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Pathways to Increasing Farmer-led Investments in Sustainable Agricultural Water Management in sub-Saharan Africa

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Working Paper: Pathways to Increasing Farmer-led Investments in Sustainable Agricultural Water Management in sub-Saharan Africa

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SUMMARY

Without a transformative leap forward in the use of irrigation, Africa will continue falling short in the struggle to feed its growing population, improve its people's nutrition, grow its economies, adapt to the impacts of climate change, and eliminate poverty. While Africans must lead this transformation for it to be successful, the international community can help African countries substantially increase the use of more productive and sustainable water management practices and unlock the potential of farmer-led irrigated agriculture. Achieving highly productive irrigated agricultural systems in Africa requires an enabling environment that facilitates the full engagement of farmers, public and private investments, and commercial enterprises. This paper briefly outlines the challenges and identifies promising types of investment opportunities to achieve rapid progress.

The Challenge: Africa Cannot Sustainably Feed Its People without Irrigation

Impressive progress, but sustainable agricultural intensification is critical

During the past decade, agricultural production has increased in many sub-Saharan African countries, raising economic growth rates and reducing poverty. However, progress is uneven: some countries such as Ethiopia and Rwanda have done well, but others lag behind. And even the success cases are vulnerable to shocks, such as major droughts, as seen in Ethiopia in the last two years. Further, the number of hungry Africans increased in 2016 and likely in 2017, as well (FAO et al. 2017). African population is expected to at least double to over 2.1 billion people by 2050, and its food demand is expected to triple in response to this growth combined with an expanding urban middle class. These factors are putting extreme pressure on African agri-food systems. African cereal imports are increasing rapidly to meet rising demand; and its expanding food deficits will increasingly affect global food supply and long-term world food price trends (Jayne et al. 2017).

There is broad consensus that for developing countries, agricultural growth is the most critical driver of long-term economic growth and diversification. Africa's population is relatively young. If agriculture and agricultural services do not provide sufficient employment opportunities; the cities will be flooded with unemployable young people. Growing enough food to feed most of the population and creating attractive agricultural employment opportunities are necessary to achieve long term sustainable development.

Unlike other regions of the world, much of Africa's recent improvement in food production has come from cultivating more land, not necessarily from raising yields. This trend is degrading Africa's remaining forest lands and biodiversity. Recent studies have shown that raising staple cereal yields at a rate that would enable Africa to meet most of its food requirements up to 2050 is not possible through closing the yield gap on rainfed systems alone. Even doubling the annual rate of yield increases will not be sufficient, given the projected rate of population growth. In addition, there is evidence that rising temperatures and changing rainfall patterns may well reduce cereal yields in many parts of the continent. *The only pathway to achieving African self-sufficiency is a major increase in cropping intensity, which will require substantial expansion of irrigation* (van Itersum et al. 2016:5; Mashnik et al. 2017; Hall et al. 2017). This conclusion is consistent with other recent literature emphasizing that sustainable intensification of agriculture is critical for global food security (Pretty and Bharucha 2014; Röckstrom et al. 2016); and that wise investments in irrigation will have multiple benefits globally, and especially in Africa (Ringler 2017). Nutrition-sensitive irrigation development also has great potential to substantially improve nutrition and health outcomes (Domènech 2015).

Changing contours of African irrigation – but scaling-up is needed

Compared to Asia and Latin America, Africa's irrigated area as a percentage of its total cultivated area is small. During the past decade, however, there has been growing interest and substantial growth in irrigation investments from African governments, international investment banks (especially the World Bank and African Development Bank), and other investors. These investments focus on expanding the use of irrigation, as well as improving the performance of both large-scale, government-managed irrigation, and small-scale schemes collectively managed by farmers. For example, in 2013, a "High-Level Forum on Irrigation in the Sahel" proposed to increase investments in irrigation in six Sahelian countries to raise the irrigated area from 400,000 to 1.0 million ha by 2020 (ECOWAS et al. 2016). More recently, the World Bank approved the "Sahel Irrigation Initiative Support Project for Western Africa," aimed at raising regional capacity to develop and manage irrigation. This project is an innovative and ambitious attempt to promote irrigation development in a region where many past investments have been plagued by serious institutional weaknesses.

