SYNTHESIS REPORT

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Farmer-led irrigation in sub-Saharan Africa: synthesis of current understandings

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Cover image: A man and woman using bucket irrigation, Mozambique. Photo: Tessa Steenbergen.

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Acronyms

AfDB	African Development Bank
AGRA	Alliance for Green Revolution in Africa
AMPPPIDA	Assessing Models of Public-Private Partnerships for Irrigation Development in Africa
AQUASTAT	FAO database of statistics about water
CAADP	Comprehensive Africa Agriculture Programme
CAWMIA	Comprehensive Assessment of Water Management in Agriculture [IWMI 2007]
CIAWDF	Continental Irrigation and Agricultural Water Development Framework
DEGRP	DFID-ESRC Growth Research Programme
DFID	Department for International Development
EPG	Evidence and Policy Group
EPIC	Établissement public à caractère industriel et commercial (Public body of industrial and commercial character)
ESRC	Economic and Social Research Council
FAO	Food and Agriculture Organization of the United Nations
FARA	Forum for Agricultural Research in Africa
FCFA	CFA franc
FLI	farmer-led irrigation
GDP	gross domestic product
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GWSP	Global Water Security & Sanitation Partnership
ha	hectare
HIC	high-income country
hp	horsepower
ICID	International Commission on Irrigation and Drainage
IFPRI	International Food Policy Research Institute
IWMI	International Water Management Institute
k	thousand
KfW	Kreditanstalt für Wiederaufbau (Credit Institute for Reconstruction)
LDC	least developed country

LIC	low-income country
LMIC	lower-middle-income country
LSIS	large-scale irrigation scheme
M	million
MIC	middle-income country
NEPAD	New Partnership for Africa's Development. An economic development programme of the African Union.
NGO	non-governmental organisation
ODI	Overseas Development Institute
OdN	Office du Niger, Mali
PPP	public-private partnership
PV	photovoltaic
SAFI	Studying African Farmer-led Irrigation
SDG	Sustainable Development Goal
SME	small and medium-sized enterprise
SSA	sub-Saharan Africa

Summary

Interest in irrigation in sub-Saharan Africa has revived since 2000, in line with the revival of interest in agricultural development and food security in general. Compared to Asia, where more than one-third of cultivated land is irrigated, official records for sub-Saharan Africa (SSA) show corresponding statistics of just 4% to 6% of cultivated land irrigated. To meet Africa's food needs in 2050 without increased imports will almost certainly require a considerable expansion of irrigation.

At first sight, given the small fraction of agricultural land irrigated at present and considerable unused water sources, there should be scope for expansion. To do so, however, is challenging, whether irrigation is promulgated by farmers or governments, as this report will show.

This report focuses on irrigation initiated by smallholders, 'farmer-led irrigation' (FLI). Most farmers in SSA are smallholders, and much of the increased area under irrigation seen in the new century has come from FLI, rather than from public schemes or the irrigation on large commercial farms. The report addresses the following questions:

- What is known about the extent of FLI in sub-Saharan Africa in the 2010s? What has been developed, and how?
- How successful has FLI been? What problems arise? How do such developments compare to irrigation that has been initiated by public authorities?
- How has public policy either assisted or hindered FLI? What are the lessons for policy-makers?

This synthesis brings together findings from research conducted under the DFID-ESRC Growth Research Programme (DEGRP) with the wider literature on irrigation in SSA, especially relatively recent findings.

Previous experience of irrigation in sub-Saharan Africa

From colonial times onwards and into the early years of independence, governments across SSA favoured large-scale public schemes for irrigation, with tenant farmers supervised by a central authority. Designed with priority to engineering considerations, these large show-case schemes all too often failed to meet their objectives and did so at high cost. Smaller-scale public schemes suffered similar fates. By 1980 or so it was clear that too many had failed, and governments became wary of creating new schemes.

To remedy some of the defects of the public schemes, the 1980s and 1990s saw more farmer participation in their operation, either with greater participation in decision-making by the central agency, or by farmers taking over control of some or all operations through water user associations. Despite the high hopes vested in this reform, often they were frustrated: having farmers run the schemes did not overcome some of the technical problems experienced, nor did it reduce the high costs of some schemes. Enthusiasm for farmer participatory management of public schemes thus wilted.

Subsequently, much of the expansion in irrigation has been from farmer-led initiatives.

Farmer-led irrigation in the 2010s

The full extent of FLI, much of it small-scale and informal, is not known. It seems that substantial areas are not captured in official statistics. Localised estimates indicate that such irrigation may cover considerable areas, several times the area officially recorded as irrigated. Hence some of the much-vaunted additional area to be irrigated may well already have been developed.

Forms of FLI are diverse. Generally, farmers prefer, where possible, to abstract water from lakes and rivers and deliver it to fields by gravity. When gravity is not possible, then water has to be pumped, sometimes by hand or animal, but

increasingly using small motorised pumps. When surface water cannot be found, then wells may be dug to obtain water, be they shallow wells to reach water tables close to the surface, or deeper tubewells to tap groundwater aquifers.

Farmers, lacking formal finance, tend to economise on capital costs, resulting in some fairly rudimentary but cost-effective and locally suitable structures, canals and water application methods.

FLI has been stimulated by market opportunities, above all the rapidly growing urban markets for higher-value produce. Most of the newly irrigated areas produce fruit, vegetables, fodder for dairy cows, and the like – but not often staple crops, with the marked exception of rice, which is something of a premium staple in many parts of Africa.

Most investments by famers in irrigation rely on informal finance, from borrowings, savings, family and friends.

Although plenty of FLI is individual, economies of scale in capture of water and conveyancing in canals means that farmers' groups have been formed to make irrigation possible. Groups then allocate informal rights as well as financial contributions, duties and rules of water use.

Among the diverse forms of FLI, two contrasting extremes can be seen. At one end of the spectrum can be seen micro-irrigators, watering plots of a tenth of a hectare (ha) or less, often by hand, to produce vegetables for home eating and local sale. For those on very low incomes, such tiny irrigated plots can be a vital component of their livelihoods, but they do not necessarily contribute much to overall agricultural output. At the other end of the spectrum lie small-scale commercial irrigators who water between one and 10 ha, typically using motor pumps, who farm intensively, and sell much of their harvest to generate gross returns that can reach $5,000 per ha or more – thereby allowing them to buy inputs and equipment, and to hire labour. They make a significant contribution to overall output and to the local economy.

Although this simplifies, since irrigators are distributed across a spectrum rather than divided into two camps, the distinction can help to resolve some debates about FLI. If some see FLI as largely about micro-irrigators, while others see the small-scale commercial growers, then the stage is set for debate at cross-purposes.

Assessing farmer-led irrigation

Assessments of informal irrigation tend to suffer from a bias to surviving systems. When informal irrigation fails, it often disappears, unlikely to attract the attention of researchers.

Most assessments of irrigation focus on **increased physical production and increased incomes for irrigators**. When irrigation works well, soils are productive, farmers have the skills and can get their produce to market, returns from irrigated land can be several times what is possible from rainfed crops. Irrigation also generates more jobs than rainfed cultivation. Such employment is especially welcome in the dry season, when previously there was little work to be had. Furthermore, irrigation can multiply local activity, stimulating additional activity in supply chains, as well as in the rural economy as a whole, as irrigators spend some of their increased incomes locally.

Much less is quantitatively known about the **productivity of water and the efficiency of its use**. In many cases, such measurements, which are costly to undertake, may not add that much extra knowledge to how farmers manage multiple inputs and constraints, but this gap does mean stakeholders cannot objectively judge the performance of different types of irrigation.

Most of the **physical problems** reported from FLI concern over-abstraction of water, especially when water scarcity and competition increase in dry seasons and droughts. When groundwater is overused, well levels can fall. When surface water is unduly abstracted and consumed, downstream users may be denied irrigation or even drinking water. Depletion may increase to the extent that streams and rivers dry up, leading to impacts on environmental flows and economic activity (such as hydropower generation).

In other cases, irrigation conflicts with the interests of pastoralists who lose dry season grazing or who find that their migratory routes have been blocked by farmers keen to protect irrigated fields or works from damage.

Other problems concern **the relation of irrigation to the rest of the economy and society.** Almost nowhere do the ideal conditions for irrigation apply. Access to formal finance, to good quality farm inputs, are commonly deficient – while lack of storage and transport difficulties can mean difficulties in selling extra produce from irrigation and avoiding market gluts that lower prices.

Social equity is a critical concern. Who gets to irrigate, and what are the consequences for their neighbours who do not? Many accounts of informal irrigation record that those irrigating tend to be those with better-than-average incomes, land, labour and education – so that irrigation has been described as a 'privileged solution'.

Not much evidence exists, however, on what effect this has on those less fortunate, or less enterprising. Potentially, irrigation helps others since it creates more jobs, both on-field and in subsequent processing, storage and transport – with additional jobs arising from multipliers as irrigators spend their enhanced incomes. Increased output from irrigated land may improve the availability of food locally and reduce its price.

On the other hand, if the land irrigated has been co-opted, it may deprive others of their livelihood. This is particularly likely when irrigation spreads on lands regarded as commons, for rainfed farming, grazing, hunting and gathering. Systematic evidence of such impacts, positive or negative, does not seem to exist: it is thus hard to appreciate just how often they arise and under what circumstances.

The impacts of irrigation on women are varied. On the plus side, irrigation may allow women farmers to produce more from their land, leading to more food security or income. Irrigation may raise household incomes from which women and children benefit; while other farmers' irrigation may create increased demand for labour and push up rural wages, on which some women on low incomes depend. Canals and furrows may be a more convenient source of water, saving time collecting water.

On the downside, men may appropriate irrigated land formerly allocated to women. Women may have to spend more time working in household fields, while men decide the crops to be planted and use of the income generated. Where irrigation has increased health risks – see below – women may bear the brunt of caring for sick members of the family.

Much depends on power relations and gender norms. When women are more empowered – having access to land and water; being able to decide on crops and their disposal; being able to decide how to spend household income – there's more chance that irrigation will benefit them and their children.

Where women are less empowered, they benefit less or end up becoming worse off. Projects that promote irrigation technology regardless of gender routinely see men disproportionately take up the improved technology.

Irrigation affects the **natural environment** – both directly through abstraction of water changing hydrological systems, as well as less directly through the way irrigated land is farmed. Potential effects and problems include: loss of water to rivers and wetlands, affecting ecosystems, groundwater and fisheries; land and soil degradation; loss of agricultural biodiversity; and pollution from overuse of fertiliser and chemicals.

Although these risks are frequently alluded to in the literature, specific accounts of environmental impacts resulting from FLI in sub-Saharan Africa seem to be few. Over-abstraction of groundwater, however, has been reported for parts of West Africa.

Irrigation may also potentially impair **human health**, through waterborne disease in canals, toxic chemicals used on farms, higher water tables impeding sanitation, and unsafe irrigation water being used domestically. On the other hand, increased income and extra food production from irrigation can improve human health. Documented impacts on health, however, are few. The one study that tried to compare the benefits of irrigation to health costs found a net benefit.

A YOUNG MAN LAYING A DRIP IRRIGATION KIT IN HIS KITCHEN GARDEN IN KABUCHAI, BUNGOMA, WESTERN KENYA, MARCH 2011. PHOTO: KENNEDY OPONDO / FOOD ETHICS COUNCIL

Irrigation policy

The literature on irrigation policy consists in large part of two streams. One is **normative**: setting out what needs to be done. Derived from an assessment of challenges and opportunities, these typically recommend measures: to improve farmer access to irrigation technology, farm inputs and finance – especially for women farmers; to avoid harm to the environment and human health; and to develop collective institutions to govern water use.

The other stream is more **empirical and analytical**. Contemporary policies typically favoured for irrigation are assessed for their merits, often with discussion of why they were chosen. In the past this literature focused on large-scale public schemes and why they came to fail; more recent accounts have turned to FLI, noting that some governments have all but ignored it.

Leaders of irrigation agencies, they argue, tend to see smallholders as lacking the necessary skills to implement effective and efficient irrigation.

At continental level, official policy frameworks for irrigation are set within the renewed drive for agricultural development, established by the 2003 **Maputo Declaration**, made operational by the **Comprehensive Africa Agriculture Development Programme (CAADP)**, reinforced by the 2014 **Malabo Declaration on Accelerated Agricultural Growth and Transformation**.

With respect to irrigation, CAADP includes irrigation as part of its Pillar 1 Framework on Sustainable Land and Water Management.

2018 saw three significant reports and declarations with respect to irrigation. One is the **Malabo Montpellier Panel report on smart irrigation** which recommends more priority to irrigation. A second is the September 2018 **Kigali Joint Statement on Inclusive and Sustainable Farmer-led Irrigation** prepared at the 2018 African Green Revolution Forum conference. This singles out FLI and commends it. The third, closely associated with the second, is the **World Bank and Global Water Security & Sanitation Partnership (GWSP) initiative on farmer-led irrigation.**

Other similar initiatives are in the pipeline. For example, the African Union is preparing a **Continental Irrigation and Agricultural Water Development Framework** (CIAWDF) to launch later in 2019.

All three 2018 initiatives see financing irrigation and making use of improved technology as central to irrigation development: all three recognise the private sector as a prime mover in providing finance and technology. Hence much interest has been shown in public-private partnerships (PPP) between public agencies and formal firms to facilitate this.

PPP may provide the capital and know-how to improve on previous efforts: but effective partnerships require considerable care and time, including working with smallholders involved, if they are to allocate costs, benefits and risks fairly and effectively across the different parties. PPPs may spare public agencies investment funds and field staff, but they call for quite advanced skills in planning and negotiation.

Policy successes with FLI are either scarce or not documented. A prime need is to have working models of policies that have been evaluated as effective, at least in given circumstances.

Policy implications

Supporting farmer-led irrigation development (FLID)

A key challenge is to convince some policy-makers that FLID can contribute to development in the ways the evidence suggests it can. The Kigali Joint Statement on Inclusive and Sustainable Farmer-led Irrigation of 2018 and the World Bank initiative on FLI of the same year perhaps suggest that the tide is turning; that policy-makers may be approaching the topic with fresh eyes.

If so, two distinctions highlighted in this synthesis may help in framing policy: social and temporal.

Socially, for those who irrigate on a very small or micro scale, micro-scale irrigation can be seen as part of the livelihood strategies of people on very low incomes, often marginalised and vulnerable people. Public subsidies and assistance to support their irrigation thus need to be compared to cash transfers, food aid, pensions and other forms of social assistance, in terms of the benefit conferred per public dollar spent, coverage of the vulnerable and equity of provision.

Notwithstanding, a technical agenda exists for micro-irrigation. There are usually ways to make simple systems more effective and efficient, and technical problems to solve – such as making sure that drip kits are robust for field conditions. Moreover, some micro-irrigators, even if not all, may be able – with some support and assistance – to graduate to small-scale irrigation.

For the more commercial small-scale irrigators, many of their needs form part of the mainstream issues of agricultural development; that is: facilitating access to technology and finance, and marketing. Where irrigation is carried out by groups, opportunities to improve the performance of their groups may exist – such as training in book-keeping, in registering water rights, leadership skills, etc.

The other distinction is that of the **stages of irrigation development** that unfold at catchment level. Irrigation uptake and expansion can be seen as typically passing through three stages.

In Stage One, initially little irrigation may take place because conditions are lacking – including prices and incentives to grow more; skills and knowledge of irrigation possibilities; scarcity of capital to take up irrigation opportunities; or inability of farmers to combine where collective action is needed to put water to use.

In Stage Two, conditions for irrigation improve. Many more farmers, individually or in groups – depending on water resource, technology knowledge and social cohesion – take up the opportunity. This can often happen rapidly and suddenly. Once thresholds of returns to irrigated crops, of technical skills and understanding, of acceptance of risk and, indeed, of the confidence to act are passed, individuals and groups may quickly and simultaneously act, with cumulative effect, as innovators provide examples for others.

Since some farmers or groups have advantages over others in skills, access to funds, political connections and so on, this process will probably increase differences between farmers. Development projects can, of course exacerbate this by privileging some farmers or areas over others, when sites and participants are selected.

In Stage Three, irrigation becomes increasingly significant in the water basin, as substantial fractions of the irrigation potential are taken up – surpassing water capacity in some cases. Systems, both the physical irrigation schemes and the human interactions, amalgamate. What may have worked well at smaller scale can become problematic when aggregated.

In the first stage, policies and public investments to support FLI are largely quite straightforward. They consist of building roads and other public infrastructure; while ensuring that obstacles to investment in agriculture – heavy taxes on output or inputs, high inflation, cross border tariffs, etc. – are remedied as far as possible. Activities include those seen in traditional development projects: investing in infrastructure, training of farmers, organising in groups, etc. Less straightforward are the challenges of overcoming the lack of access of most smallholders to financial services, heavy plant equipment, inputs and technical knowledge.

As irrigation is increasingly taken up in the second stage, then additional measures to facilitate farmer-led development become appropriate. These include helping farmers raise the performance of their irrigation, including training, soil moisture management and water scheduling; helping would-be irrigators to overcome obstacles they face in adopting irrigation; spreading benefits to the poorest within irrigating communities; and starting to regulate use of water, especially during dry seasons and droughts, to ensure water consumption does not exceed supply.

By Stage Three more demanding policy challenges are indicated, above all in finding effective ways to regulate water use, assign rights and to mediate any conflicts over water use. Public agencies need to help create institutions and allocate rights (1) to resolve collective problems of water consumption arising from large coalesced irrigated areas that harm economic sustainability in catchments with substantial irrigation; and (2) to mediate and resolve conflicts between farmers located within and across irrigation systems. The challenges of effective and equitable regulation can hardly be overstated, given that irrigation's various impacts arise at different scales and times, the complexities of natural systems, temporal variations in water supply and demand, and the political conundrum that first movers feel they establish rights to water through their initiative.

Indeed, so forbidding is the agenda of regulation, that an understandable response is to retreat to a narrower focus on, say, irrigation engineering, where the issues appear more tractable. Neglecting the challenges, of course, is only likely to make them even more daunting when they simply must be addressed.

The organisations and institutions required, the knowledge and data, the political forums needed to address these issues cannot readily be prescribed: they will need adaptation to national and local circumstances. Moreover, if they are to succeed, they will probably need to evolve. That said, knowing about working models in other catchments and countries can provide inspiration and encourage decision-makers to begin the process of creating the structures and institutions for regulation of water.

It is easy enough to outline a policy agenda, but harder to put it into practice, for the following reasons:

- The stages outlined above are schematic. It may not be that clear when irrigation has passed from one stage to another, especially from Stage Two to Three. Moreover, within any country, different timings may apply in different catchments; while catchments may not correspond to administrative divisions. While not impossible to differentiate policy by river basins, this complicates the public task – central agencies tend to prefer standard approaches across the country.

