networks and that these locally negotiated arrangements can be more robust (Mul et al., 2011).

The remainder of this section will discuss opportunities relating to farmer participation, multi-stakeholder forums, farmer capacity and livestock integration.

Improving farmer participation

Many opportunities are associated with facilitating more effective water user associations; however, there is no universal formula for replication, and approaches need to be adapted to local conditions (Inocencio et al., 2007; Malik, Giordano & Sharma, 2014; Meinzen-Dick, 2014; Palerm-Viqueira, 2010; Turral et al., 2010).

Opportunities could emerge by improving farmer participation and collaboration with a broad range of stakeholders by identifying:

- barriers to participation by individuals and user groups (Meinzen-Dick, 2014)
- conflict-resolution methods, giving groups the mandate to consult, mobilize and solve issues (de Fraiture et al., 2014)
- opportunities to regulate upstream private irrigation and capitalize on farmers' ability to effectively organize shared resources around market principles (de Fraiture et al., 2014)
- beneficial relationships between large commercial farms and small-scale farmers, improving access to input and output markets and equipment (Bjornlund, 2009; Meinzen-Dick, 2014)

- areas where production can be adapted to global supply chains (Markelova et al., 2009; Van Koppen, 2003)
- transaction-cost reduction and better access to information on markets and new technologies, and how to enter high-value markets (Markelova et al., 2009)
- management tools for water scheduling, to support high yields and value chain participation
- strategies to increase the revenue of associations, including fines and non-irrigation services such as supplying fertilizer and seed, equipment hire, land preparation and market organization (Shah et al., 2002).

Agricultural innovation platforms (AIPs)

Approaches to improve schemes emphasize integration of a broad range of disciplines – technical, socio-economic and institutional – as well as commodity considerations (Kahinda et al., 2007; Twomlow et al., 2008). There should be a focus on problem solving rather than implementing a set of principles (Merrey, 2008), and agencies and development professionals should view themselves as participating in water users' realities (Boelens & Vos, 2014).

Writing about opportunities for small-scale public and private schemes in Africa and Asia, Giordano and de Fraiture (2014) state that multidisciplinary stakeholder management forums should be supported to assist with the complexity of issues that both support and constrain the small-scale irrigation sector.

In the context of participatory water reforms in India and Brazil, Tankha and Fuller (2010) discuss the value of creating access points for a broad range of stakeholders. For example, entrepreneurs are particularly useful, as they engage with opportunities when reform is slow or uncertain, and, together with capacity builders, they can act to make reform faster and more viable. Large-scale commercial farms can be engaged to act as 'model farms', to provide small-scale farmers with employment and improved access to input and output markets, logistics and processing facilities (Bjornlund, 2009).

AIPs are suggested as an option for improving water productivity and profitability. AIPs are facilitated forums that bring together farmers and value-chain stakeholders. It is argued that linear technology transfer is not appropriate; rather, multi-stakeholder forums are needed to foster innovative options to overcome the complexity of barriers and stimulate change and collaboration (Adekunle & Fatunbi, 2012; Adekunle et al., 2013). AIPs can also provide technical advice and address the shortage of extension officers and are comprehensively addressed in this issue (van Rooyen, Ramshaw, Moyo, Stirzaker & Bjornlund, 2017).

Improving farmer capacity

Franks, Garcés-Restrepo, and Putuhena (2008) argue that while physical infrastructure, focusing on technical issues, has dominated development for decades, there is increasing emphasis on the importance of building technical and governance capacity at different levels. There is a need to put capacity building and "people rather than technology as the primary challenge and opportunity" (Pittock & Grafton, 2014, p. 197). On-farm action to improve livelihoods is required in the short term while systems, policies and distribution are being improved (Walters & Groninger, 2014).