Private investment in irrigation has also begun to grow. This applies both to the large-scale commercial sector and the smallholder sector, including various blends of the two where the commercial sector works with communities. Companies and non-profit entrepreneurial organizations have demonstrated the huge potential for expanding small-scale farmer-driven private irrigation, especially through low-cost pumps, rainwater harvesting and construction of small reservoirs (de Fraiture and Giordano 2014; Wichelns 2014). Further, it is now clear that groundwater resources are more abundant and widespread in Africa than previously assumed and could provide a sustainable source of water, if developed wisely (Pavelic et al. 2013a, 2013b). In addition, large-scale infrastructure and equipment are required to make good use of the available water resources in many areas, for example medium-sized dams in northern Ethiopia and expansion of irrigation in the large river basins of West Africa.

Recent studies have also demonstrated that farmer-led irrigation is far more common in sub-Saharan Africa (SSA) than has been recognized – indeed farmer-led irrigation is a "blind spot" for policymakers because, in many cases, it is not recognized in official data. Evidence from satellite imagery shows that the irrigated area in SSA is two to three times the official figures; in Ethiopia, the irrigated area may be as much as 4.1 million hectares – 14 times the official figure.[1]

Nevertheless, at current trends, Africa will be forced to import a lot more food to feed its growing population. Improved agricultural water management, especially a substantial increase in irrigation, combined with improved agricultural production systems and value chains, is critical to achieving sustainable agricultural growth and intensification. The question is, how can the use of irrigation be increased in a way that is sustainable and profitable for smallholder farmers, and what role can the international community play?

The Opportunity: Investing in Water Management for Smallholder Farms

Different countries and published studies use different definitions of "small farms." Using two ha as the cut-off, Lowder et al. (2016) estimate that are at least 41 million are in SSA. There are no reliable figures on the exact number of small farms and the area represented for SSA; but globally, in low- and lower-middle-income countries (where most SSA countries fall), about 70-80% of farms are smaller than two ha, and operate about 30-40% of agricultural land. An expanded definition of small farms, up to 20 ha, would likely include most agricultural land in SSA. Herrero et al. (2017) note that smallholder farms are generally more diverse in terms of their crops and play an important role in producing a wide variety of nutrients for humans while also maintaining genetic diversity.

While very small farms will continue operating to meet household needs, there is clearly an opportunity for many, perhaps most, small farms to become profitable businesses, but only if they are well-integrated into effective market-driven value chains. Unlike the large, flat plains and deltas of Asia, African agro-ecologies – soils, climate, policies, cultural preferences – are extremely diverse. Therefore, interventions must be tailored to each context. There is a wide range of available land and water management technologies and practices that can enable African smallholders to increase their productivity and profitability[2].

[1] http://www.iwmi.cgiar.org/2016/02/irrigated-africa-and-asia/, accessed January 13, 2018.
[2] Merrey 2013 provides a recent overview for SSA.

Examples of promising agricultural water management investments

Upscaling irrigation solutions in SSA was a major theme of the April 2017 Water for Food Global Conference, hosted by the Robert B. Daugherty Water for Food Global Institute (DWFI) at the University of Nebraska. The theme was "*Water for Food Security: From Local Lessons to Global Impacts*." This section draws on the African case studies and group discussions at the conference, complemented by other sources where relevant. It is organized around three broad types of irrigation technology: 1) lifting devices (pumps); 2) community-managed small-scale irrigation schemes (especially small reservoirs); and 3) water application technologies. Each case is described briefly, with an emphasis on the potential for investments to support scaling out. Later sections highlight the conditions for success, and present specific recommendations for co-investments by governments, farmers and international financing institutions.