- Irrigation is an unusually extensive and deep change for agriculture. It can throw up a wide array of demands and challenges. For public agencies this creates heavy demands on their capacity and for coordination across agencies.
- The temptations of dysfunctional policy are clear. Politically, large schemes with highly visible irrigation works can satisfy the need to be seen to be acting decisively, to modernise and to transform. Focusing on engineering alone can be satisfying in reducing a potentially wide and complex agenda to something more focused. Treating social issues as the failings of 'conservative' or 'traditional' farmers who need to be instructed in new ways is tempting.
- Last, but not least, for some policy functions, good working models are not obvious. This applies above all to regulating resources, assigning rights and mediating disputes.

Calls for **a more comprehensive approach to irrigation** policy are well founded. Responding to President Obama's call for the 'right irrigation' in SSA, Lankford (2009) recommended taking a comprehensive approach that uses a mixture of technologies, builds on local capabilities, brings engineering know-how, is supported by a range of other services and acknowledges other water needs within catchments.

To do all this is not easy. One approach to bringing stakeholders together to address issues that affect them involves the agricultural innovation platforms, field tested in Southern Africa.

In sum, the policy challenges of FLI are substantial. Moreover, the challenges can be quite varied, ideally requiring tailored approaches to different schemes. While ideal, that is rarely possible for most public agencies in low-income countries (LICs).

Policy successes with FLI are either scarce or not documented. A prime need is to have working models of policies that have been evaluated as effective, at least in given circumstances.

Gender and policy

Those who see irrigation as an arena where patriarchal norms tend to prevail recommend two initial steps to taking a more gender-sensitive approach. One is to see that many irrigators are women farmers; the other is to recognise that women may have different priorities and perspectives on irrigation. For example, women are more likely to see an irrigated plot as a reliable provider of food for the household; they are more likely to prioritise forms of irrigation that produce food more dependably.

This does not mean that women farmers do not see market opportunities and cannot benefit from extra cash earnings: just that they do not see that as having priority over feeding the family. Reflections on women's perceptions, however, need to be appreciated within their setting of time and circumstance. Rather than being the representation of some fixed, determined differences in outlooks of men and women, women's views will vary as circumstances change and as time passes.

Beyond these considerations lie the practical needs of women as irrigators: ensuring that they have access to land and water, to technology and technical advice, to support services and inputs. And that all of these are tailored to women's circumstances of limited labour time and capital. A major challenge is to make sure that women's rights and interests are reflected in regulations and governance of irrigation, especially in situations where men's voices and interests are assumed to have priority.

Further research

This review reveals persistent gaps in evidence necessary to form a better understanding of the subject. Priorities include:

- Improving the data available that records areas under irrigation, for what crops, with what technology, and operated by which farmers. While this may not be easy to record accurately, better estimates – reliable to, say, plus or minus 20% – could be made than currently, where official data may understate the extent of irrigation by an order of magnitude. More ambitious would be to estimate the water abstracted by irrigation, how much reaches plants and how much is returned to the catchment or aquifers:
- Drawing on better data, then reviewing irrigation's sustainability by analysing its effects, including crop production, water consumption externalities on downstream water security, energy use and social costs, such as exclusion of the poorest.
- Building on the previous point, benchmark performance across different types of irrigation systems, enabling policy-makers to understand how different technologies (e.g. treadle, drip, large, small) compare across the registers of water, land, energy, labour and finance.
- Similarly, the above data collection and reviews could then form the basis for assessment of irrigation's contribution to creating decent jobs, reducing poverty and improving food and nutrition security.
- Documenting and evaluating experiences of collective action, regulation, allocation of rights and mediation in respect of water to provide more insight into what is effective under what conditions.

All the above research priorities need to go hand in hand with increased attention to gender issues, given the low visibility of women as irrigators in most studies to date.

IRRIGATED FIELD, LIMPOPO BASIN, SOUTH AFRICA, 2005.
PHOTO: CLAUDIA RINGLER / IFPRI

1. Introduction

1.1 The promise of irrigation

Providing additional water to crops through irrigation – see Box 1A for a definition – contributes disproportionately to agricultural output. Worldwide, around 20% of arable land may be irrigated, but irrigated land produces some 40% of arable output (CAWMIA, 2007).

Box 1A What is irrigation? The promise and the challenges

Irrigation is a form of water management. Farmers manage water by:

- draining land of excess water and managing how shallow groundwater moistens the soils above
- conserving moisture through crop management, such as mulching
- harvesting rainwater by terracing and ridging land so that more rain infiltrates the soil rather than running off the field
- irrigating fields.

Irrigation water may be abstracted either from surface water – streams, rivers, lakes – or from groundwater reserves through wells, either shallow or deep tubewells.

Because structures to divert water from rivers to fields have economies of scale, much surface irrigation takes place through schemes where dams and other structures divert water into distribution canals leading to fields where the system then serves many farmers. Such irrigation schemes then need to be managed collectively.

Typically seen **forms of irrigation** include:

1 **Large-scale public irrigation schemes**, growing mostly staple crops. Water is usually taken off larger rivers, sometimes with a dam for storage, and distributed through surface canals to the cultivated area. Schemes are usually operated by a state agency. Farmers may be tenants on such schemes. Where land and water conditions allow, these systems irrigate paddy rice, a growing part of African diets.

2 **Commercial privately managed systems.** Individual large farms and estates may take water from watercourses that flow through or close to the farm, or else draw water from wells. Because large commercial farms often have access to finance, techniques used may involve quite sophisticated and costly equipment, such as pivot irrigation or sprinklers. Irrigation is under the control of the farmer or farm manager and their staff.

3 **Small- to medium-scale schemes**, built and operated by groups of farmers, although sometimes they may have been upgraded through government and donor programmes. Typically, these consist of water diversions from streams and rivers, sometimes using artisan methods – structures may have to be replaced each season – with furrows and canals then conveying water to the plots of scheme members. Users agree the rules of operation of the system, and often contribute voluntary labour to operate and maintain the scheme. The irrigated plots typically grow crops of relatively high value, such as fruit and vegetables, although rice is commonly grown as a water-demanding premium food crop.

4 **Small-farm individually managed irrigation**. These are similar to type 2, only on a smaller scale. Given, however, the difficulties many smallholders have in accessing formal finance, the methods used are likely to be low-cost and labour-intensive. Irrigated plots usually produce high-value crops, often for local urban markets.

Farmer-led irrigation is any system that has been started by farmers, largely on their own initiative. Although types 2 to 4 could thus be defined as farmer-led, in practice the term is used to refer to irrigation by smallholders(types 3 and 4).

The promise

Few things in arable farming can so transform production and returns as irrigation. Fields that previously could be cropped once a year, producing per ha a tonne of grain or its equivalent, with a gross value of less than $500, can often grow two – sometimes even three – crops a year, without water stress, thereby allowing them to yield far more than before. If those crops also command a high price in the market, as applies to some vegetables and fruit, then a one-hectare field might generate a gross value of several thousand dollars a year. Irrigation can be transformational.

The challenges

Irrigation, however, is often a far more complicated change to a farming system than a change of crop or variety, use of better seed, fertilisation, crop protection or mechanisation. As a technical change, irrigation can be demanding in the following ways:

- Setting up irrigation usually involves considerable initial capital costs, in diversion of water from streams, drilling wells and installing pumps, and on-field costs including land levelling, bunding and adding sprinklers or drip lines.
- Water control demands a new set of technical skills, of applying water to crops, of conveying water, of drainage. It involves making choices about technologies – is it worth going to the expense of lining canals or of using sprinklers?
- Irrigation schemes, even quite small ones, usually require cooperation between farmers making use of the water, thereby introducing the challenges of collective action and cost sharing. Cooperation may also be needed with other water users in the catchment, both upstream and downstream.

Irrigation potentially causes widespread and significant changes to natural and human systems, as the following changes arise:

- Abstraction and consumption of water for farming deprives other natural systems of water, thereby either affecting ecological functions or reducing the productivity of those systems that provide livelihoods for other humans.
- Externalities to neighbouring areas and their populations, in pollution, drainage and health risks from disease vectors.
- Multiplier effects from successful irrigation that create more activity and jobs in agricultural supply chains and in local economies as irrigators spend increased incomes on local goods and services.

Irrigation thus creates at least three broad governance challenges for both irrigators and society as whole:

- How to allow and organise multi-farm irrigation, including how to fund collective investments, and how to operate and maintain irrigation works? Hierarchical organisation is one answer, as applies when a public agency builds and operates a scheme, or a private firm operates a large-scale irrigated farm – perhaps with smaller-scale farmers as tenants. Alternatively, the answer may lie with a voluntary association of farmers that manages the scheme cooperatively.
- How to adjudicate rights to water within catchments in a way that protects the rights of vulnerable people while allocating water to some social optimum among competing users? And how to ensure the rights established are respected, any conflicts resolved, and sharing is assisted, not undermined, by infrastructure? Answers to these questions are not straightforward: a combination of institutions to set the rules of the game and public or collective organisations to implement them are needed, probably also needing to be tailored to specific circumstances.
- How to deal with any external costs imposed on others by irrigators? Rules and regulations, or taxes and fines, can variously reduce the incidence of such external costs, or else compensate those harmed.

These challenges are made especially demanding in sub-Saharan Africa (SSA) because information, especially regarding catchment hydrology, water abstraction and externalities arising from irrigation, is often missing and imperfect. Furthermore, the knowledge and skills necessary to meet these challenges range across disciplines. To irrigate, farmers need not only agricultural skills, but also the ability to run collectives such as water associations. For public bodies seeking to facilitate and regulate, knowledge of the systems requires expertise in natural sciences, such as hydrology and agronomy, as well as social and human sciences, not forgetting economics, sociology, management and law.

Given all these considerations it is no surprise that, while irrigation can deliver remarkable results, the demands it makes and the potential problems it throws up explain why the promise is sometimes not fulfilled.

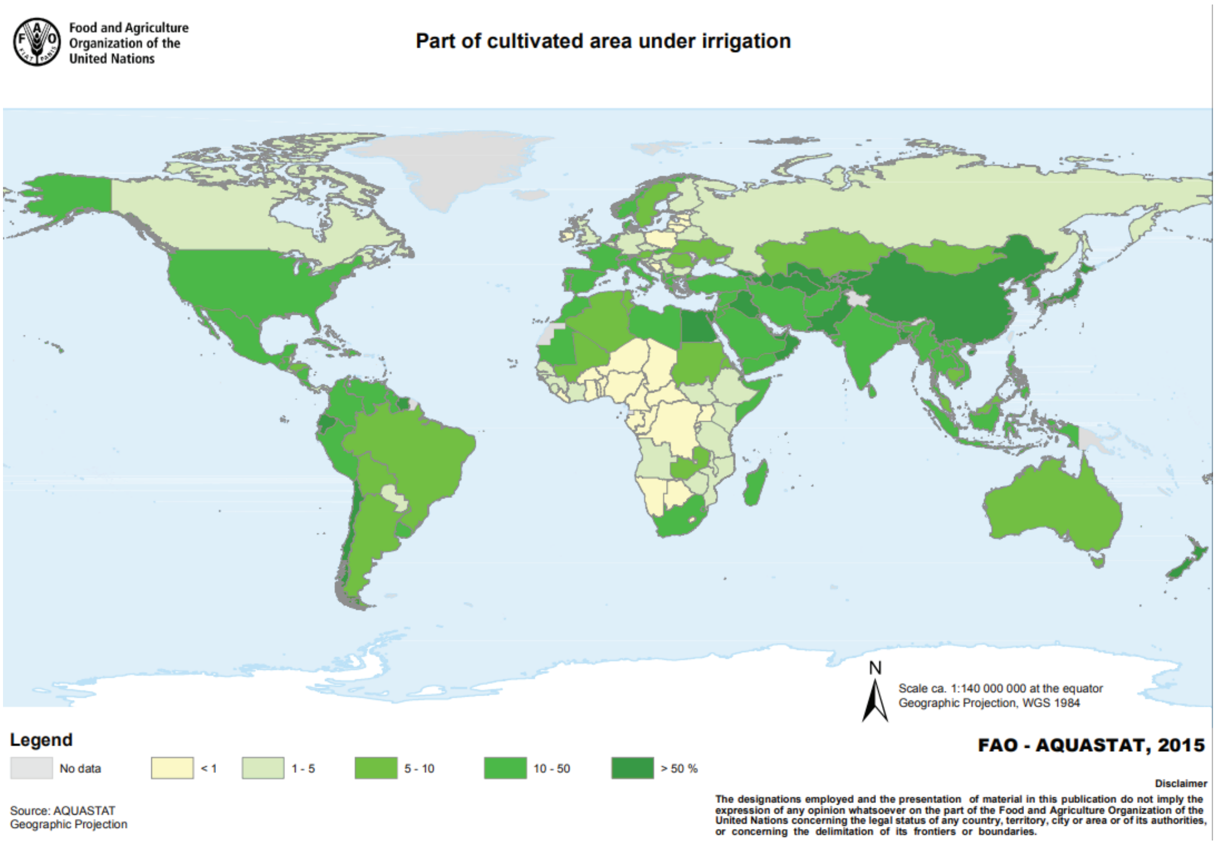
SOURCES: CAWMIA (2007), GIORDANO AND DE FRAITURE (2014); LEFORE ET AL. (2019)

Irrigation is concentrated geographically, being most common in areas that have both physical access to enough water, whether surface or groundwater, but where rainfall would not be enough to grow most crops. Hence irrigation is common across parts of Asia, the Middle East and North Africa, Mediterranean and Andean countries (Figure 1.1). SSA stands out for its relative lack of irrigation – although in some areas irrigation is common.

Despite its relative overall absence, irrigation in SSA is exceptionally important in producing food, feed and fibre, in generating incomes for farm households – while dryland fields rarely produce more than $500 a year per ha, irrigated fields can produce several times more – and in creating jobs in local and regional economies. By recognising these benefits, and the consumption of water, we can see why irrigation supports, influences and is influenced by a variety of Sustainable Development Goals on poverty, food, health, water, energy, cities and the environment (respectively SDGs 1, 2, 3, 6, 7, 11 and 14).

Given the revival of interest in agricultural development in many parts of SSA since the 2003 Maputo Declaration, it is not surprising that special interest has been shown in irrigation. Asia is often used as a yardstick against which to compare Africa's agricultural development. It is thus common to observe that while 37%

Figure 1.1
Share of the cultivated area irrigated, world, 2015



SOURCE: FAO AQUASTAT, ACCESSED 3 MARCH 2019

of cultivated land in Asia is irrigated, the equivalent fraction for SSA is no more than 4% (You et al., 2010).1

At first sight, then, the scope to expand irrigation in SSA – and thereby raise yields and output – should apparently be considerable (see section 3). As will be explained in the next section, however, public irrigation schemes have often not succeeded, and hence hopes of expanding irrigation lie first and foremost with schemes started by private actors, be they large-scale, commercial farmers or by family farmers, acting individually or in groups. The role of government and donor investments in seeding future large-scale systems, however, should not be discounted.

The focus of this synthesis is on (small) farmer-led irrigation. It concentrates on smallholders partly because most farmers in SSA operate at small scale – they work holdings largely using household labour, sometimes with a little assistance from machinery, and hence cultivate 10 or fewer hectares; and partly because the challenges of irrigation are usually greater for smallholders than for larger-scale scheme operators. This applies especially when smallholders have to operate schemes collectively; but it also applies to individual small-scale irrigation where, although the actual irrigation may be technically straightforward, smallholders typically have too little access to finance, technical knowledge or support services.

1 Different sources cite slightly different fractions, usually between 4% and 6%. Given how inaccurate the data are, it is pointless to quibble over the precise figure.

1.2 Questions addressed

This report addresses questions pertinent to the realisation of irrigation's potential through farmers' initiatives, namely:

- What is known about the extent of FLI in sub-Saharan Africa in the 2010s? What has been developed, and how?
- How successful has FLI been? What problems arise? How do such developments compare to irrigation that has been initiated by public authorities?
- How has public policy either assisted or hindered FLI? What are the lessons for policy-makers?

This report brings together findings from research conducted under the DFID-ESRC Growth Research Programme (DEGRP) – see Box 1B – with the wider literature on irrigation in SSA, and especially recent findings.

Box 1B DEGRP's contribution to research on irrigation in sub-Saharan Africa

The DFID-ESRC Growth Research Programme (DEGRP) funds scientific research on inclusive economic growth in low-income countries (LICs). The programme aims to generate reliable policy-relevant research and to communicate it to key policy decision-makers. It is supported by the Evidence and Policy Group (EPG) based at the Overseas Development Institute (ODI), whose goal is to maximise the profile, uptake and impact of DEGRP research.

This Box summarises the contributions DEGRP-funded projects have made to improving the understanding of irrigation in SSA.

Three such projects have been funded under DEGRP:

Innovations to promote growth among small-scale irrigators

Led by Elizabeth Harrison from the University of Sussex, this research aimed to explore the role of power, politics and institutions in shaping the impacts and responses to environmental (climate) change among small-scale irrigators.

Ethnographic fieldwork was carried out in locations in which irrigation has been informal and the result of local innovation in Tanzania and Bangladesh, and ones that have been more formalised in Tanzania and Malawi.

- In Tanzania, the donor-supported Dakawa irrigated rice farm was compared to irrigation innovations taking place in Choma on the lower slopes of the nearby Uluguru Mountains.
- In Southern Malawi, research focused on the rehabilitation of a well-established irrigation scheme at Muona and a newer scheme at Chitsukwa, both in Nsanje District.
- In Bangladesh, comparative fieldwork considered the innovation of irrigated watermelon production in the Noakhali chars (land recently created from alluvial deposits).

The project found significant evidence of farmer innovation regarding irrigation. This was most common when irrigation practices were less formalised and located close to markets. However, increased productivity has not always resulted in improved livelihoods. This was especially so where barriers to markets were present. There is also frequently competition with other livelihood strategies, such as livestock management.

Irrigation has often been promoted in schemes that bring farmers together into collective organisations. Such organisations can obscure inequality and conflicts within the schemes as well as between the schemes and adjacent areas. The formalisation of scheme management can consolidate such inequalities and does not necessarily overcome tendencies towards individualised production priorities.

A lack of integration between government departments promoting irrigation and national agricultural infrastructure can create barriers to irrigation development. Farmers can also be reluctant to learn from, and distrustful of, those who are used as 'lead farmers' by non-governmental organisations (NGOs) and extension services, especially when these are singled out for 'study tours'.

Irrigating farmers do not appear to be changing their practices in response to climate change-induced water scarcity. More generally, the strengths and weaknesses of different approaches to irrigation need to be considered as part of the wider hydro-politics within which they are embedded, in which access to water resources is increasingly contested.

Assessing Models of Public-Private Partnerships for Irrigation Development in Africa (AMPPPIDA)

Led by Ruth Meinzen-Dick of the International Food Policy Research Institute (IFPRI), the study aims to guide governments on the role of irrigation PPPs, how they operate, what their outcomes are and how they may be improved.

Drawing on insights from focus groups, key informant interviews, document review and mapping of networks in Ghana and Tanzania, the project has developed a framework for assessing PPPs.