Farmers require a broad mix of agronomic, irrigation and business skills, as well as training in the selection, operation and maintenance of equipment and infrastructure (Evans, Giordano, & Clayton, 2012). As noted earlier, the shortage of extension officers is a barrier to improving farmers' capacity, which is discussed more fully in this issue (Wheeler et al., 2017). There is a need to address the lack of understanding of crop water requirements, water-saving technologies and crop varieties (Walters & Groninger, 2014). FAO (2012a) also notes fertility and pest control as information requirements to improve yield and water productivity. Wichelns (2014, p. 164) reminds us that water productivity is not the main issue; farmers should focus on "reducing the variance in crop yields and soil moisture availability and increasing the mean values of crop yields". The use of new monitoring technology to improve farmers' understanding of soil moisture and nutrient management is also discussed in this issue (Stirzaker et al., 2017).

Franks et al. (2008) emphasize the importance of social and experiential learning for water management in developing countries and add that facilitation should include a range of agencies: public, private, NGOs and community-based organizations. The formation of farmer groups, for demonstration and exchange between farmers, is also advocated to enhance the spread of conservation agriculture techniques (Evans et al., 2012). Overall, capacity-building opportunities are context-specific: "It is impossible to be prescriptive about capacity development needs and approaches, and to write guidelines which fit every situation" (Franks et al., 2008, p. 20).

Globally, the irrigation sector is described as having missed many information technology opportunities, with agriculture being decades out of date, but access to this technology is now cheap (Turral et al., 2010) and increasingly adopted by farmers. The enforcement of water rights and allocation is underpinned by effective monitoring, particularly of large-scale users (McCartney et al., 2007). At project scales, monitoring also underpins adaptive management and provides feedback on whether actions are having the desired effect. The expense of monitoring has been a barrier to adaptive management, but the emerging availability of simpler and more cost-effective equipment has the potential to change this (Stirzaker & Pittock, 2014).

Opportunities that assist in overcoming financial barriers to technology and crop inputs include vouchers for women, lease-to-buy options, rural credit cards, microfinance, pump rental markets, irrigation service providers (Giordano & de Fraiture, 2014) and savings clubs (Shumba & Maposa, 1996). Affordability of credit is important (Wichelns, 2014) and should be extended to dealers so they can have a varied inventory of products (Giordano & de Fraiture, 2014).

Integration of livestock

Integrating livestock into the economy of smallholder irrigators has significant potential to improve profitability, as livestock provide food, income, manure, draught power, social status, savings, and a buffer against risk (FAO, 2010). High mortality rates have undermined these benefits, but integration with irrigation has the potential to overcome some of the identified barriers, such as poor nutrition and lack of water (FAO, 2010). In the rural areas of developing countries, dwindling government budgets make supplying animal health services and veterinary supplies almost impossible, and existing extension services are very poorly trained in livestock management. There is a need to provide a broader range of skills and services,

such as insurance, animal health services, credit and marketing, in order to reduce livestock mortality and improve profitability.

However, several livestock-related problems have been identified in irrigation schemes, such as high mortality rates – caused by extreme weather events, poor nutrition or lack of water (FAO, 2010) – and unrepaired fencing (Shah et al., 2002), which allows cattle into fields, causing damage. On the other hand, conflicts can arise when fencing prevents livestock from accessing water (de Fraiture & Giordano, 2014).

A comparative discussion of the key findings from Mozambique, Tanzania and Zimbabwe

Irrigators in the six case-study schemes were asked in a baseline survey to consider the major barriers preventing them from increasing productivity and profitability. Very few mentioned issues associated with irrigation infrastructure or access to water and land, and there was also little mention of governance issues. Uniformly, farmers perceived other, 'softer' issues to be the major barriers, such as (1) access to output markets; (2) access to affordable and high-quality inputs; (3) timely access to use of critical farm implements; (4) knowledge about water and farm management and crop selection relative to market demand and prices; and (5) knowledge of finance.

Access to credit and market

Lack of financing and access to financial products were particularly explored in the context of Tanzania (Mdemu, Mziray, Bjornlund, & Kashaigili, 2017), where they were found to prevent farmers from purchasing adequate inputs and having timely access to farm implements and transport to markets. This is consistent with the findings of Giordano and de Fraiture (2014). However, when markets and prices are uncertain, farmers are reluctant to take credit, and banks are reluctant to grant it; the risk of default is seen by both parties as too high. Hence, there is evidence to suggest that poor market information and lack of integration into the value chain are preventing farmers from accessing credit.