Low-cost pumps

Small, low-cost pumps have been available in Asia for several decades and are now becoming ubiquitous in many SSA countries, as well. There are basically three types: manual or pedal ("treadle") pumps; diesel or petrol-powered pumps; and solar pumps, which are entering the market. These pumps are generally marketed to individual farmers, though there are cases where either a small group of farmers purchases a pump, or, still rare, private firms rent out their pumping services. Value chains are slowly building up in many rural areas, linking farmers to importers (or rarely, local manufacturers), wholesale and retail outlets, and repair services.

Treadle pumps

In the early 2000s, treadle pumps were touted as an important pathway for smallholders to "peddle out of poverty" (Shah et al. 2000; Kay and Brabben 2000). They are more affordable than motorized pumps, though they require considerable labor to operate. They offer the lowest cost solution for poor farmers having little capital, but with access to shallow groundwater, small streams or ponds. Despite success in parts of South Asia where this technology helped many smallholder farmers move from rainfed to irrigated agriculture, treadle pumps have not been widely embraced by African smallholders, except in a few areas (e.g. in Malawi; see Kamwamba-Mtethiwa et al. 2012). But Kickstart International, a non-profit social enterprise, has developed a successful model for expanding the use of treadle pumps. It produces several pump models, which are small, durable, easy to use and repair, and energy-efficient. Retail prices range between $90 and $160.

Working in 16 countries in eastern and western Africa, Kickstart has established a private sector supply chain reaching from manufacturers in China to local shops, with all parties, including the farmers, having viable enterprises. These pumps constitute a major capital expenditure for the farmers, but the benefits can be dramatic. Kickstart reports that, on average, farmers' profits are about $700 annually. It is innovating further through establishing partnerships with other NGOs, financial institutions, businesses, and governments. They also offer financing, such as a layaway plan in which women make micro-payments through their cell phone, and rent-to-own options.

Researchers estimate the potential expansion area of treadle pumps at 24 million ha around SSA (Xie et al. 2014). As in South Asia, treadle pumps may yet prove to be the entry point for many smallholders to move to highly productive irrigated agriculture. They may further intensify production by purchasing motorized pumps with the profits earned with treadle pumps.

Solar pumps

There is growing interest in the potential for using solar irrigation pumps in agriculture. They are non-polluting, can be used at any scale, their costs are declining rapidly, and their availability is increasing. Experiments in west Africa combining solar pumps with drip irrigation for raising high-value crops demonstrated they could be profitable even with high capital costs (Burney et al. 2010; Burney and Naylor 2012; Alaofè et al. 2016). Solar pumps are available commercially in some African countries, such as Kenya (e.g. Sunculture).

A recent project led by the International Water Management Institute (IWMI) examined the suitability of three types of irrigation pumps in Ethiopia: tractor-mounted pump with drip irrigation provided by a service provider; rope and washer pumps, and solar photo-voltaic (PV) pumps[3]. Ethiopia has an estimated potential of seven million hectares that could be irrigated using pumped ground and surface water. The study found that all three types of pumps had advantages and disadvantages, but overall, solar pumps are economically feasible, reduce labor costs, benefit women because they can be used for multiple purposes such as obtaining domestic water, and produce extra income for farmers, for example by charging batteries. The cost of the pumps assessed were about $350 plus installation, but profits were high in comparison to the costs. They pump from shallow wells and irrigate 710-950 m^2.

The study is continuing, examining three business models for supplying solar-powered pumps:

1. Individual farmers purchase a solar pump for own use and/or sale of excess water for profit;
2. Out-grower or insurer scheme-supported model (i.e. agro-business contracts with farmers and provides a pump); and
3. Supplier model with bundled financing (i.e. financing provided directly or indirectly by supplier, including “lease-to-own”).

The next phase of the study will assess the feasibility of these business models. Conditions in Ethiopia are largely favorable for expanding the use of solar pumps in areas where there are accessible water resources and viable market linkages. Demand for solar pumps is high as there are good potential markets for selling produce, as well as high value commodities like coffee for the domestic and export markets; there are government programs aimed at encouraging the use

[3] This case is based on the presentation made at the DWFI Global Conference, but is supplemented by information in a forthcoming research report (Otoo et al. forthcoming).

of renewable energy in agriculture; there is no custom duty on imported pumps; and there is some potential for financing. Donor-funded projects are already introducing solar pumps.