The research shows that PPPs for irrigation are gaining importance in policy, political and investment circles, mainly to overcome financial constraints. While they do have potential to tap both financing and external expertise, preliminary work suggests several shortcomings in the ways that these arrangements are typically implemented:

- The roles of the various partners and the distribution of costs, risks and benefits are often not clearly spelled out.
- More should be done to involve smallholder farmers – as key private sector actors – in PPPs.
- Because access to land and water is essential for irrigation, (re)distribution of land and water rights needs careful examination in PPPs, including attention to existing customary rights and claims, to ensure the PPP does not exacerbate inequalities.
- Sound data on long-term water availability and seasonal fluctuations are needed to ensure that new water users do not deprive existing users.
- Extending irrigation access is only the beginning. To succeed, PPPs need to attend to the entire chain of irrigation services and marketing of increased production.

Assessing the growth potential of farmer-led irrigation development in sub-Saharan Africa (SAFI)

This research, led by Phil Woodhouse from the University of Manchester, examines the characteristics of farmer-led irrigation, the processes and outcomes, and relationships of irrigators to other actors and agencies. In Mozambique and Tanzania, informal irrigation schemes have been studied in detail, national policies have been examined, and a framework developed by which to compare the irrigation schemes reviewed.

Findings reported to date include that of the under-reporting of informal irrigation (see Box 3A) and the great variety of informal irrigation that can be observed.

1.3 Organisation of the report

To understand current challenges for irrigation, it is necessary to appreciate the previous experience of irrigation development in SSA, above all the experience of publicly led irrigation.

Following that, the report then organises material according to the three questions set regarding the extent of FLI, its successes and challenges, and the role of policy. In concluding, the report also includes discussion of research gaps.

SMALLHOLDER RICE IRRIGATION SYSTEMS IN SOUTHERN TANZANIA. PHOTO: BRUCE LANKFORD.

2. Previous experience of irrigation in sub-Saharan Africa

2.1 Large-scale public schemes

During the first half of the twentieth century, colonial administrations in SSA invested in large-scale, gravity-fed public irrigation schemes covering thousands of hectares. While a central public agency built and operated dams, water diversion structures and conveyancing canals, the irrigated area was then typically divided into family-sized plots worked by households who were tenants of the scheme. Prominent examples include Gezira in the Sudan and the Office du Niger in Mali, schemes that covered more than 800k ha and 75k ha respectively.

In the 1960s and 1970s, under the newly independent governments, further such public schemes were favoured. Large-scale irrigation schemes (LSIS) were seen as highly promising. Previously dryland crops producing meagre yields could potentially be cropped twice a year with high yields, to produce either valuable food crops such as rice, or export crops such as cotton. Jobs would be created both on the scheme and in processing and marketing the crops. The large schemes would moreover be symbols of agricultural and economic transformation, of modernisation, and of the powers of the new nation states.[2]

However, by the mid-1980s, if not earlier, it was clear that many of the LSIS were failing, often quite badly. Failures included schemes at Bura on the Tana River in Kenya, schemes to irrigate along the Gambia River, several dams in northern Nigeria. Large-scale public irrigation was a disappointment. Multiple problems were observed by researchers at the time – for example, Adams (1987, 1988, 1991, 1993), Carney and Watts (1990), Chambers (1988), Kadigi et al. (2012), Moris (1987), Wade (1988) – including:

- Cost and time overruns as engineering works ran into more difficult conditions than expected.
- Only a part of the planned area being irrigated, owing either to there being less water than expected or to shortcomings in the distribution system.
- Lower crop yields than planned, owing variously to poor distribution of irrigation water or the lack of it in critical seasons, difficult soils, or to lack of diligence by farmers alienated by their tenant status and the top-down management of the scheme.
- Difficulties in operating large schemes, including those of the incentives and discipline of publicly employed water operators who had little incentive to distribute water effectively and every incentive to seek side-payments from tenant farmers.
- Conflicts over land on the schemes, arising from disputes over original entitlements to land taken over for irrigation, or to intra-household disputes over whether the irrigated plots belonged to men or the women who, in some cases, had previously worked the land.
- Conflicts with livestock herders who lost dry season grazing to irrigated fields.
- Unanticipated economic and environmental harm from changes to the hydrology and ecology of the catchment owing to excessive water consumption.

Behind these specific problems, observers identified two underlying drivers repeatedly seen in these schemes. One was the political desire to create highly visible and dramatic results from public investments: such investments often had a political momentum that overrode professional scrutiny of whether the schemes would work as intended.

The other was the primacy of irrigation as engineering: planning and construction of the schemes focused on capturing water and distributing it to fields, with less attention to agronomy, and very little consideration of how

2 Bernal (1997) argues that the giant Gezira irrigation project in the Sudan was undertaken by the British colonial authorities in part to demonstrate their ability to tame nature and create prosperity out of arid lands. From 1956 onwards, the independent Republic of the Sudan was equally determined to use the scheme to demonstrate its capacity to transform nature and agriculture.

the scheme would operate, in the light of farmers' perspectives and the prevailing economic and social context. Indeed, planners were not encouraged to foresee any difficulties of this kind (Harrison, 2018).[3] Then again, the schemes were presented as pillars of modernity: if water and land could be physically transformed by applied science, then how hard could it be for farmers to make similar changes? All that was apparently needed was enlightenment, through farmer training to improve skills and change attitudes.

In many cases, the difficulties experienced on LSIS were so great that by the late 1970s it was evident that that heavy investments in irrigation had failed to generate the output and economic returns predicted of them.

Reforming large-scale irrigation schemes

Irrigation can, of course, change through time. Schemes that work well initially may later run into problems, while problematic and failing schemes may be rehabilitated, reformed and revived – so that apparent early failures are turned into successes.

One example of improvement comes from the village irrigation schemes of the Senegal Valley. In the 1990s, reports indicated that many were failing – in part because male labour was absent in the dry season when irrigation was expected to be in full swing (Niasse, 1991; Woodhouse and Ndiaye, 1991). Subsequently, good yields of rice, 5–6 tonnes per ha, have been seen in the valley (Larson et al. 2010).

In Malawi, the donor-funded and publicly constructed Bwanje Valley rice scheme was failing when studied in 2001/02, affected by problems of silting at the intake and farmers being more interested in their dryland crops than the irrigated rice planned for them. (Veldwisch et al., 2009; Chidanti-Malunga, 2009) On a return visit in 2010, the principal found that the scheme was being fully used, owing to

> *a combination of market innovations, smart re-designs of some strategic infrastructural nodes and institutional strengthening.*
> (Veldwisch, 2010)

TENDING THEIR CROPS. PHOTO: LAURA ELIZABETH POHI / BREAD FOR THE WORLD.

3 In the early 1980s, feasibility studies for an irrigation scheme in Kenya showed that the supposedly vacant land earmarked for irrigation was in fact already occupied by recently arrived settlers, who had not been consulted about the irrigation scheme. The sociologist's inconvenient report that warned of conflict if informal settlers were removed to make way for the scheme was suppressed. In the event the scheme was not funded so the problem fortunately did not arise (Wiggins, personal experience).

Even more striking has been the revival of the Office du Niger in Mali: a very large scheme in the inland delta of the Niger started in colonial times. This failed to achieve its objectives owing to several problems, but above all, the stultifying effect of the central agency that tried unsuccessfully to manage all aspects of irrigation and farming, but only succeeded in alienating the farmers on the scheme. Reforms started in the 1980s that reduced the remit of the operating agency and gave greater freedom to farmers to grow and market the crops they chose has led to a remarkable turnaround in the fortunes of the scheme (Box 2A).

Box 2A Office du Niger: turning around a failing large-scale scheme

The **Office du Niger (**OdN) began as one of the most ambitious projects by the French colonial administration of the 1930s. The scheme aimed to convert 950,000 ha of the inland Niger delta into irrigated cotton and rice fields, managed by a French public company, the OdN.

At independence, the French colonial company was nationalised, and specialised in rice. The Office du Niger then controlled the entire paddy production, processing and marketing chains in the irrigated zone. Until the 1980s, 80% of rice was marketed by the OdN.

By the end of the 1970s, however, irrigation systems began to deteriorate, yields began to decline, and the authoritarian management of paddy farmers came under criticism.

Reform of the OdN began in the early 1980s, with renewed investments to upgrade and maintain the irrigation infrastructure; while the company reduced its remit to focus on its comparative advantages in irrigated land development, credit, processing of paddy and marketing of rice. Attention then turned to building a functional market: prices were progressively liberalised, while private rice mills were subsidised, and credit to traders facilitated.

In 1994, the OdN was turned into a profit-making public company, the **Établissement** public à caractère industriel et commercial (EPIC), and its staff and responsibilities were further restricted to land and water management, operation and maintenance of irrigation works, management and provision of extension. Services provided by the OdN to the Malian government and farmers associations were then regulated through a tripartite contract between government, company and farmers.

Reform has been a joint effort of the Malian government and its partners: during the first phase, 1988–1998, the World Bank, AFD (France), Dutch cooperation and KfW (Germany) provided about 75% of funds. A key reason for success was strong leadership by the Malian government that decided to set up an independent and high-level delegation attached to the prime minister to manage the reforms. It helped reformers that farmers were keen to see OdN controls relaxed.

In both cases, domestic reformers and some donors were able to work together productively, to build a broad consensus for reform.

Outcomes

The rice supply chain functions better: processing and marketing costs have been cut, in part thanks to the operations of the small-scale rice mills, so that farmers get a higher share of the final price. Output of rice has increased: from 1990 to 2007 rice production grew by 7% a year on average, stimulated in part by the 1994 devaluation of the currency (FCFA).

Freed of the controls of the OdN, farmers have been able to diversify into higher-value crops such as shallots, raising their incomes. The company itself, with its restricted functions now no longer depends on public subsidies.

SOURCES: BARRY ET AL. (2009), WORLD BANK (1999)

Reforms in Mali were helped by a better commercial environment, as urbanisation and better road access from irrigated area to market have created new incentives to irrigate.

2.2 Farmer-managed public schemes

Given the disappointments, investments in large-scale public schemes became much less common from the mid-1980s onwards. Donors, much exercised by bad news described in the formal evaluations of schemes they had funded, were particularly reluctant to consider further investments. Instead, attention switched to improving the operation of existing schemes. If public agencies found it hard to manage schemes, it was argued, then why not have farmers either take over the running of the schemes or participate in management, through a water users' association (Kulkarni and Tyagi, 2013)? The association would have the incentives to operate the scheme, the moral authority to do so, and would benefit from local knowledge.

Yet handing over schemes to the users did not necessarily result in high performance (Bjornlund et al., 2017; Kadigi et al., 2012; Vermillion, 1997). Having groups of farmers operate the systems did not solve any technical problems with the scheme, such as water losses in canals, complicated designs where intakes silted up faster than expected, or scheduling water on time to soils with low moisture-holding capacity.

Moreover, in some cases transfer of authority meant that the associations were saddled with heavy costs in maintenance, repair and rehabilitation: costs that farmer members either could not meet, or could not understand clearly, or did not feel that they should have to assume – since they still viewed the scheme as belonging to the government.

Furthermore, collective action was costly to farmers and their leaders in time spent in long meetings and dealing with problems. Although farmers often worked together in small groups, their enthusiasm for formally instituted water user associations was accordingly muted.

By the mid-1990s it was clear that farmer management of large schemes was no panacea for the challenges facing the schemes, so enthusiasm for this approach ebbed.

2.3 Informal, farmer-led irrigation

Yet while disillusion with publicly promoted irrigation mounted, irrigation in SSA was expanding, largely by the efforts of individual farmers and small, informal groups of farmers, in some cases complemented and catalysed by public (usually donor-funded) investments in smallholder schemes. The contribution of new or rehabilitated large-scale schemes was far less. Much of the expansion in irrigated area since then has – apparently, since the data are indicative rather definitive, as will be explained in the next chapter – been farmer-led.

Meanwhile, since 2000, agricultural development has seen its priority as development policy rise, marked by the Maputo Declaration of 2003 and the establishment of the NEPAD/African Union Comprehensive Africa Agricultural Development Programme (CAADP). Individual governments across Africa have reaffirmed the importance of agricultural development, supported by governmental development partners, multilateral agencies and foundations.

Priority has been given to more intensive agriculture, aiming for higher yields per ha and per animal. Irrigation fits this agenda with its promise of multiple crops per year and higher yields. Indeed, the first pillar of CAADP (2009) concerns sustainable land and water management, with expansion of irrigation as a priority.

The revival of public interest in formal irrigation investment has coincided with new economic opportunities (World Bank, 2006; Turral et al., 2010). The worldwide rise in agricultural commodity prices seen from 2007 to 2014 prompted much interest on the part of multinational and national companies in acquiring land and farming on a substantial scale, on farms of several hundred thousand hectares (von Braun and Meinzen-Dick, 2009; Deininger and Byerlee, 2011). Planned investments often contemplated irrigating the land. Moreover, urbanisation in Africa has led to much larger domestic demand for agricultural produce, especially higher-value items such as fruit and vegetables, thereby creating further opportunities for irrigated crops – while improved roads in some areas have made it possible for irrigated lands to serve those markets.

At the same time, the cost of imported pumps and other irrigation equipment has fallen in real terms. That has benefitted would-be irrigators, large and small. Small pumps of two to seven horsepower (hp) have become sufficiently cheap, as evidenced by their widespread uptake, numbering millions of units in SSA (de Fraiture and Giordano, 2014), bought by individual farmers or small groups to lift water from wells or watercourses.

Comparisons with irrigation in Asia have frequently been drawn, above all the lower yields realised for most crops in SSA than in Asia, and the much smaller fraction of arable land irrigated. Typically, it is reported that one-third or more of Asia's arable lands are irrigated, while the corresponding share for SSA is 4% to 6%. But when Asia is used as a benchmark for Africa it is not clear to what extent the Asian experience of irrigation informs debates within Africa (Box 2B).

Box 2B Asian experiences with irrigation

Asian experience of irrigation provides some contrasts with Africa, and some similarities.

The **contrasts** arise with physical conditions and history. Compared to much of SSA, the irrigated areas of South, Southeast and East Asia benefit from:

- Stronger monsoonal rainfall signal and contribution versus more erratic rain in East and Southern Africa.
- Better and more suitable irrigable soils in Asia, owing to soil type and formation. Soils with moisture-holding capacities of > 150 mm allow for a more forgiving scheduling of irrigation, allowing a second crop from the stored soil moisture in the dry season. More acidic soils on the basement complex in Africa with moisture capacities of <120 mm are much trickier to manage with irrigation. Asia's floodplains differ considerably to the savannah plains of Africa.
- A long history of irrigation in Asia, often going back many centuries, giving farmers plenty of experience and examples to copy and develop. In contrast, Africa's early and precolonial irrigation has been largely restricted to the Nile and some relatively small, informal irrigation, such as the furrows around Mount Kilimanjaro.

Similarities, however, arise in the common story of difficulties and disappointments with large-scale public schemes, and the subsequent flourishing of individual, farmer-led irrigation. In East Asia, irrigation has benefitted from reliable sources of water owing to less fluctuation in rainfall. In many parts of the region, hilly terrain means that catchments are quite small, facilitating small irrigation schemes where the costs of collective action to develop, operate and maintain gravity systems are quite low.

In South and other parts of Asia, however, natural conditions differ, with wide valleys, floodplains and deltas where very large-scale schemes for gravity irrigation have been possible. Monsoon rainfall in South Asia that charges the rivers has in some areas been less reliable than East Asian rainfall, making it harder to provide irrigation without considerable water storage.

Operating and maintaining very large-scale public schemes in Asia has proved difficult. With vast schemes, neither water operators nor farmers feel a close connection to the overall success of the system, so that rent-seeking by operators and indiscipline by farmers have proliferated. Indeed, in some cases, political systems have developed whereby bribes are extracted from the irrigation system at all levels, bribes that fund the next election campaign.

At the same time, as pumps have become cheaper, and in some countries egged on by subsidised rural electricity and cheap credit, individual irrigation from tubewells has proliferated. While this has allowed the 'green revolution' to spread, aquifers tend to be overdrawn, so that wells must be deepened to reach the falling water table.

SOURCES: BURNS (1993), KIKUCHI ET AL. (2003), LANKFORD (2005), MOLLE ET AL. (2009), MOORE (1989), WADE (1984), WOODHOUSE ET AL. (2017)

2.4 The scope for expanding irrigation in sub-Saharan Africa

From 2005 and through the 2010s, a renewed sense that it is possible, and perhaps necessary, to expand irrigation in SSA has taken hold (Commission for Africa, 2005; Xie et al., 2014; Malabo Montpellier, 2018). To meet the food demand of a larger population in 2050 without increasing imports of cereals and other staples, it will be necessary not only to close the gaps between yields commonly seen in the field and the potential achievable by improved crop management, but also to increase cropping frequency and use more irrigation (Guilpart et al., 2017; van Ittersum et al., 2016).

IFPRI studies (You et al., 2010, Xie et al., 2014, 2018) suggest that enough water exists in SSA to water a much larger irrigated area. Moreover, advances in technology, falling real costs of equipment and rising prices for outputs make such an expansion both more feasible and more economically rewarding than ever before.

The total potential expansion calculated could be as much as 81M ha or more – if the calculations for irrigation by different means overlap, since some areas may be irrigated by more than one method. The largest potential comes in the form of diversions from rivers, the rest from small reservoirs, treadle and motor pumps (Xie et al., 2014).

The potential reported in Table 2.1 is breathtaking, given that FAO reports total cropland in sub-Saharan Africa[4] at 222M ha in 2016, with just 6.4M ha under irrigation.

A more modest estimate of potential for expansion is the 38M ha cited by the Malabo Montpellier report (2018), but even this represents six times more than the officially recorded irrigated area of 6.4M ha.

Are such expansions possible?

Irrigation hydrology and the 'irrigation potential' of Africa. Is the irrigation potential (the land that can be irrigated) really as big as is often stated? It is important to distinguish between the view that a soil and land type is 'irrigable' and that a landscape has a large irrigation potential, which may not be the case if there is insufficient water. Irrigation systems consume a considerable amount of water; a reasonable guide is that irrigation systems in

Table 2.1
Ex-ante potential for the expansion of smallholder irrigation in SSA (x 1000 ha)

	Motor pumps	Treadle pumps	Communal river diversion	Small reservoir
Central Africa	8579	6,313	15,005	5,087
Eastern and Indian Ocean countries	10,617	8,491	21,821	7,474
Gulf of Guinea	12,363	10,130	25,050	8,550
Southern Africa	6142	4,536	9,848	3,110
Sudano-Sahelian	10,239	7,221	9,997	2,917
All SSA	47,939	36,691	81,721	27,139

SOURCE: TABLE 4, XIE ET AL., 2014

Note: The countries in Central Africa include: Angola, Cameroon. Central African Republic, Republic of the Congo, Democratic Republic of the Congo, Equatorial Guinea and Gabon. The Eastern and Indian Ocean countries include: Burundi, Ethiopia, Kenya, Madagascar, Rwanda,Tanzania and Uganda. The Gulf of Guinea countries include: Benin, Côte d'Ivoire, Ghana, Guinea, Guinea-Bissau, Liberia, Nigeria, Sierra Leone and Togo. The countries in Southern Africa include: Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Zambia and Zimbabwe. The Sudano-Sahelian countries include: Burkina Faso, Chad, Eritrea, Mali, Mauritania, Niger, Senegal, Somalia, Sudan and The Gambia.