Government extension

Government extension services were reported as important sources of information and advice for irrigators in all three countries. However, resource constraints in both Tanzania and Mozambique have limited the availability of extension services, as found by Markelova et al. (2009). In Mozambique, there is little extension presence in the schemes because public-sector pay and working conditions are very poor and the most qualified staff seek private-sector work. Hence, there is a shortage of extension officers, and once recruited they do not stay long (de Sousa et al., 2017). In Tanzania, the number of extension officers is below government guidelines, and due to resource constraints, the officers are also given other responsibilities, such as serving both irrigated and dryland farmers and serving as business development officers. Hence, extension officers do not pay routine visits to schemes; farmers have to book a time and also pay transport costs. Further, there are inadequate resources to secure ongoing and up-to-date training of the officers, and irrigators consider their advice outdated (Mdemu et al., 2017). Wheeler et al. (2017) found that better educated farmers in

Tanzania were less likely to use extension services, possibly because they believe they can obtain better advice elsewhere. On the other hand, extension officers are far more readily available in Zimbabwe, and there is evidence that they have irrigators' trust (Moyo et al., 2017). However, there is no evidence that farmers in Zimbabwe are doing any better than in the other two countries; on the contrary, the schemes in Zimbabwe have the lowest yields and the largest proportion of unused land. There is evidence that irrigators in Tanzania and Mozambique, in the absence of extension officers, seek more advice from other sources; while in Zimbabwe it was identified that a pluralistic extension system is required, as it is unreasonable to expect one extension officer to provide high-quality advice on irrigated and dryland cropping as well as livestock and markets.

Livestock issues

In both Zimbabwe and Tanzania, livestock mortality rates are unacceptably high, with more animals dying each year than the numbers of eaten and sold. This is disappointing, considering that livestock are widely owned in the schemes and could make significant contributions to household income and food security, as well as providing a buffer when crops fail or excess floods the market. This is consistent with findings from other developing countries (FAO, 2010). There seems to be a serious lack of advice on livestock management and marketing, as well as veterinary services; national policies are reported as giving "scarce attention" to this sector (FAO, 2010). In Zimbabwe, the training of extension officers is clearly focused on cropping, and there is little emphasis on managing the integration of cropping and husbandry (Moyo et al., 2017). Most farmers in all the schemes have a combination of irrigated and dryland. Hence, there is a substantial opportunity to integrate the management of irrigated and dryland with animal husbandry and improve productivity, as is reflected in the literature (Herrero et al., 2010).

Infrastructure

The focus on these softer issues does not mean that infrastructure, water, land and governance issues are not important, real and tangible ways to improve farmers' productivity and profitability, but it does support the argument of Wichelns (2014) and Meinzen-Dick (2014) that by itself fixing technical issues will not make small-scale irrigation schemes productive and profitable, and it accords with Adekunle et al. (2013), who suggest that the most critical issues to address are the softer issues discussed above. Once productive and profitable schemes have evolved, the issues of access to and control of water, land and infrastructure and the associated institutional arrangements will come to the fore. Hence, it is important to address both the softer and the technical barriers in an integrated and holistic way, consistent with the findings of Walters and Groninger (2014).

It could be argued that engineers, together with donors, have been somewhat successful in constructing and refurbishing irrigation schemes. Designing canals and slopes and mixing concrete are relatively well-known processes. However, organizing people and resolving governance and softer issues is far more complex and requires a very different and far less tested skillset. Hence, in very few cases have small-scale irrigators been successfully integrated into the market and the broader economy such that they become profitable, have adequate food and have sufficient surplus to secure their children's education and their

family's health. Only then will farmers be willing to pay water levies adequate to cover the full cost of scheme maintenance and to contribute sufficient labour to properly maintain the infrastructure. Further, governments and donors will be much more comfortable and willing to fund new schemes and refurbish existing schemes if they can see irrigators in existing schemes following a business model that leaves them profitable, capable and willing to maintain the systems.

While issues associated with infrastructure, land and water access, and governance were not mentioned by irrigators in the baseline survey, they were apparent in field observations and were raised in focus groups with farmers and discussions with stakeholders at AIP meetings.