But there are also some constraints, including difficulties farmers have in accessing information and incentives; under-developed value chains; domestic production potential still not realized; limited rural finance; high initial costs; and low capacity for installation, services and repairs. IWMI plans to further pilot-test several investment scenarios. This example shows the importance of establishing effective policies to successfully scale-up new technologies.

SNV, a non-profit international development organization, recently compared the value and effectiveness of a range of water lifting options, including gasoline and diesel pumps, wind-powered pumps, and solar PV and solar-thermal pumps (Nederstigt and Bom 2014). While conventional pumps retain some cost advantages over solar PV pumps, this advantage is disappearing as solar pump costs are rapidly declining. Research estimates the potential expansion area for motorized pumps in sub-Saharan Africa is 30 million ha. A prosperous agricultural economy built on individualized pump irrigation has potential to diversify the rural economy, creating millions of new jobs and improving people's nutritional status (Xie et al. 2014).

While the rapid expansion of low-cost water-lifting devices is an important pathway to scaling-up irrigation by smallholders, there is one caveat: where many individuals are exploiting a common water source, i.e. a small stream or an aquifer, there is potential for over-exploitation in the absence of resource management institutions. This has been documented in Ethiopia, for example. Several farmers saw the adoption of pumps as a way of escaping the social responsibilities entailed in the use of long-standing communal irrigation schemes. The rules for sharing the limited resource that worked well for these schemes were not seen as applicable to the use of pumps, leading to rapid depletion of small streams (Dessalegn and Merrey 2015).

Small-scale community-managed surface/ reservoir systems

There has been a long-standing interest in farmer- or community-managed small-scale irrigation schemes. Most existing SSA schemes have been constructed, rehabilitated or "modernized" with government or donor assistance, with mixed results. There are thousands of small reservoirs in SSA, accounting for nearly half of all irrigated land. They provide farmers and communities with a supply of water for agriculture and other uses, although their productivity is often lower than expected, and they are often not well-maintained. It is therefore critical to understand why this is, and to develop business models for these schemes that are both financially and environmentally sustainable and socially equitable.

There are two types of small-scale communal irrigation systems in SSA: small communal reservoirs constructed for multiple uses, with either very basic or no infrastructure for delivering water to fields; and formal irrigation schemes that include a reservoir or offtake from a small river, conveyance canals, and, usually, control gates. In some formal scheme types, government agencies have a continuing operational role.

Small multiple use communal reservoirs[4]

These are earthen or cement dams generally found in eastern and southern Africa and the Gulf of Guinea region (West Africa). The cost of constructing such schemes is relatively high and normally requires external funding. There is high demand from communities, because they can be used as a source of water for multiple uses, including small-scale irrigation, livestock watering, domestic and small business uses, and fisheries. These benefits are substantial. However, their performance is often below their potential, for many reasons: faulty physical design and poor construction quality, institutional issues related to both construction (corruption) and management, and lack of access to markets. There are also serious potential negative health impacts that must be managed (e.g. malaria, schistosomiasis). Interestingly, these small reservoirs are not very sensitive to climate change scenarios.

A detailed set of tools is available online[5] to support the design, location, maintenance and operation of small multi-purpose reservoirs. These tools can help ensure correct location, design and management of small reservoirs and better control of costs. An important consideration is the institutional arrangements at community level to manage the reservoirs: as Venot et al. (2012) argue, imposing external institutional designs does not work. Rather, development agencies need to encourage local communities to build on existing multiple institutions, such as traditional authorities, to manage their reservoirs.

One estimate claims the potential for expansion is 22 million ha, benefiting some 370 million people with a net revenue from expansion of over $20 billion per year (Xie et al. 2014[6]). Studies in Ghana have found that small reservoirs can meet women's needs for water very effectively. As with other potential investments, a strong value chain is necessary to make these schemes economically viable.