4 Sum of statistics given for all regions of Africa – Eastern, Middle, Southern, Western – other than Northern Africa.

SSA need over one year about 400 to 500 mm of irrigation on top of, say, a rainfall contribution of 700 mm (if one irrigation season of rice or two seasons of vegetables or a perennial crop such as citrus or sugarcane are to be obtained). This is the reason to be sceptical of irrigation potential narratives that argue millions of hectares can be irrigated: there is not enough water without significant storage being constructed or without downstream users being severely impacted. The Malabo Montpellier report (2018) asserts 38 million ha of potential in Africa, but this will require approximately 150 cubic km of water (assuming a depth of 400 mm irrigation per year per ha is consumed). See also the next point.

Irrigation seasonality and irrigation 'potential'. Ideally irrigation works best when farmers manage crop and soil water from both irrigation and rainfall. In other words, farmers reduce their consumption of surface and groundwater by cropping during the rainy season, making irrigation 'supplementary' to rainfall. If, however, rain is scarce (e.g. during the dry season or during a drought) then the farmer ends up seeking more irrigation water, leading to an increase in consumption and a decrease in water availability downstream or for other users of groundwater. Thus, an irrigation system that is manageable on paper because it is assumed irrigation takes place during the rainy season, in effect desiccates the catchment during all other times. And because rainfall is typically spatially and temporally erratic, and farmers naturally try to bank available water into their soil, large irrigation areas will invariably stress their environs. So, while an irrigation potential might be millions of hectares in theory, in practice only a fraction of this may be appropriate.

For example, Tanzania often refers to its irrigation potential of 30M–40M ha, and yet only 50k–60k ha of irrigation in the catchment of the Great Ruaha, one of the main rivers in the south of the country, creates significant water allocation problems via water depletion (McCartney et al., 2007).

Furthermore, irrigation systems need to be designed with the dry season and water scarcity in mind, rather than using a calculus to maximise production during the wet season (Lankford and Beale, 2007)

Irrigation scale and hydrology. A small-scale (i.e. 0.5 ha) irrigated plot uses a smaller amount of water (annually 2,500 m^3 if 500 mm irrigation is applied), but this computation hides two cautions. First, if lifted by human labour powering a treadle pump, this water (2,500 tonnes) represents a huge effort: ancient Egyptians and Mesopotamians used animal power and not humans to lift water. Second, considering small-scale schemes individually hides a water regulation and governance problem when many small plots cumulatively add up to a large irrigated area which can tip the balance towards excessive consumption during water scarce periods. The governance problem arises when having to persuade many *individual* irrigators to throttle back their demand rather than work via one irrigation intake that cascades that scarcity to *networked* irrigators.

Hydrology, irrigation water consumption and climate change. A common view is that irrigation is a suitable response to climate change:

> *Irrigation can also be an important coping mechanism against the adverse impacts of climate change and can strengthen farmers' resilience in the face of increasingly frequent and extreme weather events.*
> (Malabo Montpellier, 2018: 2).

However, this mitigation requires reliable and excess water, unlikely given the uncertainty and extremes that climate change brings. In other words, irrigation, by consuming scarce freshwater resources, can exacerbate climate variability: it can thus magnify variability rather than mitigate it.

3. Farmer-led irrigation in sub-Saharan Africa in the 2010s

3.1 Extent of farmer-led irrigation

According to FAO figures, the area irrigated in SSA has expanded by 56% since the early 1990s, compared to a 31% increase in the area under arable crops, so that by 2014/16 some 3.4% of arable land was irrigated, compared to 2.8% in 1990/92 (Figure 3.1).

Of the more than 2M ha that have been added to the irrigated area since the early 1990s, it is believed that much has come from individual or small groups of farmers irrigating their fields by diverting water from streams, pumping from watercourses or lifting water from wells. Most of this has been farmer-led, rather than the result of a government project. Only a small part of the 2M ha expansion has come from official irrigation schemes.

These numbers, however, are in large part those officially reported by governments to FAO: they very probably under-record irrigation, for two main reasons. One arises from differences in defining irrigation. FAO's AQUASTAT places irrigated areas into four categories, as follows:

(1) land equipped for full control irrigation

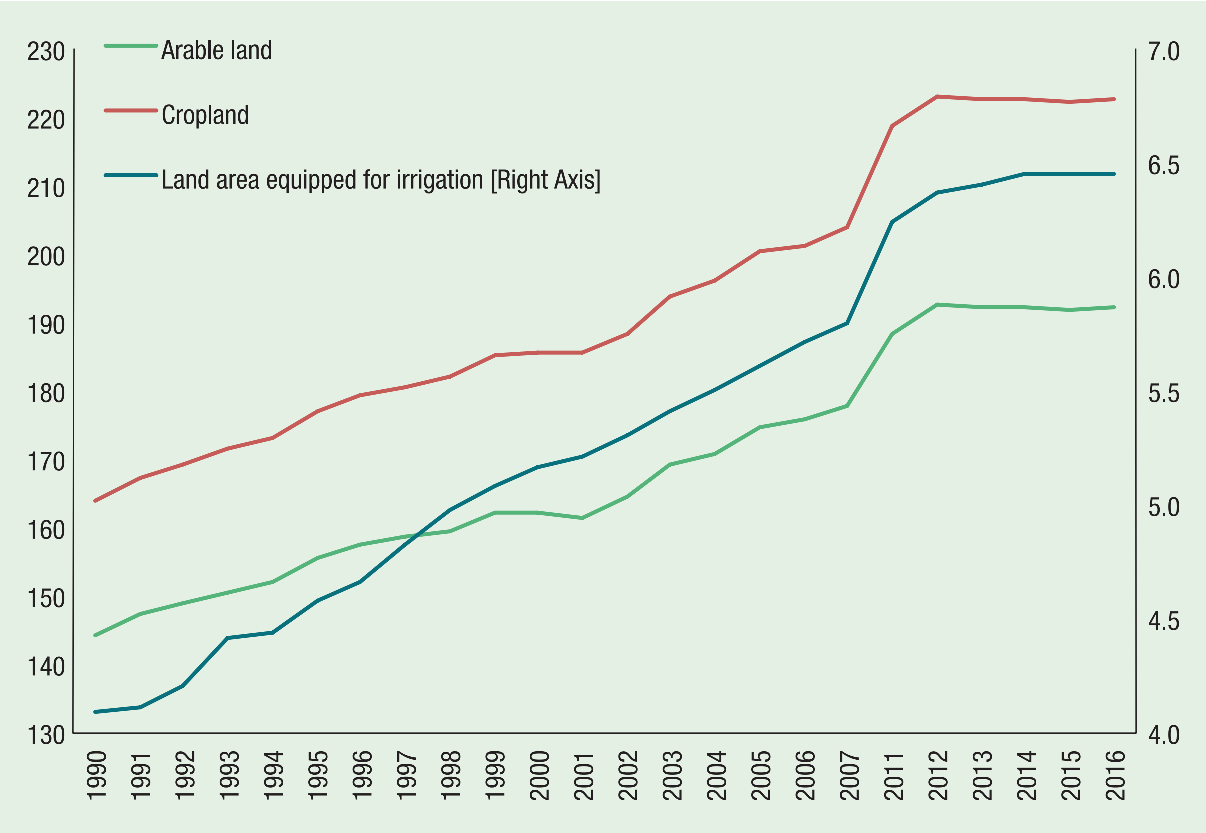
(2) land equipped for partial control irrigation

(3) land with water harvesting

(4) land cultivated in flood recession areas and in wetlands.

Governments typically report only the first two categories as being land irrigated; and some report only the first category, land with

Figure 3.1
Irrigated area in sub-Saharan Africa, 1990 to 2016, in million hectares



SOURCE: COMPILED FROM FAO DATA

Notes: Shows areas for all of Africa, less Northern Africa. Units are million hectares.

fully controlled irrigation. In practice, this first category is usually treated as official public irrigation schemes and formal private irrigation. Most informal irrigation thus falls into the other categories and is not always reported (Bowers et al., 2019).

The other reason for under-reporting is more straightforward: informal irrigation is often small-scale and fragmented, hard to count and, indeed, in some cases, hard to detect. An agricultural census might capture this, but few developing countries carry out such detailed surveys more frequently than once a decade. On the other hand, when underperforming schemes are abandoned and signs of their ever having been present fade, the official record can overstate the area irrigated.

When officially reported data are compared to other sources, the differences can be very large, as the cases of Ghana and Tanzania show (Box 3A).

Box 3A How much (largely informal) irrigation appears in official records? Insights from Ghana and Tanzania

Ghana officially reported 36,000 ha as being equipped for irrigation in 2016. Researchers, however, have estimated the areas irrigated by different means as follows:

	No. of farmers, k	Area, k ha
Public schemes	11	7.185
Small reservoirs	25	6
Motor pumps	160	120
Buckets and watering cans	335	66
Treadle pumps	< 0.1	< 0.02

SOURCE: DE FRAITURE (2013)

In total, 189,000 ha may be irrigated, with most of the area under private irrigation, mainly in small areas irrigated either by motor pumps or by bucket – no less than five times the officially reported area (de Fraiture, 2013).

The DEGRP-funded team Studying African Farmer-led Irrigation (SAFI) team in Tanzania used radar imaging to estimate the area irrigated in Kilimanjaro, Rukwa and Shinyanga Regions. Compared to the areas reported in the agricultural census of 2007/08, the results were as follows:

Region	Census 07/08, ha	Radar 2016, ha
Kilimanjaro	36,607	27,000 ± 7,800
Rukwa	8,316	26,600 ± 11,800
Shinyanga	29,783	267,000 ± 37,000

In Kilimanjaro, radar understates irrigation, because the predominant hill furrows water small gardens and do not reflect much of the radar signal. In Rukwa and Shinyanga, where rice is irrigated, the wet fields produce a strong signal. As can be seen, radar detects three times as much irrigation as the census for Rukwa, and nine times as much in Shinyanga (Bowers et al., 2019).

Given that the radar imagery was collected nine years after the census, part of the difference may well arise from expansion of irrigation over those nine years. For example, if irrigation had increased by, say, 10% a year from the census record the irrigated area would have reached 20k ha in Rukwa and 70k ha in Shinyanga: still much less than radar indicates. A good part of the difference probably comes from under-recording, rather than the different years reported.

Similar under-reporting has been seen in the Usangu catchment in Southern Tanzania (McCartney et al., 2007).

Under-reporting is not surprising. Much of the unrecorded area consists of small areas where farmers have taken the opportunity to divert water to create rice fields. Although these create a clear signal on radar imagery, because of relatively depleted numbers of staff working in small irrigation departments it takes several years before they are recorded and verified statistics make their way through to FAO and ICID (International Commission on Irrigation and Drainage) databases.

Hence, no accurate and reliable statistics on the total area irrigated in SSA appear to exist, nor on that which is farmer-led. That said, evidence from Ghana and Tanzania indicates that the area irrigated may be several times what is officially reported and that most of the difference is accounted for by FLI.

While that might be welcome news, it would reduce the potentially irrigable area that remains to be exploited. It also may mean that in some catchments much more water is already being used for irrigation and that the point at which irrigation competes with other uses of water may be fast approaching — or have already been reached.

Inaccurate reporting of irrigation areas, also seen for large-scale and commercial irrigation – because of the way that larger schemes grow over time using water savings and drainage water for irrigation (Perry et al., 2017) – makes recommendations to expand irrigation questionable, if this leads to unsustainable consumption of scarce water needed elsewhere.

3.2 Typical characteristics of farmer-led irrigation

Origins and motivations for farmer-led irrigation

In most accounts, the opportunity to grow and sell high-value crops to cities has been the prime reason to irrigate. Opportunity has often been facilitated by new or improved roads that have made it possible to reach urban markets relatively quickly and cheaply. Markets are growing as a result of urbanisation, dietary changes and the emergence of middle-class consumers who can buy higher-value foods.

Most FLI is applied to relatively high-value crops, including fruit and vegetables, fodder for dairy cows, and cotton, rather than to food staples. Growing higher-value crops maximises the returns to the physical gains from irrigating crops. Rice is the exception among food staples. That is because it tends to be a premium staple, commanding higher prices per unit than alternatives such as maize or cassava (Dimithè et al., 1999; Yade et al., 1999).

Water source and technology in farmer-led irrigation

Because it is usually the cheapest way to irrigate, farmers tend when possible to irrigate by gravity from streams, lakes or reservoirs. Such methods can be very simple: for example, in Mgeta Division, Morogoro Region, Tanzania, farmers dip hosepipes into mountain streams that run next to their plots (Mdee et al., 2014). More commonly, however, structures such as intakes or dams have to be built, to feed canals or pipes that lead the water to fields. These tend to be constructed largely by manual labour using readily available materials, hence with minimal use of machinery or purchased materials. While this economises on scarce cash, the resulting artisan structures may be impermanent, requiring frequent repair and, in some cases, seasonal reconstruction.

When local topography does not allow gravity flow, then water may be lifted, in order of ease, from:

- Watercourses, lakes, wetlands and reservoirs
- shallow aquifers. In river plains and depressions – areas that may flood during the wet season – the water table in the dry season may be only a few metres deep, so that shallow wells can be dug – often by hand. Examples include the Fadama plots of northern Nigeria (Abric et al., 2011; Mortimore, 1993) and the dambos of Southern Africa (Woodhouse et al., 2017)
- deeper groundwater aquifers may be tapped by tubewells. These have proliferated in West Africa since the 1990s owing to the introduction of manual drilling, which is cheaper and more affordable than machine rigs (Abric et al., 2011).

Lifting is typically powered by humans or motors. While animal draught might be used to power water lifting, no examples were seen in the recent literature.

For small plots, buckets and watering cans may be used, as seen for plots of tomatoes in Brong-Ahafo, Ghana (Okali and Sumberg, 1999). Treadle pumps operated by foot have been favoured by some donors as cheap and appropriate technology. To irrigate small vegetable plots of no more than 0.5 ha, they may be adequate: for larger areas the amount of effort to raise water can be daunting, requiring hours of treadling. It is reported that some, perhaps many, donated treadle pumps have been abandoned by users (Burney and Naylor, 2012).

Motor pumps have been adopted widely by farmers in SSA in the new century. Small, 2–10 hp, motorised pumps are becoming common in rural Africa as costs fall in real terms – in part since they are often imported duty free. With costs often less than $300 a pump, they are increasingly affordable to better-off farmers, or to small groups of farmers. For those who cannot afford the capital, in some cases they can be rented from owners (Abric et al., 2011; Giordano and de Fraiture, 2014).

Diesel pumps require fuel to operate. Hence interest in photovoltaic (PV) cells to capture solar energy and drive electric pumps is growing rapidly, with several initiatives to test and promote technology by donors and NGOs underway. Costs of PV cells have fallen notably during the new century, so that small solar systems are being advertised at prices below $500 on international web sites. The promise for solar-powered irrigation in quite remote parts of rural Africa is clear: pumps with minimal running costs, that do not demand fuel supplies, and which produce no greenhouse gas emissions. Indeed, an early concern is that solar pumps may extract water at such low marginal cost that water sources are depleted. Solar thermal pumps may also be a possibility (Mohammed Wazed et al., 2018; Otoo et al., 2018)

The method used to lift water depends in part on the capital cost of equipment and its running costs. It also depends on the area to be watered: using buckets and watering cans involves much labour, but is bearable for vegetable plots measured in tens of square metres, if unthinkable for field crops grown on a larger scale.

Water conveyancing and distribution

Water is conveyed to fields from the source either by pipes, although usually only when the source is on or next to the field, or through canals. The latter are often unlined, prompting some observers to worry about water efficiency.

On-field equipment is rarely more than watering cans and buckets, or hoses from pumps. Drip irrigation has been promoted by some agencies, notably NGOs, but too often drip lines are abandoned by users – owing variously to farmers not understanding how to use and maintain them, poor quality hoses, damage (including that caused by animals) and drip holes becoming clogged (Burney and Naylor, 2012; Friedlander et al., 2013). Sprinkler systems are not common with FLI, presumably owing to their relatively high capital and operating costs (Namara et al., 2014).

Financing investment in irrigation

Irrigation requires some form of capital investment, in works, wells and on-field investment. While labour-intensive construction can reduce the cash costs of initial investments, capital costs can nevertheless be appreciable for smallholders with limited access to cash, savings or credit (Table 3.1).

Table 3.1 Typical costs of irrigation

System	Capital cost, US$ per unit or ha	Annual operating cost, US$/ha	Source
Communal river diversions	440 per ha	200	C
Small reservoirs	Usually government constructed	200	C
Riverine or shallow well	16–21 unit		B
Permanent shallow well	79		B
Permanent shallow well, with lining	101 unit		B
Bucket	< 50 per ha	< 10	A
Treadle pump	60–75 unit	< 10	A
Treadle pumps	69	190	C
Motor pump	78 per ha	185	C
Motor pump	400 unit	330	A

SOURCES: (A) DE FRAITURE AND GIORDANO (2014); (B) TABLE 2 IN NAMARA ET AL. (2011); (C) TABLE 6 IN XIE ET AL. (2014)

Farmers have typically met capital costs by using their own labour to construct diversion works and dig canals or wells; but then have had to find cash to finance equipment and running costs, such as diesel. Cash typically has been drawn from own savings, or loans from traders, family and friends. Rarely have smallholders had access to formal finance (Shah et al., 2013; de Bont et al., 2019; Woodhouse et al., 2017).

Some FLI has been aided by grants and subsidies from projects funded by governments with development partners or by NGOs. This seems to have been more common in West than East Africa, as in the former region large programmes to support smallholder irrigation have been implemented (Abric et al., 2011).

Given the potential returns to motor pumps, reports are increasing of suppliers offering hire-purchase and leasing agreements to farmers, and of inter-farmer rentals of pumps to ease the use of these for smallholders who lack funds to buy the equipment outright (Namara et al., 2014).

Organisation of farmer-led irrigation

Farmers usually prefer to irrigate individually, when that is feasible and does not raise costs. Cooperating with other farmers is almost always costly in time and requires skills in leadership and group organisation (Curtis, 1991).

Some forms of irrigation can indeed be individual. The farmer who pumps from a well or a watercourse on or next to their fields may well be able to do this alone, at an economic cost, without relying on neighbours. A danger exists in this: that since everyday irrigation does not rely on others, that collective issues, such as just how much water can be drawn without depriving others of water, become neglected (Dessalegn and Merrey, 2017).

Several aspects of irrigation, however, typically require farmer cooperation owing to economies of scale. Intakes from rivers are a case in point: structures typically tend to draw water sufficient for areas larger than a small farm, while their construction requires a scale of effort and expense beyond the means of most smallholders. Hence most intakes built on farmer initiative usually involve cooperation among a group of farmers. Such groups may be quite small, a handful of neighbouring farmers, or may be village-wide – as in central Tanzania, where canals serve all the river plain lands of the community (Mutabazi et al., 2017), or even multi-village groupings when the canals constructed command larger areas – as applies for the small water furrows that track down the slopes of Mount Kilimanjaro, providing water for multiple uses, including vegetable plots (Grove, 1993).