Governance

In both schemes in Zimbabwe, there is significant confusion about who controls and is responsible for irrigation infrastructure (Moyo et al., 2017). Traditionally, this was the sole responsibility of the government, but more recently it has become a joint responsibility. Further, the schemes were designed and constructed in a centralized and top-down manner without any input from the irrigators or their leaders, which has resulted in members being disenfranchised. Reflecting this confusion and disenfranchisement, only about half the irrigators consider that they have to do any maintenance work in addition to paying their water levy. While farmers at the Silalatshani scheme owe a maintenance levy in addition to their water levy, only 38% reported paying it. On the other hand, at the Mkoba scheme, irrigators do not have to pay such a levy, yet 58% reported paying it. Therefore, Mkoba farmers must believe that the water levy is for maintenance. There is clearly confusion. Among the leaders in the Irrigation Management Committee there is uncertainty over their legality and authority, which contributes to lack of capacity and willingness to enforce critical rules. All of these factors have resulted in low participation in maintenance work and conflict over payment of water and maintenance levies. This has led to degraded infrastructure and significant water losses; widespread, blatant and silently accepted theft of water from the main canal; and unmaintained fences that allow stray cattle to damage field infrastructure and cause production losses, consistent with Shah et al. (2002).

In Tanzania, similar issues have resulted in a lack of enforcement of basic rules such as membership in irrigation organizations, water levies set far below what is prescribed and needed for maintenance, stray cattle found in the fields, upstream-versus-downstream water distribution issues, and lack of participation in maintenance (Mdemu et al., 2017). In all six schemes significant hard issues were also identified, such as unlined canals, flood-damaged pumps and broken pipes in Mozambique (de Sousa et al., 2017), and unlined and temporary canals, insufficient offtake size and lack of siltation traps in Tanzania (Mdemu et al., 2017). All these issues cause water losses, supply disruptions and production losses. Uncertainty of mandate, ownership and responsibility, as factors that affect irrigation-scheme productivity, have been widely reported in the literature (e.g. de Fraiture & Giordano, 2014).

Land tenure

Land tenure and security of tenure were also mentioned as productivity barriers in both Tanzania and Zimbabwe, as were the small plot sizes and the policy focus on subsistence

farming. In Zimbabwe, these factors seem to have resulted in only 20% of land being utilized and, as farmers have little to sell, comparatively little concern over market access. The concepts of subsistence farming and irrigation are not well matched. For irrigation to be successful, enough surplus income is required to pay for the maintenance and management of infrastructure. Where families need their crops for their own consumption this is not possible. It has often been pointed out that lack of secure tenure provides a disincentive for farmers to invest and makes it difficult to obtain financing, as farmers do not have land to mortgage (Deininger, 2003; Meinzen-Dick, 2014). In Tanzania, irrigators can and should obtain formal title. However, less than 5% have, which they attribute to the high cost, a view consistent with Meinzen-Dick (2014).

Conclusion

There are two main types of barriers to increasing the productivity and profitability of small-scale irrigation systems: those associated with the technical aspects of irrigation infrastructure and those associated with softer issues such as access to markets, knowledge, farm implements and financing, as well as governance. Both are reflected in the literature and the case-study findings. This and other articles in this special issue argue that while much research, policy and donor focus is centred on the technical barriers, it is the softer barriers that are foremost on irrigators' minds. They see these issues as the day-to-day struggle that prevents them from increasing their productivity and profitability. The three country articles also identified a number of technical issues that seriously affect productivity in the schemes. However, even if all the technical issues are resolved it could improve productivity without improving profitability. It does not help to increase the production of products for which there are no markets, or for which markets are already flooded. Collectively, this results in either no profit and/or very low prices. Increased productivity and profitability are determined by many of the softer barriers, such as timely access to knowledge, high-quality inputs and critical implements. To turn increased output into increased profitability, irrigators need to be linked to appropriate market channels and the value chain. In conclusion, this research suggests that a new business model for small-scale irrigation is needed that addresses both the technical and the softer barriers, including governance issues, in a holistic and integrated manner; a promising opportunity is AIPs, which allow better coordination of the actors in the total value chain.

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