Formal small-scale irrigation systems

Community-managed irrigation schemes, both reservoir-based and those diverting water from rivers, have traditionally been seen as a relatively cost-effective investment to make agriculture more productive and reduce rural poverty. There is evidence they do indeed have better returns than large-scale publicly managed irrigation schemes (Inocencio et al. 2007; Fujii et al. 2011), and, while they often under-perform relative to expectations (Amade 2014; Mwamakamba et al. 2017), they do have significant positive impacts in terms of poverty reduction (e.g. Tesfaye et al. 2008; Gebregziabher et al. 2009). The reasons for under-performance are complex – therefore, there are no universal panaceas. The "barriers to improving farm productivity and profitability in small-scale irrigation schemes are a broad and complex mix of institutional, market,

[4] Drawn from AgWater Solutions Project, Venot et al. (2012) and Merrey (2013).

[5] Small Multipurpose Reservoir Planning Project (https://waterandfood.org/2011/10/21/small-multi-purpose-reservoir-planning/) Accessed January 13, 2018.

[6] This study also suggests there is a potential expansion area for communal river diversion of 20 million ha.

infrastructure and production issues"[7]. Therefore, a multi-pronged approach is needed to support improving these schemes and learning lessons to inform future development.

At the April 2017 Water for Food Global Conference, Sithembile Ndema Mwamakamba, from FANRPAN, reported the results of a recent project aimed at increasing irrigation productivity in Mozambique, Tanzania and Zimbabwe[8]. While the specific findings and recommendations vary in the three countries studied, the broad finding is clear: reform of currently insecure land (and water) tenure, strengthening farmer organizations, and reforming policies so that governments step back from scheme management and foster market access are required (Mwamakamba et al. 2017). Examples of specific issues that must be addressed include: plot sizes that are too small to sustain irrigation operations and household livelihoods (Shah et al. 2002; Moyo et al. 2017); government imposition of rules requiring cultivation of staple food crops; and poor or no access to labor-saving equipment or effective markets.

Four broadly applicable lessons emerged (Pittock et al. 2017; DWFI 2017):

1. Because small-scale irrigation schemes are complex systems, multiple, concurrent interventions are required to transform them to more profitable and sustainable states.
2. It is as important to invest in people as in hardware to achieve success: "soft barriers were most limiting for the farmers."
3. Governments need to clarify their objectives and empower farmers. Farmers should be encouraged to produce profitable crops for local markets, and to expand their enterprise where they can.
4. Effective markets provide both the incentive and the means to invest: "it is this positive reinforcement from the agricultural market that will maintain more sustainable and profitable irrigation."

On-farm water application technologies

While there are excellent investment opportunities in technologies that bring water to smallholder farmers' fields (e.g. pumps, communal irrigation schemes), there are fewer tried and tested on-farm water management application technologies that are attractive to smallholders. Here we briefly review experiences with low-cost drip irrigation kits, center pivot irrigation, and several other potential smart technologies.

Drip irrigation

Drip irrigation has been widely adopted by commercial farmers for irrigating high-value crops. High-pressure drip irrigation has many benefits for such farmers. Therefore, many donors,

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[7] Sithembile Ndema Mwamakamba, speaking at the DWFI Water and Food Conference (DWFI 2017).

[8] See papers recently published in *International Journal of Water Resources Development* Volume. 33, No. 5 https://doi.org/10.1080/07900627.2017.1326881.

governments and NGOs have sought to develop and disseminate low-cost, low-pressure drip irrigation kits to smallholders. Several NGOs and private firms, with donor support, have developed low-cost drip kits, pilot-tested them in the field, and attempted to promote wider uptake.

However, the evidence[9] that these low-cost drip kits produce the expected benefits sustainably and at scale is scant, and assessments that are available demonstrate that farmers struggle to continue using them after projects end. However, this does not mean that drip irrigation has no future. Rather, the focus of investments should be on making modular higher-quality drip irrigation systems available in the market. "Modular" is important, as a smallholder may wish to start with using drip irrigation for high-value crops on a small scale, and expand it after gaining experience. Private firms should be encouraged to continue investing in drip irrigation improvements, marketing and farmer education. Making such high-quality modular drip irrigation systems available along with pumps and other equipment would increase the likelihood of synergies.