While pumping may often be possible on a small, individual scale, economies of scale can apply so that collective pump stations, operating at a much higher scale than the 7–10 hp individual pumps, can give lower unit costs of lifting water. Such stations were used to water *périmètres irrigués villageois* [village irrigation schemes] along the Senegal river (Diemer et al., 1991, Niasse, 1990, 1991; Woodhouse and Ndiaye, 1991).

When farmers have organised to abstract and distribute water collectively, such arrangements typically:

- allocate work quotas for group members for operation and maintenance of facilities, collect funds to pay for any purchased materials
- set rules for abstraction of water, avoidance of pollution of water in furrows that have human uses
- allow renting and exchange of plots so that less wealthy members can access irrigation and take advantage of different agricultural conditions of soil, slope, etc.
- in some cases, but far from all, undertake further functions in marketing crops and procuring inputs (de Bont et al., 2019; Barham and Chitemi, 2009; Gross and Jaubert, 2019; Grove, 1993; Scoones et al., 2019)
- only occasionally has recent research focused on the organisation of irrigation: most studies describe and comment on organisation as a secondary concern without necessarily addressing questions about organisation as systematically or rigorously. With that qualification, accounts of local organisation for irrigation tend to commend them for their functionality and evidence of farmer initiative.

A SMALLHOLDER FARMER WORKS IN HIS VEGETABLE FIELD TO TAKE ADVANTAGE OF SEASONAL RAINS, BAROTSE FLOODPLAIN, ZAMBIA. PHOTO: SURENDRAN RAJARATNAM / WORLDFISH.

Local institutions are, however, unusually subject to survivor bias: that is, the ones observed are those that have worked, while those that did not are no longer visible. Local leaders, moreover, often delight in telling visiting researchers idealised accounts of their institutions, tending to downplay their failings and shortcomings. The more careful accounts of local institutions sometimes allude to disputes and conflicts as well.

That said, local organisations often work well enough to allow collective irrigation; were this not the case, much FLI would simply not have taken place. When research specifically addresses questions of organisation, the finding is usually that what works depends heavily on circumstances, and that whatever form organisation takes, it needs to fit with local social relations – see, for example, Nkoka et al. (2014) on different ways of organising furrow irrigation in Mozambique. In this, the recent literature accords with longer-standing insights on irrigation management (Korten, 1980; Adams and Anderson, 1987; Walker, 1990).

3.3 Different kinds of farmer-led irrigation

An important distinction within FLI has been raised: the difference between those who irrigate on a micro scale – typically on plots of less than one-tenth of a hectare; and those able to irrigate at scales of one, two or more hectares (Shah et al., 2013; Scoones et al., 2019).

Micro-irrigators are often unable to operate at larger scale, since they lack access to, variously, land and water, finance, labour and technical skill. Not having capital to invest in machinery, they usually have to rely on laborious manual methods to water their small plots: buckets, watering cans and sometimes a treadle pump. These plots typically grow vegetables for home consumption and some for local sale.

Those who **irrigate at larger scale**, say more than a hectare, have more resources of all kinds. They have been able to buy equipment, typically a motor pump and pipes, to pay for fuel to run the pump, to construct wells where necessary, and to hire labour for peak operations. They have often had the social connections to gain access to land close to water sources. With a hectare or more under irrigation, devoted to vegetables and other high-value crops, remarkably high gross returns can be achieved – $10,000 or more per ha each season. Among more than 1,500 farmers in nine countries of SSA, irrigators with motor pumps – who almost always operate at scale – had significantly higher returns, by a factor of three or more, to their land and labour than rainfed farmers (Shah et al., 2013).

Such a dichotomy should perhaps not be overstated. In between the archetypes can be found irrigators who aspire to greater operational scale and returns, but who struggle to do so for lack of resources. With time. some may become larger-scale operators, while others may remain trapped at a lesser scale, for lack of the means. (Scoones et al., 2019)

As will be seen in chapter 5 on policy, these distinctions matter in policy debates. Those who see farmer-led irrigation as evidence of productive irrigation and higher productivity farming tend to have the larger-scale operators in mind; while those who consider FLI as a side-show and distraction tend to have the micro-irrigators in mind. Policy debates can thus be confused, since the parties are arguing at cross-purposes.

Gender and irrigation

Gender analysis of irrigation can be seen at two levels. At an overall level, it is argued that thinking about irrigation tends to be masculine: irrigation is seen as mastering nature through technical advances to produce more output as effectively and efficiently as possible. In such considerations, gender does not appear: most actors are assumed to be men, as engineers, builders and farmers – all focused on using technology to maximum effect. Women are not only sidelined in such discussions, but also their voices and concerns are unwelcome, even seen as inappropriate – because these are seen as private and domestic matters that should not intrude into the public realm of irrigation (Zwarteveen, 2010).

In similar vein, irrigation becomes another stage in which negotiations between genders takes place, where norms establish who can decide on irrigation, who does what work, and who is entitled to rewards.

For example, for Sibou in Kenya's Rift Valley, an area where for several hundred years local farmers have watered their fields with furrows, men have traditionally been concerned with hydraulic works while women have farmed the irrigated plots to grow food for their families. More recently, opportunities have arisen to sell cash crops to markets, while early signs of climate change have been seen in more variable and less reliable weather. Men have started to grow the cash crops, thereby entering what had been women's space: implicit gender contracts based on access to resources – women to the fields, men to livestock, they have switched to contracts based on use of household incomes. Yet, underlying these changes, men have more power: they have greater say over use of income, while women find themselves with greater workloads (Caretta and Börjeson, 2015).

More commonly, however, studies of gender and irrigation focus on practical arrangements, rather than the norms that determine these, looking at access to resources. They record how women as irrigators are often disadvantaged, having lesser access to resources – land, labour time, inputs, technical advice, capital – compared to men (Sinyolo et al., 2018; Shah et al., 2013). Given that irrigation tends to demand capital and labour, more inputs, more technical expertise than rainfed farming, women are likely to be disproportionately disadvantaged.

Another disadvantage for women irrigators arises when irrigation requires collective management, when forums may be dominated by men, and where women's concerns are marginalised. One possible consequence is that, when irrigation is allocated by a time rota, women may be allocated slots that conflict with domestic chores or during the night when it would not be safe for them to water their plots.

4. Assessing farmer-led irrigation: successes and challenges

Outcomes from FLI vary considerably. Although the literature often reports that farmers have increased production and gained income, selections are biased: failed irrigation is less likely to be reported than successful irrigation, simply because abandoned irrigation is much less visible than surviving, successful irrigation.[5]

With that significant qualification, then, this section summarises insights on technical performance, economic results, social and environmental impacts.

4.1 Technical resource performance

Introduction

The technical performance of irrigation concerns the relation between the desired outcomes of irrigation in agricultural production and the use of natural resources (principally land, water and energy) to achieve those outcomes. For example, performance can be measured by the following ratios:

- **Land productivity**, principally crop yield per hectare (kg/ha).
- **Water productivity**, as the yield (kg) or value ($) of crops per cubic metre of water used.
- **Irrigation efficiency**, as the unitless ratio (%) of water transpired by the crop to the water withdrawn into, or consumed by, the irrigation system, a distinction explained next.

Unlike land area, water is difficult to measure. Part of the total water entering an irrigation system (irrigation withdrawals) is used consumptively, being lost, beneficially and non-beneficially to the local environs or to the atmosphere as evapotranspiration, and part is used non-consumptively because it returns as drainage to the catchment or aquifer. These distinctions, although influencing many other factors, such as timing and location of irrigation water, allow us to account for water in an irrigated basin and to judge water productivity and irrigation efficiency.

While on paper these distinctions look to be understandable, in practical terms it is very difficult to accurately measure consumptive and non-consumptive or beneficial and non-beneficial flows as a one-off research effort or as an ongoing activity, because comprehensive (or even minimal) metering of inflows and outflows is rarely seen in irrigation. And, even if armed with this flow data, it is difficult to calculate irrigation efficiency and water productivity at different field, irrigation and basin scales because real hydrological flows do not neatly migrate between start and end points in neat proportions. Associated with these significant problems, the irrigation literature continues to debate the merits, demerits and applications of irrigation efficiency (Perry, 2007; Lankford, 2012; Grafton et al., 2018).

Given these gaps in knowledge, we cannot say with confidence whether many irrigation systems are performing at good, satisfactory or below-par levels. In examining the literature on smallholder irrigation, this Synthesis Report agrees with Burney and Naylor (2012: 112):

> *most current evidence on their [smallholder systems in Africa] performance has been anecdotal.*

Anecdotal and alternative evidence on performance

Bearing in mind these knowledge gaps, many documents address irrigation performance in ways that *appear* technical but are not supported

5 Researchers may also be biased in their choices of study sites. Successful irrigation may be easier to study, since those engaged will probably be more open to discussing their experiences – as will anyone from government, NGOs or private firms who may claim some credit for the success.

On the other hand, failed schemes that were started with some fanfare also attract attention when they fail: much has been written about the shortcomings of some public schemes – see section 2.

by robust, long-term quantitative research of changes in resource use using data gathered at different scales by different methods. For example, although Burney and Naylor (2012) report on, and then attempt to systematically assess, smallholder irrigation, their work does not show how they measure 'water use', one of their three water adoption strategies, or how they reflect on efficiencies related to water.

Box 4A gives a sample of alternative technical ways of reporting irrigation. While all the examples in Box 4A add knowledge and none are incorrect, it can be said that researchers, farmers and policy-makers end up not offering objective evidence in discussions about improvements to irrigation performance, as they are insufficiently systematic about resource use.

Another way that widespread beliefs on technical performance are reinforced is by employing relatively basic or first impressions on apparent differences between irrigation systems yet, without referring to how systems can be better or worse

Box 4A How irrigation is reported technically

Typical metric reported	Comment
Qualitative rating of criteria between types of irrigation (drip, sprinkler, canal, small, large)	One-star to five-star ratings of the differences in (e.g.) labour, energy, land suitability and water use applied to irrigation types introduce issues, but do not guide on performance
Observations on the growth and/or distribution of irrigated land	Satellite measurements and cadastral surveys of land are easy to conduct but cannot guide on water use at farmer-relevant spatial/time scales
Records on x% increased crop yields and changes to cropping systems as a result of watering	Indicate benefits of irrigation, but often no information on water consumption. If the latter is given, these are often at one scale (e.g. field), but not at other system/catchment scales
Results from modelled resource use; especially those expressed at the catchment, national or global scale	Modelling (which shows and tests theory, practice and policy) needs calibration and validation under real conditions. Furthermore, deriving irrigation water use from agricultural production via a standard water footprint method does not guide how to manage water on real irrigation systems
Ways of engaging with farmers technically, e.g. using GPS mapping and wetting front detectors	Whether these make a net difference at field, system and catchment scales. Farmer engagement should be placed alongside an understanding of how livelihoods, knowledge and infrastructure drives irrigation practices and performance
Judging irrigation on the basis of count data (e.g. the number of irrigation doses, or treadle pumps that fall into disuse)	Quick, efficiently collected data, but give little indication of resource use and performance
Beliefs regarding irrigation system improvements, e.g. lining canals or installing meters (also see next Box 4B)	Research on (a) how these actually boost and sustain irrigation performance; (b) compare to alternatives; (c) are sequenced and prioritised, is often missing

SOURCES: BURNEY AND NAYLOR (2012); COMAS ET AL. (2011); KONAR ET AL., (2016); MALABO MONTPELLIER (2018); PITTOCK ET AL. (2017); ROSEGRANT ET AL. (2014); STEDUTO ET AL. (2017); YOKWE (2009)

Box 4B Why first impressions may not help in comparing canal gravity systems to drip irrigation

Canal/gravity irrigation	Drip/pressurised irrigation
Irrigation losses are less of a concern if (a) rainfall meets a high proportion of crop water demand, and (b) losses flow, without transaction costs, to the aquifer or basin, reducing net consumption.	
Canal leaks and losses might be a small proportion of the total losses and, in some field irrigation systems (e.g. rice), may meet crop water requirements	Drip systems age due to sunlight, operation, fire and pest damage. Drip lines inside fields are difficult to monitor; breakages and blockages are not easily located
Distributed via gravity, canal water losses do not represent 'lost' energy costs	In a pressurised system, water losses represent a fuel or energy cost (and a carbon footprint)
Earth and concrete are relatively easy to install and repair	Drip systems wear out and are discarded leading to plastics waste
Gravity irrigation is well-suited to field irrigation of staples such as rice	Drip is well-suited to irrigation of row crops such as fruit trees and vegetables
Collective arrangements between smallholders on gravity tend to function well	Small farmers running collective drip systems struggle to share complex maintenance and energy bills
Field and canal losses can be adjusted and reduced in many ways, using lining, canal density, gradients, lengths	Drip irrigation 'out of the box' as well as requiring maintenance, can be adjusted by time/flow operation and density of lines and emitters

SOURCES: BURNEY AND NAYLOR (2012); COMAS ET AL. (2011); KONAR ET AL., (2016); MALABO MONTPELLIER (2018); PITTOCK ET AL. (2017); ROSEGRANT ET AL. (2014); STEDUTO ET AL. (2017); YOKWE (2009)

managed, or how they fit the host farming system. This tendency is especially seen when it comes to comparing 'modern' drip to 'traditional' canal irrigation (Tables 1 to 3 in the Malabo Montpellier 'Water-wise' report are an example of this approach). With respect to comparing 'efficiency', see Box 4B for an explanation of the difficulty of comparing leaks and losses on these two types of irrigation technologies using first impressions.

Conclusions

This lack of knowledge about performance leads to four policy gaps:

(1) The design of interventions that work with irrigation systems, farmers and other irrigation actors and components institutionally, organisationally and physically to raise technical performance.

(2) Whether these interventions actually boost productive outputs and incomes.

(3) Whether they reduce the net consumption of the resource input – which also raises the efficiency and productivity of irrigation and lowers its impact on the wider environment.

(4) How to effect (1), (2) and (3) sustainably and equitably in cost-effective ways at the individual, system and aggregate catchment scales over long time periods covering fluctuations in resource scarcity.

The significance of all four policy gaps applies to FLI in Africa where, although incomes and crop production on a single plot of 0.5 ha might be impressively high, we still need to judge this output in equivalent water consumption and productivity terms to: (a) manage water shortages and allocations at scale if and when FLI grows in aggregate area and water use; and (b) compare FLI with other irrigation types.

In future, in a more resource-constrained and populous world, we will need to do better. By conjoining information on the use of water, land, energy, ecosystems and materials, with people's knowledges and institutions, we can build an accurate systemic picture of which types of irrigation system are 'fittest' to the conditions found, and address subjective opinions regarding types of irrigation. Although their analysis does not calculate the water used in different smallholder systems, van Averbeke et al. (2011) provide a framework showing how this might be done, covering the following criteria:

- plot size for each farmer
- technology used for irrigation access and distribution
- institutional factors such land tenure and as agreements regarding maintenance
- prevalence of support services
- other farming practices such as fertiliser use
- programmes to rehabilitate irrigation systems

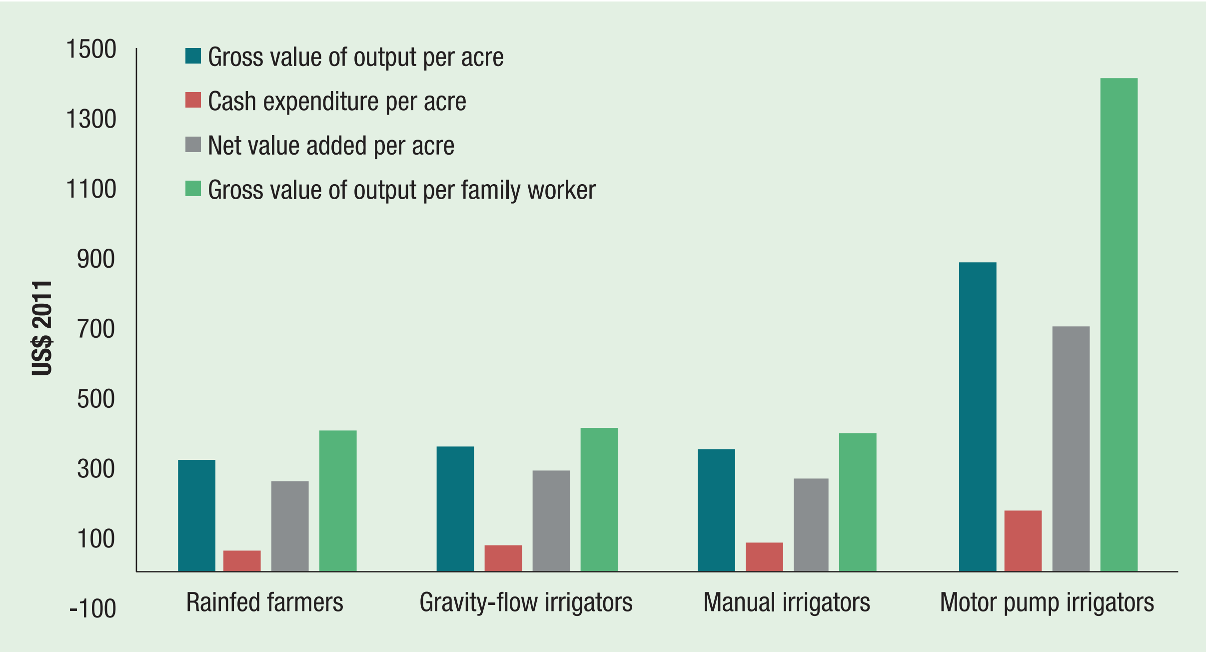
4.2 Economic results

Most observations of irrigation performance focus on crop yields, production and farm incomes. Irrigation should improve yields per ha, may allow more than one crop a year to be raised – especially during dry off-seasons, and may permit cultivation of higher-value crops that require more water or more controlled application of water.

Irrigation is usually combined with more intensified production. For example, at 18 sites of FLI in Mozambique and Tanzania, purchased fertiliser was applied to 42% and 49% of irrigated plots, respectively, while improved seeds were planted on 52% and 38% of irrigated plots, respectively. Irrigated plots were much more likely to receive manufactured fertiliser and improved seeds than plots that were not irrigated at the 18 sites (de Bont et al., 2019). In Upper East Region, Ghana, almost all the small plots irrigated from wells were treated with manufactured compound fertiliser (Namara et al., 2011).

Not all irrigators, however, intensify their production more than equivalent farmers who have only rainfed fields (Figure 4.1). A survey of more 1,500 farmers in nine countries found only small, barely significant differences in the intensity of cultivation between rainfed farmers and those irrigating from gravity flow,

Figure 4.1
Intensity of production per unit area, nine countries, 2011



SOURCE: COMPILED FROM DATA IN TABLE 4 IN SHAH ET AL. (2013)

Notes: Results from surveys of 1,544 farmers in Burkina Faso, Ethiopia, Ghana, Kenya, Malawi, Mali, Niger, Nigeria and Tanzania or manually lifting water. Only those irrigating with motor pumps showed a marked increase in both intensity of production and the returns they achieved per acre and per household worker.

Returns to irrigation at field level

Irrigated land potentially produces more, perhaps also more crops with high unit value, leading to increased revenues and, probably, greater margins over costs.

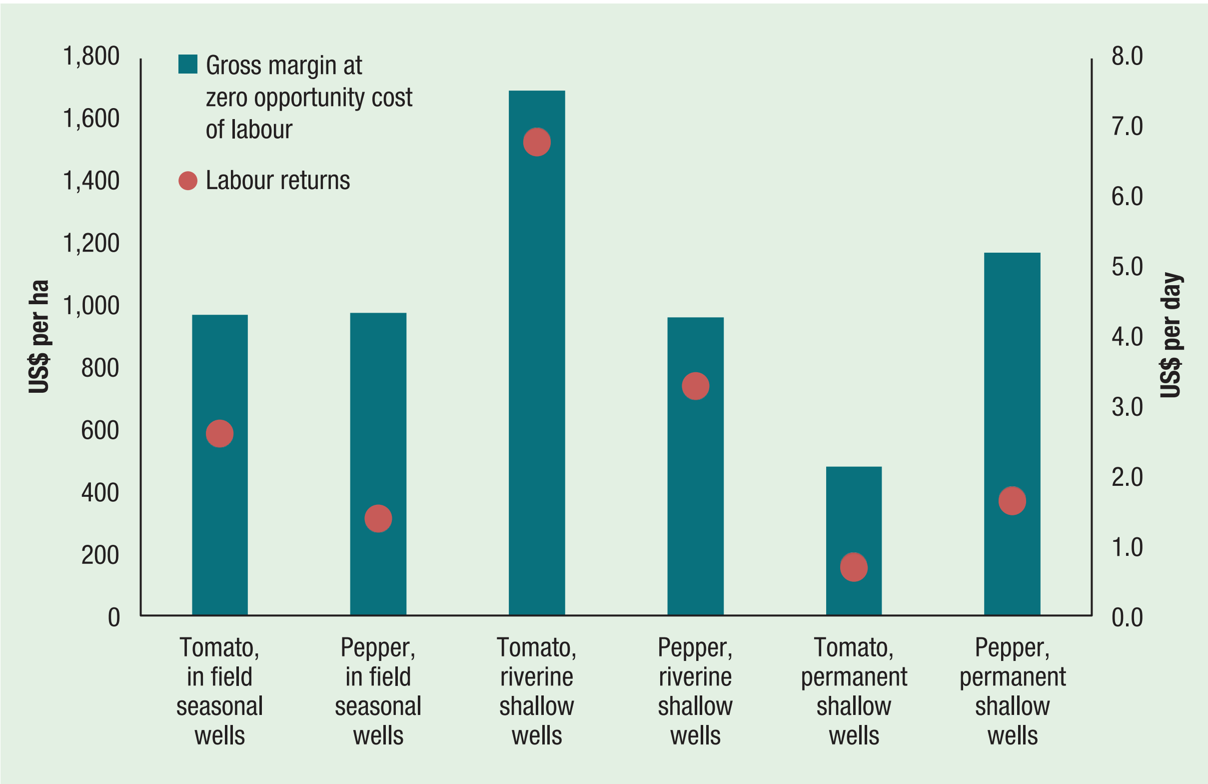
At field level, gross margins, calculated as the difference between revenues from the crop and costs other than fixed costs – that is, seed, fertiliser, chemicals, labour, bags, etc. – give an initial indication of returns to irrigation.

Gross margins on irrigated crops can be high, much higher than those from rainfed crops. In Upper East Region, Ghana, a remote, semi-arid part of the country where most live on low incomes with out-migration as a necessity for household livelihoods, irrigation from shallow wells can generate relatively high returns per ha watered. Gross margins from shallow wells used to irrigate tomatoes have been estimated at more than $1,600 – but without taking into account labour costs (Figure 4.1). Fixed costs were minor: assessed at between $13 and $85 per ha.

Since much labour is used on the irrigated tomatoes and pepper – between 230 and 700 days per ha – implicit returns to labour are not quite so impressive,[6] but can reach more than $6 a day: far above the going wage rate in the Upper East Region (Namara et al., 2011).

As can be seen in Figure 4.2, returns vary considerably across the six variants of irrigation observed: and no doubt vary by as much or more between different wells. Much depends on crop yields, itself a function of diligent cultivation and the incidence of pests and diseases.

Figure 4.2
Gross margins for irrigators in Upper East Region, Ghana, 2008/09



SOURCE: NAMARA ET AL. (2011).

6 Implicit returns to labour taken as the gross margin divided by the number of days worked.

In Lume District of central Ethiopia during the early 2010s, some farmers had dug shallow wells then used motor pumps to irrigate small plots of between 0.1 and 0.5 ha with vegetables. These were sold in Addis Ababa two hours' drive away along a tarmac road or in the closer, regional centre of Nazaret. While previously dryland crops could generate gross margins of up to $1,400 per ha, irrigated onions could result in a margin of $3,500 per ha (Figure 4.3) (Wiggins et al., 2014).

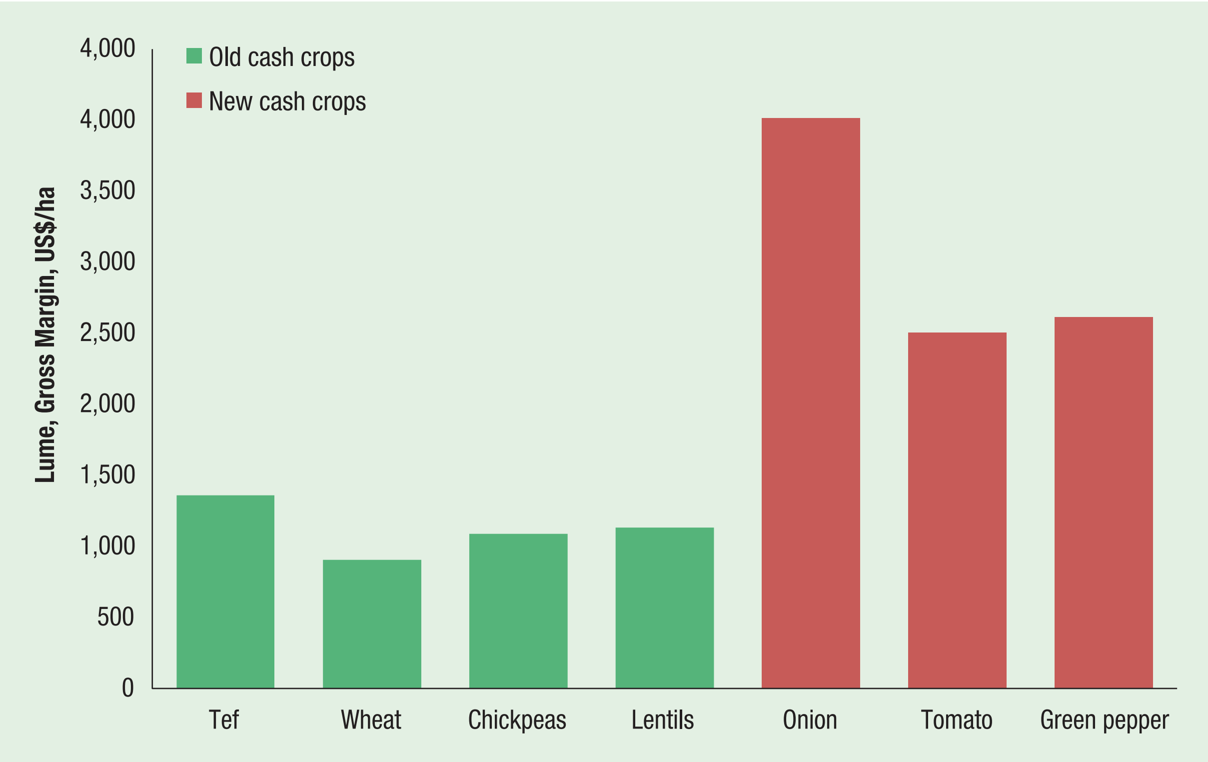
In Kenya, very high gross margins, of more than $13,000 per ha were reported for farming on virgin land in Narok District, where the local Maasai had allowed incoming farmers to create plots along streams which they used to irrigate tomatoes. These were sold in regional centres, such as Kisumu and Nakuru. Virgin land could produce high yields, with low susceptibility to pests and diseases. On older fields, yields fell, but gross margins in excess of $8,000 per ha could still be had (Wiggins et al., 2014).

Less spectacular margins were seen for irrigated onions in central Tanzania in 2010, yet returns to labour spent on the plots could be high, with median returns of $10–$16 a day calculated (Mutabazi et al., 2010).

These examples of returns to irrigation at field level reflect what is possible when at least two critical conditions apply. One is that water can be abstracted and conveyed to the field at low cost. When fields are close – up to a few hundred metres – to surface water or when shallow wells can be dug on or next to fields, this condition can be met. Returns will be lower for cases where surface water has to be conveyed over greater distances, or where water has to pumped from deep aquifers.

The other condition is that the land watered can grow high-value crops that can be delivered to a market where good prices are paid for such crops. In the above examples, the crops are all vegetables that typically fetch good prices in the growing towns and cities of SSA – provided that there is not a glut of production that drives down prices. Can staple crops be irrigated and still provide adequate returns? Yes, for rice, grown for sale in inland cities. Perhaps not for less valuable cereals (Box 4C).

Figure 4.3
Gross margins to irrigated crops, 2010s, Lume District, Ethiopia



SOURCE: WIGGINS ET AL. (2014)

Box 4C Irrigation of staple food crops in sub-Saharan Africa

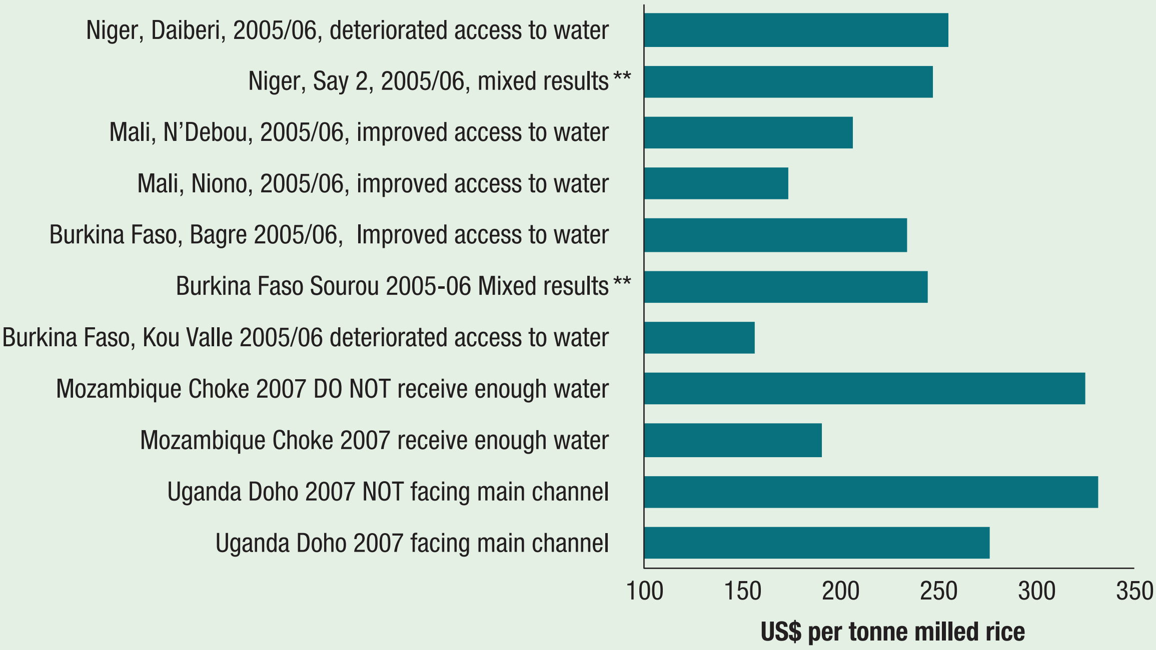
Across Asia, it is common for rice to be irrigated.

By and large, most accounts of irrigation in SSA, and especially reports on recent farmer-led irrigation, concern the irrigation of relatively high-value crops, with vegetables most commonly reported.

The exception in Africa is rice: irrigated both because the crop is quite demanding of water and because rice is, among staples in Africa, a premium crop with higher prices per tonne than other staples, such as maize.

Nakano et al. (2011) compiled reports of the economics of irrigated rice at nine sites. Cost of production of milled rice ranged from $157 to $332 a tonne, with a median of $245 a tonne (Figure 4.4).

Figure 4.4
Cost of production, irrigated rice, nine sites in sub-Saharan Africa



SOURCE: COMPILED FROM DATA IN NAKANO ET AL. (2011). COST OF HOUSEHOLD LABOUR FOR SITES IN WEST AFRICA ASSUMED TO BE $100 PER HA.

These costs need to be compared to the landed cost of imported rice from Asia. Such rice in recent years has been available for export at $250 to $300 a tonne: to which must be added shipping to Africa, after which costly land transport when imported to landlocked countries such as Uganda and the Sahel: say, $400 to $450 a tonne. Irrigated rice can thus compete well with imported rice.

What of the economics of irrigating other cereals, that are less valuable per unit weight? A study of this was not found. Irrigated cereals would, at most times and in most places, have to compete in this case with home-produced dryland crops. While the yields may not be high, costs are quite low. Irrigated cereals would probably need to have production costs of less than $150 per ha to compete – in years of average harvests. In drought years, irrigated cereals would face much higher prices, competing with imports rather than a failed local harvest.

Hence, while the economics can appear attractive for current irrigation, that will not necessarily apply to expanded irrigation – where the costs of obtaining water may be higher, where it may not be possible to grow high-value crops, and where expansion of output might outstrip growing market demand and depress prices.

The variability of returns to irrigation is high. Plenty of accounts of failed irrigation since 2000 can be found, even if a bias to reporting visible successes exists. For example, the impact of small reservoirs built, usually with government or donor funds, in northern Ghana on the incomes of small-scale vegetable producers was found to be small and insignificant (Acheampong et al., 2018). The nine-country survey by Shah et al. (2011) showed hardly any gains to most forms of small-scale irrigation over dryland cropping, except for when motor pumps had been used.

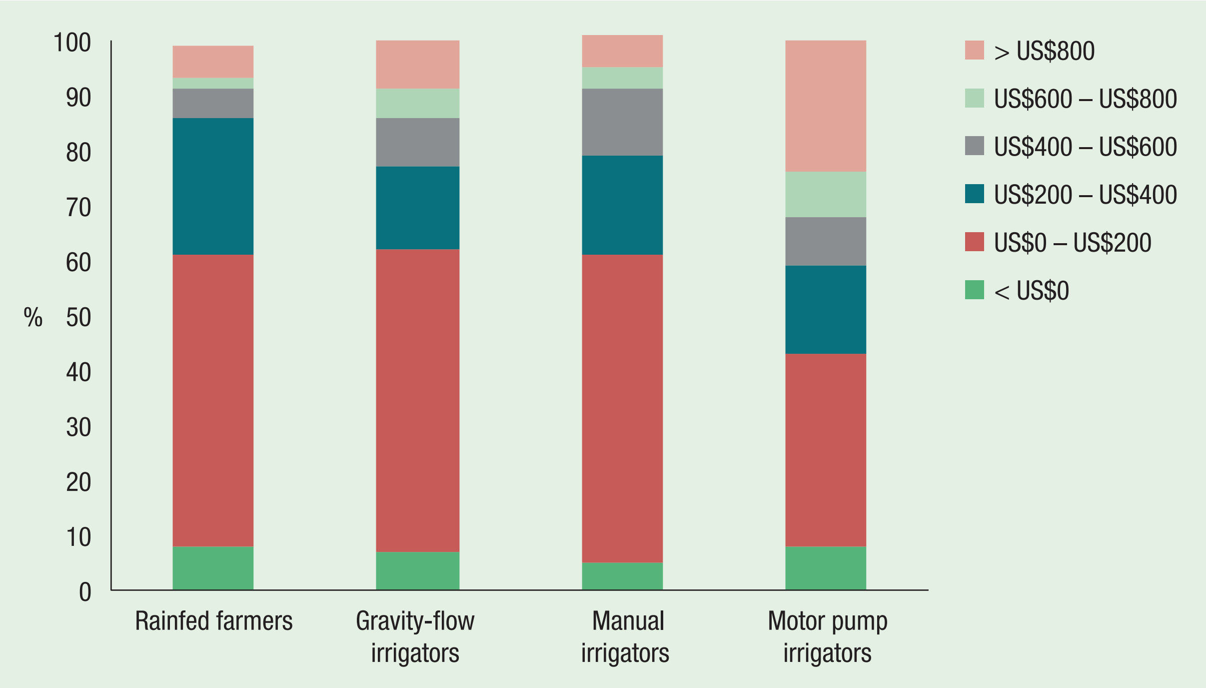
Large variations apply even when irrigators are grouped by similar characteristics. For example, in the nine-country survey of irrigators, within every group some households reported negative net returns to their land (Figure 4.5), even among those with motor pumps who were otherwise notably successful.

Economic effects of irrigation on the wider economy

Irrigation can affect the wider economy substantially. In the local rural economy, irrigation can generate many more jobs per unit of land, especially for vegetables, where the need to raise seedlings and transplant them by hand, to fertilise, weed, apply chemicals, and to harvest the crop by hand can easily require more than 400 days labour per ha per season.

In the Upper East Region of Ghana, for example, Namara et al. (2011) calculated that more than 350,000 days of labour a year had been created on the well-irrigated plots during the dry season, when almost no alternative employment is on offer. If people worked for 100 days during the dry season on the irrigated plots, that would create work for no less than 3,500 people: a very considerable boost to the local economy. In former times, the Upper East has seen heavy out-migration in the dry season (Cleveland, 1991).

Figure 4.5
Net returns per acre for different water-control groups



SOURCE: SHAH ET AL. (2013)

SCREENING MAIZE FOR DROUGHT TOLERANCE, KIBOKO, KENYA. PHOTO: ANNE WANGALACHI / CIMMYT.

The cash earnings from the sale of irrigated crops can be similarly large. In Tanzania, for example, the mean value of sales from irrigating households at 10 sites surveyed in 2015/16 was $884 a year: among similar households not irrigating, the value was just $162 a year (de Bont et al., 2019). The marginal addition to cash of more than $700 is substantial.

Aggregating this by the number of irrigating households can reveal very large injections into the local economy. The same researchers in Tanzania estimate that the total value of irrigated rice in Shinyanga Region is worth at least $89M. For Rukwa Region, the additional value of sales from irrigated land was estimated at $22.8M–$44.4M a year [P. Woodhouse, personal communication, 2019].

Similarly, within the White Volta basin, for 35 communities in Upper East Region, Ghana, Namara et al. (2011) estimated the value of sales from the irrigated vegetable as $1.1M.

Given that smallholder irrigators are likely to spend a good share of additional earnings locally – housing improvements, entertainment, etc. – the multiplier effect on the local economy can be strong, as spending creates jobs and incomes for those with non-farm occupations – masons, carpenters, tea-shop staff, drivers, musicians, etc.