Center pivot irrigation

At the April 2017 Water for Food Global Conference, Richard Berkland, from Valmont Industries, Inc. reported on the application of the *CIRCLES concept* to make center pivot irrigation a viable option for small farmers in Africa. Berkland sees a potential to organize several small farmers to cultivate under one center pivot irrigation system if costs can be reduced, viable business models developed, and critical issues, such as land tenure can be addressed. He demonstrated that adding additional spans to increase the length of the pivot increases the potential area irrigated at a rapidly decreasing cost per hectare. In other words, while a small pivot can be prohibitively expensive per hectare, at the 40- to 75-hectare size, the cost is more affordable.

This experiment is at an early stage, although there are similar investments underway elsewhere in Africa. The goal is to demonstrate how smallholder farmers could significantly increase net household income by farming under center pivot irrigation. Success requires the use of modern methods in irrigation, seeds, tillage, fertilizer, and pest control; flexible, affordable credit and the opportunity to build equity; access to local, regional, and export markets; and institutional support that empowers farmers and their communities.

Previous attempts to promote joint management by African smallholders of capital-intensive irrigation technologies, including center pivot systems, have had mixed results. In both southern Africa and West Africa, the available data show they are difficult to sustain, especially when handed over to the community without ongoing support. Problems include uncertain market conditions, lack of access to financing at a reasonable cost, inadequate and unreliable availability of spare parts and service, and the transaction costs involved in coordination and enforcement of rules among multiple farmer (Merrey and Sally, 2014; Sher and GRET Groupement, 2012; Van Averbeke 2012). Therefore, more analysis of the necessary policy and infrastructure enabling

[9] See Merrey and Langan 2014, Merrey 2017, and Venot et al., eds. 2017 for reviews of experiences.

conditions combined with investments in practical field experiments are needed to identify whether there are viable business models that can overcome these impediments. Partnering smallholder groups with commercial enterprises is one possible approach.

"Smart" irrigation management technologies for small farms

As more African farmers adopt irrigation, the demand for tools that help them increase their irrigation efficiency, productivity, and produce quality, and reduce costs, will grow. The DWFI Global Conference highlighted impressive water management technologies that are available to American farmers. These include satellite- and internet-based tools that enable farmers to precisely target irrigation and fertilizer to specific sub-areas within their fields. In their current form, these are unlikely to be suitable for direct adoption by small or medium-sized farms in SSA. However, there are interesting experiments underway to test low-cost technologies in partnership with smallholder farmers to increase the efficiency and effectiveness of their irrigation practices. While this is encouraging, it is important to carefully consider whether such support tools are likely to be of use to farmers or other potential users in the value chain, or are simply a solution seeking a problem.

An example is *wetting front detectors*, which are basically tubes buried in the soil containing a calibrated float. When the soil water gets to a certain level, the float rises, indicating that the desired level of wetness has been attained (Stirzaker 2003). Uptake has been limited, but recent experiments have focused on co-learning with farmers in Ethiopia (Schmitter et al. 2016) and in several southern African small-scale irrigation schemes (Stirzaker et al. 2017). Farmers responded positively, and there is evidence that both their yields and water productivity improved. There is also some evidence of adoption by neighboring farmers. This suggests that investments should continue in collaboration with farmers, and with support to encourage private firms to produce and sell them.

Affordable smart phones with access to the internet are becoming ubiquitous in many rural areas of Africa. These, too, offer still-untapped business opportunities, not only as ways to gain market information or as a means to transfer funds, but also to access weather forecasts and online software to make irrigation more precise and cost effective. An example is Farmerline, which provides daily weather updates as well as assistance on getting seeds and fertilizer on credit and access to market prices in local languages in 11 African countries. Other examples can be found on the Apps4Agriculture database, which lists about 400 apps available to enhance agriculture as a business. A major need is financial support, both for further development of technologies, and for social marketing to inform farmers of their availability and how to use the new tools.

Strategies for scaling-up irrigation management innovations

Scaling-up the pace of African irrigation development, and helping farmers increase their productivity and profits, requires new thinking about the means to do this. Farmers need to have greater access to information, such as how to use water more productively, as well as input and output markets. Two recently developed approaches to increasing farmers' knowledge are the use of “Farm Business Advisors”, and the use of social-learning approaches, such as innovation platforms.

Farm Business Advisors (FBAs) are commission-based entrepreneurs who provide four basic services to farmers: inputs and equipment, for example drip irrigation kits; services, mainly in the form of agricultural advice and installation and servicing of equipment; advice on output markets; and advice and assistance in obtaining loans. iDE, a non-profit international social enterprise, has pilot-tested this model in Zambia. Over time, the cost of fielding FBAs declined significantly as the number of clients increased, and both the FBAs and the farmer-clients have profited financially. Factors contributing to this success include a built-in data feedback loop, sales training for FBAs, and adaptive, flexible management. Most FBAs use their mobile phones to collect data and arrange meetings. The profitability of this model for all partners makes it an attractive option for scaling-up.

The other approach focuses not on transferring knowledge from “advisors” to farmers, but on co-learning through joint design and implementation of experiments and periodically sharing experiences among a wider set of stakeholders using *innovation platforms*. As discussed above, researchers and farmers used a co-learning approach to test wetting front indicators, with positive results (Stirzaker et al. 2017). A more sophisticated approach is based on the premise that irrigation systems (or more broadly irrigated agriculture) are socio-ecological systems embedded in complex institutional networks in which multiple actors – not only farmers, but local government officials, local business people, local citizens, etc. – have roles and stakes in the irrigation enterprise. Innovation platforms are an institutional mechanism to bring representatives of these interests together to identify, co-test, co-learn, and adopt innovations to improve irrigation performance (van Rooyen et al. 2017; Swaans et al. 2013).

Although the FAB and innovation platform models are based on somewhat different premises, combining them could offer a cost-effective way to help African irrigators use their water more productively and profitably. More work is needed to develop practical approaches to co-learning shared lessons, disseminating knowledge widely, and business models for providing new technologies.

Conditions Necessary for Successful Investment in Smallholder Irrigation

Traditional approaches to developing and revitalizing publicly funded irrigation systems have underperformed in terms of agricultural productivity and financial viability, especially in SSA (Lankford, et al. 2016). This, until quite recently, contributed to a reduction in government support for such investments. While public funding to the sector sharply declined, in parts of Asia, farmer-led investments, such as the development of groundwater, led to an overall continued expansion of irrigated agriculture through private funds, albeit with government subsidies. This process has also begun to be observed in SSA. *Intensification and, where resources permit, expansion of irrigated agriculture and increasing its productivity, sustainability and profitability must be farmer-driven to succeed.*

Based on the cases reviewed in this paper and other experiences, this section briefly outlines five necessary conditions for successful investments in irrigation.

1. *Irrigated agriculture must be profitable*. In the past, policies focused on achieving national food security have required farmers to produce a particular staple crop, despite it being less profitable than other options. Investments in irrigation must begin with assessing the potential demand for irrigated agricultural products – for which competitive output markets, and information about what is demanded, are necessary. Well-functioning input markets are critical as well—if irrigation equipment or inputs like seeds are too expensive, farmers will not invest. Market effectiveness is being enhanced through cellphone systems.
2. *Affordable financial services must be available*, providing access to credit, so farmers can purchase the inputs and equipment they need. Even seemingly low-cost treadle pumps are a major investment for most African smallholders; small-scale irrigation technology is "elitist," as one participant noted at the DWFI Global Conference. More innovations need to be promoted to enhance the availability and affordability of financial services in rural Africa.
3. *Fertile land and a reliable, sustainable water supply* are obvious necessities. But studies have shown that secure land and water tenure and clarity on responsibilities for maintaining and managing irrigation infrastructure are critical to encourage farmers to invest. Therefore, governments need to establish clarity on water and land rights, as well as on responsibilities involved with irrigation infrastructure.
4. *Effective and fair institutional arrangements at the local level* are needed to manage common resources and infrastructure. The work on small multipurpose reservoirs has shown that building on existing local institutional arrangements is more effective than attempting to impose a formal water users' association model. As noted by Pittock et al. (2017), "improving sustainability of these complex systems will require: multiple interventions at different scales; investing in people and institutions as much as hardware; clarity in governments' objectives for their smallholder irrigation schemes; appropriate business models to enable farmers; and better market linkages." Equity is a crucial ingredient: smallholders are in weak positions compared to large firms and women are often treated as second class citizens. Providing women with access to productive resources and markets has been shown to have excellent benefits; but because conditions vary greatly, strategies to achieve greater gender equity need to be tailored to the local situation.
5. *Leveraging the multiplier effects of irrigation.* The total benefits accruing to the larger economy from multiple linkages between profitable irrigated agriculture and other sectors can be huge: examples are creating new businesses such as providing services to irrigators (see e.g. Bhattarai et al. 2007; Hagos et al. 2009; Jayne et al. 2017; DWFI 2017), and job creation for young women and men[10]. In India, at least two thirds of the benefits of irrigation