Estimates of just how strong the impacts of irrigation can be on regional economies in SSA do not seem to have been made.

Economic problems and challenges

Almost nowhere in rural SSA do ideal conditions for irrigation apply, with deficiencies plain to see and commonly reported, including:

- Irrigators cannot obtain formal finance for investment, upgrading and maintenance.
- Supplies of quality seed, fertiliser and crop protection chemicals are lacking.
- Marketing of products is made more difficult or less profitable owing to undermaintained roads, varying prices in markets, inability to store produce at times when prices are low, and alleged trader cartels that bid down prices. That said, reports of marketing difficulties are less common, since FLI only tends to be undertaken when it is possible to market produce at a profit.

Official irrigation schemes also sometimes find that farmers are not interested in irrigating in the dry season, since the men of the village have migrated out — as was seen for the irrigation perimeters on the River Senegal, where men left in the dry season to work in Dakar (Diemer et al., 1991; Woodhouse and Ndiaye, 1991).

4.3 Social impacts of irrigation

Poverty and food security

Many studies of irrigation argue that irrigation can reduce poverty and improve food security, although studies that actually try to measure such impacts are few.

An exception concerns the wells and reservoirs of Upper East Region, Ghana (Namara et al., 2011). Comparing irrigators to those without irrigation, they found that some groups of irrigators had experienced less poverty, fewer months of food insecurity and more diet diversity – but not all of them, and with gains not consistent across the three dimensions of poverty and hunger (Table 4.1).

Proving that irrigation reduces poverty is not that simple, since the paths from irrigation to welfare impacts are several and involve multiple steps. For example, in trying to assess irrigation's impact on nutrition, Passarelli et al. (2018) identified four main causal paths from irrigation to food security, as follows:

- **Production**: more crops grown, more fruit and vegetables, more food available in the dry season.
- **Income from crop sales** enabling irrigators to buy food, health care.
- **Water**: irrigation may increase the supply of clean water for domestic use, or it may create extra health risks if the water is contaminated or becomes a habitat for disease vectors.
- **Women's empowerment:** irrigation may or may not give women more say over production and consumption. It may or may not increase their burden of labour.

When they tested these paths using data for households in Ethiopia and Tanzania, unadjusted comparisons showed that:

> *irrigating households in both countries produced more vegetables, fruits and cash crops, are less food insecure, have a higher-value of production, and have higher production diversity and dietary diversity compared to non-irrigating households.* (Passarelli et al., 2018)

When, however, controlling for selection bias, their model showed that in Ethiopia irrigation led to greater diet diversity of irrigating households, mainly owing to increased income. In Tanzania this effect was not statistically significant. The authors comment that diet diversity was affected considerably by the gender of the household head and by having off-farm income. Hence, they concluded that the impacts of irrigation on food security were contingent on other important factors.

Social equality, gender and conflict

Households irrigating tend to be those with better-than-average incomes, land, labour and education: this applies all the more when considering those who irrigate with motor pumps and who irrigate areas greater than garden plots (de Fraiture, 2013; Namara, 2013; Scoones et al., 2018; Shah et al., 2013). This does not surprise: across much of rural Africa, few

Table 4.1
Impact of irrigation on poverty and hunger, Upper East Region, Ghana 2010

Compared to non-irrigators:	Sig. reduction in poverty	Sig. reduction in months of food inadequacy	Sig. increase in diet diversity
In-field shallow wells	No	Yes	Yes
Permanent shallow wells	No	Yes	No (reduction)
Riverine shallow wells	Yes	No	Yes
Small reservoirs	Yes	Yes	No (reduction)

SOURCE: NAMARA ET AL. (2011), TABLE 8

households can readily afford to spend the little cash income they have on motor pumps and pipes.

It is not just monetary wealth that counts. For Zimbabwe, Scoones et al. (2019) emphasise how the more commercial irrigators they interviewed almost always had the social and political connections that allowed them to access land close to water sources, to abstract water regardless of whatever regulations might limit the amount taken, to recruit labour, and to find the better-connected trader to buy their produce at better-than-average prices. Those irrigating garden plots with buckets, on the other hand, were often households that had been marginalised – often small households headed by women.

It might thus be imagined that irrigation tends to benefit those already disproportionately better-off – and that others get either little or no benefit or even suffer harm.

On the plus side, irrigation usually increases the demand for farm labour. Irrigating households typically hire in significant amounts of labour, creating jobs for people who lack other assets and who cannot irrigate. In Upper East Region, Ghana, Namara et al. (2011) estimated an additional 350,000 days of employment from the dry season shallow wells: a considerable potential benefit in a region with few other jobs on offer. The authors consider that the wells have helped stem migration from the region.

Other studies also report increased employment on irrigated plots; but they do not give details of just who does this work, and what impact this has had on the income and welfare of non-irrigating households.

One might assume, as well, that the injection of cash earned from irrigated produce to the local rural economy produces multipliers that create additional work and income for other households. Studies in SSA that test for this effect could not be found.

On the negative side, irrigation may widen existing social inequalities. In DEGRP-funded research, using case studies of irrigation in Tanzania and Malawi, water user associations on formal schemes could be controlled by the more powerful and better-off in the community (Harrison and Mdee, 2017a; Harrison and Chiroro, 2017)

In Malawi, the formalisation of land and water rights on an irrigation scheme excluded those who had previously been irrigating on the area under the scheme, most of them women farmers (Harrison and Chiroro 2017).

The impacts of irrigation on women are varied. Women can benefit from irrigation in several ways: irrigation may allow them to produce more from their land, leading to more food security or income; irrigation may raise household incomes from which women and children benefit; other farmers' irrigation may create increased demand for labour and push up rural wages on which some women on low incomes depend; and, canals and furrows may be a more convenient source of water, saving time collecting water. On the other hand, men may appropriate irrigated land that formerly was allocated to women. Women may have to spend more time on household fields, while men take the decisions over use of crops and the income generated. Where irrigation has increased health risks – see below – women may bear the brunt of caring for sick members of the family (Domenech and Ringler, 2013).

Much depends on power relations and gender norms: when women are more empowered – having access to land and water; being able to decide on crops and their disposal; being able to decide how to spend household income – they have more chance that irrigation will benefit them and their children (Ibid.).

Where women are less empowered, women get less advantage or end up becoming worse off. In Kenya, for example, the NGO Kickstart thought that promoting irrigation for sales of crops to markets would benefit both sexes, but it was men who disproportionately adopted the pumps being promoted (Njuki et al., 2014). Similarly, in Ethiopia, irrigation projects may have targeted both sexes, but it was men who were seen to control irrigation technology and had more control over income arising from the adopted technical advances (Nigussie et al., 2017).

In some cases, **people can lose out absolutely from irrigation**, typically when conflicts over water arise. Upstream irrigation can deprive downstream users of water. For example, as DEGRP research reports, the Dakawa irrigation scheme in central Tanzania was built to pump water from the Wami River in both wet and dry seasons, but cannot do so in the dry, since the river flow has fallen because of upstream irrigation (Harrison and Mdee, 2017a). Hosepipe irrigation in Mgeta Division of Morogoro, Tanzania, has been condemned by authorities in the town of Morogoro for depriving the town of water for drinking – and, apparently, swimming pools (Harrison and Mdee, 2017b).

Reports of competition seem to be growing, as might be expected given the growth of FLI. One instance that can annoy official agencies is when a dam has been built by public funds to irrigate lands below the reservoir by gravity; but then around the reservoir informal irrigators begin to pump out water, thereby imperilling supplies to the officially planned and sanctioned irrigators.

For example, at Korsimoro in Burkina Faso, a small reservoir was built to allow 32 ha of rice to be irrigated downstream. Meanwhile, from the banks of the reservoir around 1,000 farmers have irrigated 285 ha of vegetables. The initiative of the informal irrigators may be commended: especially as the value of their vegetables from an area more than eight times larger than that of the intended rice, must be many times greater than the value of the planned irrigation. On the other hand, for those running the official scheme, the informal irrigators appear to be opportunistic freeloaders (de Fraiture, 2013).

In other cases, irrigation conflicts with the interests of pastoralists who lose dry season grazing or who find that their migratory routes have been blocked by irrigated fields or works. For example, in the Sourou Valley of south-east Mali, a dramatic expansion of irrigation in the late 1980s and early 1990s saw 6,000 ha of rice planted around a new lake. This led to disputes with pastoralists over access to dry season grazing (Woodhouse et al., 1997).

In other cases, irrigation works can harm other communities, as DEGRP research shows. In Malawi, for example, a protective bund was built to protect a scheme from flooding, but this simply resulted in catastrophic flooding in neighbouring villages (Harrison and Chiroro, 2017).

4.4 Environmental and health impacts

Irrigation affects the **natural environment**, both directly through abstraction of water and the resulting changes to hydrological systems, as well as less directly through the forms of agriculture practised on irrigated land. Potential effects and problems include:

> River depletion and consequent degradation of downstream aquatic ecosystems, including effects on groundwater and fisheries.
>
> Drainage of wetlands and runoff or discharge of wastewater to surface water – and groundwater-dependent ecosystems.
>
> Groundwater depletion by overexploitation for irrigation, causing damage to groundwater-dependent ecosystems.
>
> Land degradation and alterations of local to regional climate from land-use changes.
>
> Pollution from overuse of nutrients and agrochemicals, with consequences for terrestrial and aquatic ecosystems and for human health because of water pollution.
>
> A worsening of water pollution problems by river depletion, decreasing possible river dilution, as illustrated in the tributaries to the Aral Sea and in the severe health problems caused to downstream populations
>
> (CAWMIA 2007, Chap 6)

To this list may be added loss of biodiversity, from changed local ecosystems and from the loss of agricultural biodiversity on farms that can result from more intensified production.

Although these risks are frequently alluded to in the literature, specific accounts of environmental impacts resulting from FLI in sub-Saharan Africa seem to be few.

Most of the **physical problems** reported from FLI concern over-abstraction of water. In the case of groundwater aquifers, this can lead to depletion with wells having to be sunk ever deeper to tap the water table – as reported by Abric et al. (2012) for parts of West Africa. The extent of this seems uncertain: systematic surveys with reliable results that factor out seasonal variations seemingly do not exist.

For a scheme in Western Kenya, Awinda and Kitetu (2012) reported significant problems with siltation of canals, soil erosion and loss of biodiversity. Siltation contributed to water scarcity, while soil erosion and degradation had led to falling rice yields.

In Rwanda a reservoir irrigation scheme showed problems of soil acidity, and sedimentation in the reservoir and canals (Majoro et al., 2016).

On four irrigation schemes in the Upper Awash basin of Ethiopia, Ayalneh et al. (2007) reported that while irrigation had led to higher incomes, more jobs and more activity from backward and forward linkages, the schemes were nevertheless suffering from inefficient use of water, loss of soil fertility, soil erosion, and soil salinity at two schemes.

Irrigation may also affect **human health**, with the following the main potential dangers (CAWMIA, 2007):

- Waterborne disease, including malaria and schistosomiasis, resulting from irrigation water providing a habitat for vectors of disease.
- Toxic chemicals used on plots either ingested through touch or inhalation, or else polluting sources of domestic water.
- Higher water tables impeding sanitation.
- Unsafe irrigation canal water being used by humans.

Again, relatively few studies of these potential effects resulting from small-scale FLI can be seen for sub-Saharan Africa.

Assessing the health impacts of irrigation along the Tana River in Kenya, Mutero (2002) identified increased incidence of malaria and schistosomiasis, and exposure to toxic chemicals as the main risks. On the other hand, nutrition was expected to improve from increased farm production.

Ayalneh et al. (2007) reported contaminated drinking water on the four schemes on the Upper Awash.

In Tigray, northern Ethiopia, Ersado (2005) found that, while irrigation dams had raised incomes and created jobs, they were associated with more disease from malaria, which cost households labour time that affected their production both on their irrigated fields and in non-farm activity.

In southern Ethiopia, irrigators were found to be aware of the dangers of toxic chemicals, but few took precautions, and many reported illnesses likely to have been caused by poisoning (Gesesew et al., 2016).

Just one study was found that tried to assess the advantages of irrigation against health costs. This showed that being closer to an irrigation dam created benefits for agriculture, although there were offsetting costs from loss of labour and healthcare. The balance, however, was in favour of being closer to the dams (Table 4.2).

Table 4.2
Estimates of marginal benefits and costs per unit (km) proximity to nearest microdam

Benefits/Costs (in Birr)	Estimated Value
Marginal benefits	53.25
Improved yield	19.25
Firewood collection	9.80
Forest stock	6.90
Interaction	17.30
Marginal costs	18.98
Cost agricultural land to trees	0.87
Sick labour and/or caring for sick	17.42
Financial cost of healthcare	0.69
Net benefit	24.27

SOURCE: TABLE 10, ERSADO (2005)

5. Irrigation policy

5.1 Introduction: normative and descriptive accounts of irrigation policy

The literature on irrigation policy consists in large part of two streams: normative and empirical.

The **normative**: stream sets out what needs to be done. Typically, the argument proceeds from a consideration of the challenges faced and opportunities in irrigation to a consideration of priority policies and actions.

Official frameworks that set out policy priorities invariably are normative, developed from an assessment of problems and opportunities, to derive objectives and action plans. Those that apply at continental level will be reviewed in section 5.2.

Much of the literature on smallholder irrigation in SSA concludes with policy implications that arise out of the analysis reported. By and large, these prescriptions outline potential policies, but few enter into detail about precise instruments, how they might be implemented, and the challenges likely to be faced in doing so.

For example, Lefore et al. (2019) review the challenges faced by smallholder irrigators; above all limited access to finance, limited labour and underdeveloped supply chains for equipment, parts and servicing. They argue that farm households on very low incomes and those socially marginalised are unlikely to benefit from irrigation. They warn that the wrong kind of irrigation can harm both the natural environment and human health. Priorities for irrigation development, they propose, are thus:

- finance and supply chain development
- support to women farmers
- measures to avoid harm to health and the environment
- development of institutions, especially local collectives using participatory monitoring, games to get engagement.

Similarly, de Fraiture's (2013) lecture on informal irrigation argues for four sets of intervention to assist small-scale private irrigation, thus:

- For equity, improve access to technology – including facilitating finance for irrigators, supporting equipment rentals, both with special attention to the needs of women irrigators.
- For efficiency, developing input supply chains – including credit for dealers, more technical information for farmers and dealers, investment in crop storage, and try-before-buying schemes.
- For efficiency, ensure coherence in policies for energy and water – including reviewing taxes and import duties, import procedures, and privatising the supply of irrigation equipment.
- For the environment, take a watershed approach – including promotion of cooperation, consideration of all water investments, community-based planning and monitoring, and development of alternative energy sources.

The other stream of policy argument is more **empirical and analytical**: policies typically favoured for irrigation are assessed for their merits, often with discussion of why they were chosen. From the 1970s if not earlier, observers – for example, Adams (1990, 1991), Carney and Watts (1990), Kadigi et al. (2012), Moris (1987) – noted the penchant for public agencies to build gravity-flow canal schemes irrigating relatively large areas, with centralised management by a public body. They argued that the design of schemes focused disproportionately on the (optimal) engineering of hydraulic works, at the expense of sufficient attention to other aspects, particularly the human dimensions of irrigation – farm economics, scheme operation and management, farmer organisation, land tenure, etc. Schemes then often ran into severe problems on these human dimensions (see section 2.1).

This bias in the design of public irrigation schemes was not just seen in Africa: similar tendencies have been reported for large-scale canal schemes in Asia (Blake, 2019; Burns, 1993; Molle et al., 2009). Studies in Asia have also documented how incentives in the operation of large public schemes have not encouraged efficient scheme management. Indeed, in some cases, scheme operators who extract bribes from irrigators may operate the scheme unreliably so that farmers know they will get water when they pay bribes (Moore, 1989; Wade, 1984).

More recently, since large-scale public schemes have fallen out of favour, those assessing irrigation policy have tended to focus on FLI. Their studies report how some governments – particularly in East and Southern Africa – have paid little attention to FLI and offered little support to it (de Bont et al., 2019; Woodhouse et al., 2017). Indeed, some argue that leaders of irrigation agencies believe that technical progress in irrigation can only be made by the state or by formal private enterprise: smallholders, they believe, lack the necessary skills to implement effective and efficient irrigation. FLI is thus, almost by definition – but also supported by inspections of artisan intakes and unlined canals – seen as inefficient: a false start, rather than something to encourage (de Bont et al., 2019; Woodhouse et al., 2017).

5.2 Official policy frameworks

Since irrigation is part of agriculture, it lies within the ambit of overall agricultural policy frames. For Africa as a whole, since 2003 the prime framing is the **Maputo Declaration** by ministers of agriculture from across the continent. This declared that governments needed to renew and redouble their efforts in agricultural development. It set a target of 6% annual growth of agricultural output, to be supported by allocating 10% of public budgets to farming. At the same time, the **Comprehensive Africa Agriculture Development Programme (CAADP)** was launched to plan and coordinate efforts to achieve those aims (NEPAD, 2003). Subsequently the 2014 **Malabo Declaration on Accelerated Agricultural Growth and Transformation** reaffirmed those commitments.

Development partners, including private foundations, have backed these initiatives with increased finance for agricultural development. New forums for coordination have been set up, such as the Alliance for a Green Revolution in Africa (AGRA) and the Forum for Agricultural Research in Africa (FARA).

With respect to irrigation, CAADP includes irrigation as part of its Pillar 1 Framework on Sustainable Land and Water Management.

Three reports and declarations in 2018 with respect to irrigation in Africa stand out. One is the **Malabo Montpellier Panel report on smart irrigation strategies for Africa** (Malabo Montpellier, 2018). This proposes that Africa has much scope to expand irrigation – drawing on the work of You et al. (2011) and Xie et al. (2014) – that can raise yields, increase farmer incomes and provide jobs. Improved techniques, especially solar pumps, drip irrigation and mobile apps, can facilitate irrigation. The main barrier is seen as being farmer access to finance. It recommends that governments should prioritise irrigation, in partnership with the private sector that can provide finance and know-how.

A second is the September 2018 **Kigali Joint Statement on Inclusive and Sustainable Farmer-led Irrigation** prepared at the 2018 African Green Revolution Forum conference. This singles out FLI and commends it:

> *In order to be most effective and enduring, a substantial portion of irrigation expansion must be "farmer-led." This means that the technology, practice, financing, operation, and maintenance needs must be determined by the farmers and community directly impacted by the irrigation system.*

Box 5A sets out the statement in full.

Box 5A Kigali Joint Statement on Inclusive and Sustainable Farmer-led Irrigation

We, the participants of the African Green Revolution Forum, including African Heads of State, ministers, and representatives of farmer organisations, private agribusinesses, financial institutions, academics, development partners, NGOs, and civil society, affirm this joint statement supporting inclusive and sustainable farmer-led irrigation (FLI), providing a common understanding of its goals, and principles guiding its development for food security and poverty reduction.