[10] For more examples of youth engaging in agri-businesses, see https://www.devex.com/news/for-the-new-generation-of-farmers-it-s-business-unusual-

development has accrued to the non-farm sector (Bhattarai et al. 2007). Planning and encouraging investments in related sectors can enhance the benefits of irrigation investments. Collaborating with farmers to co-learn lessons and build capacity as well as self-confidence should be at the core of such investments.

Recommendations: Where to Invest to Promoted Irrigated Agriculture in SSA

The case studies illustrate irrigation technologies with very high potential as investment opportunities. These should be considered seriously by governments and both public and private investors. We conclude by identifying five types of enabling public investments that can create more attractive conditions and opportunities that will in turn attract private as well as further public investments. These types of investments support the theme of encouraging demand-driven farmer-led irrigation development.

1. There is an urgent need for more investment in *capacity strengthening* at multiple levels: applied water management research; technical support and advisory services; entrepreneurship; and farmers' knowledge and skills. Strengthening research capacities involves both investing in human resources and reforming research institutions to make them more attractive places to work and more effective. External funders can make important contributions through long-term co-funding and partnerships.
2. Enhancing access to *financial resources* has consistently been identified as a major strategy to rapidly increasing the use of irrigation. Currently, smallholders find it difficult to afford the few hundred dollars required to purchase a pump, and small local agro-businesses also struggle to obtain operating capital to stock equipment and spare parts, or to develop and implement new services to irrigators. Innovative public-private financial instruments aimed at supporting the entire irrigated agriculture value chain should be scaled-up in collaboration with local banks, cooperatives, and farmers' organizations.
3. A major constraint to agricultural development in rural SSA is the inadequacy of *supportive infrastructure*: transport (roads, railways), electricity, communications, and storage and processing facilities for agricultural products. We recommend a two-pronged investment strategy: a) in remote areas with land and water resources that can be exploited, increase the pace of both public and private infrastructure investments in supportive infrastructure to make irrigation investments attractive in the longer run; and b) for achieving rapid impacts, target irrigation investments to areas that already have other basic infrastructure.
4. The level of investments in agricultural *research and development* in Africa is extremely low, and to date has had very little impact compared to research and development impacts in other regions (Jayne et al. 2017). Investments are especially lagging in agricultural water management, including irrigation. African governments and the private sector should be

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encouraged to raise the level of funding of applied agricultural and especially water management research, and also implement reforms to create the institutional support system that will encourage innovation. External funders could contribute to this by offering attractive long-term co-funding.

5. Finally, but perhaps most critical of all, *is policy reform*. The attractiveness of investing in irrigation technologies and services is to a large extent a function of policies related to imports, currency exchange rates, competitiveness of input and output markets, and regional trade policies. Numerous studies have identified these policy areas as major impediments to investments – and major opportunities to encourage investments (e.g. Jayne et al. 2010; Giordano and de Fraiture 2014; Fanzo 2017).

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