In order to be most effective and enduring, a substantial portion of irrigation expansion must be “farmer-led.” This means that the technology, practice, financing, operation, and maintenance needs must be determined by the farmers and community directly impacted by the irrigation system.

The Joint Statement lays the groundwork for agreement about critical policies, strategies, and programs for implementing and expanding FLI in pursuance of sustainable development and food security in Africa. This joint statement explicitly addresses the need to:

- Catalyse private and public sector support of the enabling environment though innovative finance and policy
- Provide appropriate incentives and risk mitigation tools to ensure that small-scale farmers, especially the poor, women, and youth, can access technology through private supply chains
- Integrate evidence-based knowledge and collective action in FLI to promote sustainable water resource management
- Build capacity and adapt technologies to monitor and assess the welfare and resource impacts of FLI at a variety of levels

Recognising the critical role of FLI to achieve food security and reduce poverty, we, the partners, therefore call for:

- Greater emphasis across all stakeholders in recognising the importance of irrigation and water management for ending hunger in Africa by 2025, as stated in the Malabo Declaration, and affirmed by SDG 2.
- Recognition of the potential for, acceleration of, and value of FLI as a tool to accelerate these aims and the need for adaptation of public and private sector approaches to serving farmer needs.
- Investment in distributed irrigation technologies, monitoring to ensure sustainability, and innovative financing to enable greater risk-taking by private sector actors seeking to deliver services to farmers and for smallholders seeking to adopt them.
- More concerted engagement with existing farmer-led platforms and farmer-service providers such as farmers’ organisations, cooperatives, and agro-dealers to better understand challenges and opportunities to scaling FLI.
- Support for a common learning agenda and mechanisms for exchange information and experience across public sector, private sector, civil society, farmers, and academia.
- Examination of existing public policies and investment approaches to identify opportunities for actions that better support FLI.

SOURCE: KIGALI JOINT STATEMENT ON INCLUSIVE AND SUSTAINABLE FARMER-LED IRRIGATION AND AGRF – AFRICAN GREEN REVOLUTION FORUM (2018) LEAD. MEASURE. GROW. ENABLING NEW PATHWAYS TO TURN SMALLHOLDERS INTO SUSTAINABLE AGRIBUSINESSES. FORUM REPORT. NAIROBI: AFRICAN GREEN REVOLUTION FORUM (HTTPS://AGRF.ORG/WP-CONTENT/UPLOADS/2019/01/AGRF2018-REPORT_FA_JAN-2019_WEB-VER.PDF)

The third development in 2018, closely associated with the second, is the World Bank and Global Water Security & Sanitation Partnership (GWSP) **initiative on farmer-led irrigation** (World Bank, 2018). This underlines the need to get more finance to smallholder irrigators through innovative models that link private capital to farmers, by deploying better technology, 'building on farmers' existing knowledge and experience', and 'supporting institutional adaptation and innovation for enabling policy environments'.

Other, similar initiatives are in the pipeline. For example, the African Union is preparing a **Continental Irrigation and Agricultural Water Development Framework** (CIAWDF) to launch later in 2019.

5.3 Differences in perspectives

Some large differences in perspectives, and hence in favoured policies, can be seen between some irrigation agencies on the one hand, and researchers studying irrigation on the other. The most obvious example concerns the enthusiasm of the latter for informal FLI and the scepticism about and, at times, neglect of this from official agencies.

Some of the apparent gulf in perspectives between some government agencies and some researchers may result from them referring to rather different forms of irrigation and irrigators. If FLI is seen very largely as the micro-irrigation described in chapter 3, then, yes, this is not going to contribute more than marginally to agricultural development and transformation – although it may be valuable for the livelihoods of people on very low incomes. If, on the other hand, FLI refers primarily to small-scale commercial irrigation, where the amount and value of output per ha can be strikingly high, then researchers are right to insist that this be taken seriously by agricultural ministries and irrigation agencies.

A further difference arises from whether irrigation is conceived primarily as the result of investment in physical structures to abstract water and convey it to fields – something that careful engineering and professional construction can achieve reasonably rapidly; or whether irrigation is seen as a series of changes to diverse parts of natural and human systems, where change is better seen as set of processes most likely to run on different timings, and where full development may only be seen in the medium term.

DRIP IRRIGATED VEGETABLES, ETHIOPIA. PHOTO: NENA TERRELL / USAID.

Some of the international initiatives to promote irrigation in SSA are conceived very much in the former mode. 'Water to irrigate exists, new technologies make it increasingly feasible to use that water, sub-Saharan Africa needs to raise agricultural productivity, so invest to seize the opportunity' – this is only a small exaggeration of the central message from the Malabo Montpellier Panel report of 2018 (see previous section 5.2). This kind of thinking then tends to produce plans for physical works, where the bottom line is an increased budget allocation to pay for the works.

When irrigation is seen as making multiple changes to quite complex natural and human systems, through processes that take time, then the policy priorities become wider. Finance may still be needed for works and equipment, but equally important are expanding human capacity – of farmers to irrigate, of input suppliers and advisers to support them, of staff in official agencies to facilitate and regulate the resulting developments. The scale of priorities also shifts: a focus on physical works can limit the perspective to the site of an intake, the location of canals and the land to be farmed; while a broader conception looks physically at watersheds, and in human terms, at capacity located all the way from village through urban centres to national capitals.

In budgeting, the distinction lies between irrigation being seen as something that can be achieved through a one-time loan or grant – attractive to aid agencies and political leaders who can point to tangible results; and the need for recurrent budgets to operate systems and improve human capacity – which challenge the programming of both aid agencies and governments, and produce less tangible gains.

5.4 Public-private partnerships for finance and know-how

All three 2018 initiatives see financing irrigation and making use of improved technology as central to irrigation development: all three recognise the private sector as a prime mover in providing finance and technology. Hence much interest has been shown in public-private partnerships (PPP) between public agencies and formal firms to facilitate this. Public agencies – ministries of agriculture, irrigation departments, river basin authorities, etc. – will set institutional frameworks, devise plans, coordinate public efforts, invest in strategic infrastructure such as rural roads, and promote the interests of farmers. Private firms, for their part, will finance irrigation works and equipment, and disseminate new technologies – while making a business from operating irrigated farms, processing output from irrigated land, and recruiting smallholders as outgrowers. The scope for complementary action is clear, while the division of tasks by the distinctive competence of public and private actors makes intuitive sense.

PPPs can work, but they are quite demanding of all participants – especially public agencies. PPPs may relieve public agencies from directly implementing projects, but they demand other capacities (Poulton and Macartney, 2012).

DEGRP research under the Assessing Models of Public-Private Partnerships for Irrigation Development in Africa (AMPPPIDA) study has looked at the experience of PPPs in Ghana and Tanzania. Studies show how important it is to assess the distribution of benefits, costs and risks to participating parties so that effective and fair partnerships can be formed. It is difficult to ensure this unless participating smallholders are engaged early in the process. Without their active and early participation, the (re)distribution of rights over land or water may result in worsening inequalities, where benefits accrue largely to private firms, but costs and risks are borne disproportionately by smallholders. If public agencies lack experience of PPPs and the key issues, it is easy to underestimate the risks and who bears them.

To succeed, those managing and participating in irrigation PPPs require reasonably accurate data on water availability and seasonal variations. They also need to consider how to help connect farmers to markets and other services.

Above all, PPPs do not allow the principles of good planning to be bypassed. Indeed, given the nature of contracts that lock in the obligations of the different parties, any shortcomings in planning tend to be amplified under PPP. In a purely public project, mistakes can be corrected fairly quickly by the managers concerned: in a PPP, agreement to changes needs to be sought from various parties and, indeed, the whole contract may need renegotiating (Bernier and Meinzen-Dick, 2015; AMPPPIDA presentations).

More generally, widening sources of finance for irrigation from governments and development partners to banks, input suppliers, agro-industries, etc., may bring extra benefits beyond simply more investment funds. The perspectives of additional financiers and financial software, with varying interactions with farmers, may promote more innovative and more integral approaches to irrigation than was the case under some public schemes in the past, with their stress on physical works. Farmers, for example, may have more say in irrigation development when they interact with input suppliers, bankers, fintech developers, managers of processing plants, and so on.[7]

7 An insight derived from discussions at the Second Annual Water Security Forum, Findhorn, Scotland, May 2019, attended by Lankford.

6. Conclusions

6.1 Recapping the main points

Evidence from recent research on FLI in sub-Saharan Africa can be distilled into five main points:

1. **In the new century, irrigation has risen up the agenda for agricultural development**, returning to something like the prominence it once held, back in the 1960s and 1970s, when large-scale public irrigation schemes were seen as the acme of agricultural development. The new-found interest in irrigation owes much to two factors. One is the availability of increasingly cheap (in real terms) irrigation equipment, above all diesel and solar pumps, that makes it possible to irrigate at economic cost where previously it was not. The other is the increasingly large urban markets open and accessible to many farmers in Africa, that promise good returns to higher-value crops grown under irrigation. The expansion of FLI in response to these stimuli itself constitutes another reason policy-makers have resumed their interest in irrigation.
2. Most of the increased area under irrigation seen since 2000 – and there are reasons to believe that these additions are much larger than the official records show – has come from **farmer-led irrigation (FLI)** systems.
3. **Farmers have developed their irrigation** using techniques that have low financial cost, but which are often labour intensive. In some cases, farmers have organised in small groups to construct schemes; in others, irrigation has been individual, at farm level, with motor pumps facilitating abstraction from surface or well water directly to fields. Irrigators have shown flexibility in changing crops to take advantage of market opportunity. Recorded cases show farmers taking up opportunities, overcoming problems and finding feasible ways to irrigate.
4. **FLI is diverse.** Some observers have usefully distinguished between hand-operated, micro-irrigation on plots of less than a tenth of a hectare and more commercial and capitalised irrigators who have been able to use motor pumps to irrigate areas of two or three hectares on which they grow high-value crops, usually vegetables, for sale to urban markets. For the former group, irrigation makes a valuable contribution to the livelihoods of people on very low incomes, but adds little to agricultural output. The latter group can generate high gross returns, allowing them to buy inputs and hire labour.
5. **FLI can succeed** in producing higher crop yields, more farm output, more sales, higher incomes, more jobs on farms, while stimulating links to and within the local economy. It can thus be the foundation of agricultural and rural development. Success in FLI is, however, far from automatic. Failed initiatives tend to be less well documented than successes, but they exist. Irrigation only succeeds when dedicated farmers find ways to invest and innovate, when they have access to land and water, when they have access to markets, and when policies and the overall investment climate allows.
6. **FLI, on the other hand,** may not be equally accessible to all farmers, and indeed opportunity may be taken up disproportionately by the more advantaged among smallholders. That said, employment created on irrigated plots may benefit those unable to irrigate. In some cases, irrigation systems may deprive other land users, such as pastoralists, of their means of livelihoods. In some circumstances, the systems created may harm the environment and impair the health of irrigators and their immediate neighbours.

7. **Women as irrigators** are too easily ignored: much of the discussion about irrigation is technical, aimed at maximising output at highest efficiency – it is distinctly masculine. While women farmers can benefit from irrigation as much as men can, they face disadvantages in access to land and water, to advice and technology. They often have household priorities for irrigation that differ from those of men. These differences need to be recognised, valued and acted upon.
8. The **efficiency of FLI is hard to judge**. Some FLI may be efficient in water use, constrained by fuel or labour costs, or inter-farmer competition for water; while other farmers might underwater or overwater. The lack of reliable performance data makes it difficult to generalise.
9. In some countries, most notably in Eastern and Southern Africa, **policy-makers have until very recently been unenamoured of FLI**. Some policy-makers have dismissed FLI as technically inefficient, insufficiently productive, a manifestation of underdevelopment rather than a motor of agricultural development. While they have been reluctant to encourage FLI, support is now growing.

Debates over the merits of FLI echo those concerning smallholder farming in general. Since the early 2000s in SSA, when the need to boost agricultural development was once again recognised as central to development, the potential of smallholder farming has been debated. Some have argued that the small scale of most farms is a hindrance, that larger-scale, consolidated farms have more potential (Collier, 2008; Collier and Dercon, 2014), while others have countered that small-scale farming, under the right conditions, can perform as well as larger-scale farming (Wiggins et al., 2010).

Despite the doubts of some observers that agricultural output in SSA could be increased without a significant consolidation of farms, it seems that growth output has accelerated. The (imperfect) statistics show that in most regions – Middle Africa excepted – of Africa since the early 1990s, agricultural output has grown faster than population, with increasing productivity both per ha and per agricultural worker (Nin-Pratt et al., 2012; Wiggins, 2018). The expansion and apparent success of much FLI has probably contributed to accelerated agricultural growth.

Box 6A DEGRP's contribution to the literature

The three DEGRP studies have made the following contributions:

Innovations to promote growth among small-scale irrigators, led by Elizabeth Harrison with considerable input from Anna Mdee, has shown the detail of social and political effects of irrigation, through analysis of schemes and systems in Malawi and Tanzania. In particular they report how favoured showpiece public schemes can combine both public subsidy while disproportionately favouring elite members of the scheme, sometimes to the active disentitlement of other people in the local community. In one case, they record how farmer-led irrigation has been blamed for causing water shortage in a catchment, while larger users of water have not been considered to cause scarcity.

Assessing Models of Public-Private Partnerships for Irrigation Development in Africa (AMPPPIDA), led by Ruth Meinzen-Dick, has carried out action-research that has provided both insight into PPPs and practical help to irrigation authorities in Ghana and Tanzania expected to work with PPPs, but with relatively little guidance on how to do so. Few, if any, other studies of contemporary SSA have probed PPPs in this detail.

Assessing the growth potential of farmer-led irrigation development in sub-Saharan Africa (SAFI), led by Phil Woodhouse has shown the extent, characteristics and some of the impacts of FLI in Mozambique and Tanzania. The radar imagery used to estimate irrigated areas has been innovative. In documenting the dynamism and largely positive impacts of FLI, the study has done much to raise the profile of farmer-led irrigation and move it up the policy agenda.

6.2 Policy implications

Supporting farmer-led irrigation development (FLID)

The first challenge is to convince more policy-makers that FLID can contribute to development in the ways the evidence suggests it can. The Kigali Joint Statement on Inclusive and Sustainable Farmer-led Irrigation of 2018 and the start of the World Bank initiative on FLI of the same year perhaps suggest that the tide is turning, that policy-makers may be approaching the topic with fresh eyes.

If so, they may be helped by framing their thoughts in the light of two distinctions highlighted in this synthesis: social and temporal.

Socially, for those who irrigate on a very small or micro scale, policy might be guided by seeing micro-scale irrigation as part of the livelihood strategies of people on very low incomes, often marginalised and vulnerable people. Public subsidies and assistance to support their irrigation thus need to be compared to cash transfers, food aid, pensions and other forms of social assistance, in terms of the benefit conferred per public dollar spent, coverage of the vulnerable and equity of provision.

That framing, however, does not mean that there is no technical agenda for micro-irrigation. There are usually ways to make simple systems more effective and efficient, and technical problems to solve – such as making sure that drip kits are robust for field conditions. Moreover, some micro-irrigators, even if not all, may be able – with some support and assistance – to graduate to small-scale irrigation.

For the more commercial small-scale irrigators, much of what they need can be seen as part of the mainstream issues of agricultural development: facilitating access to technology and finance, and marketing. Where irrigation is carried out by groups, opportunities to improve the performance of their groups may exist – such as training in book-keeping, in registering water rights, leadership skills, etc.

Policy in stages

The other distinction is **temporal**; that of the **stages of irrigation development** that unfold at catchment level.

By its nature, farmer-led irrigation (FLI) meets several policy concerns. For example, it boosts food production, reduces the need for direct government investment, can rapidly take up opportunities and can be highly effective. Without government intervention, locally owned expansion and improvement of irrigation can occur in line with farmers' opportunities and limitations. If farmer-led irrigation works well, then public policy should seek ways to support and facilitate it.

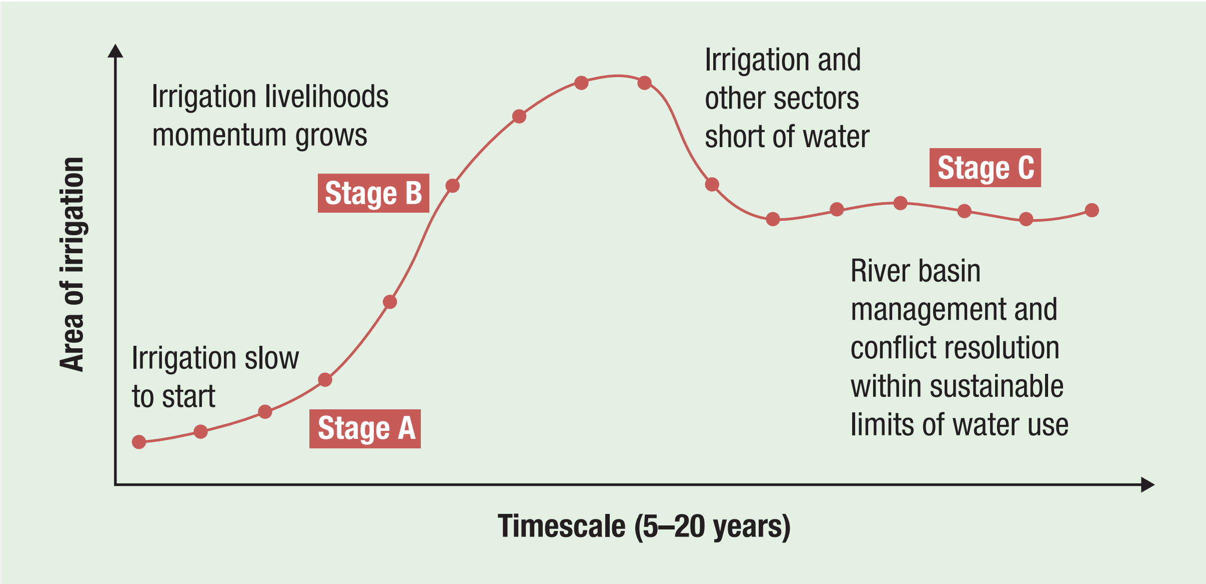
On the other hand, farmer-led initiatives leading to extensive areas under irrigation bring risks, above all those of resource depletion, environmental harm and social inequity. In such cases, public or local customary regulation is needed.

One way to appreciate the salience of these concerns is by conceptualising irrigation uptake and expansion via an S-shaped set of three stages (Lankford (2003) and Figure 6.1) and the quite distinct sets of policy implications that then apply:

In Stage One, little irrigation may initially take place because conditions are lacking. Missing conditions may include: prices and incentives to grow more; skills and knowledge of irrigation possibilities; scarcity of capital to take up irrigation opportunities; and the inability of farmers to combine where collective action is needed to put water to use.

In Stage Two, conditions for irrigation become apt. Many more farmers, individually or in groups – depending on water resource, technology knowledge and social cohesion – take up the opportunity. This can often happen rapidly and suddenly. Once thresholds of returns to irrigated crops, of technical skills and understanding, of acceptance of risk, and indeed of the confidence to act, are passed, individuals and groups may quickly and simultaneously act, with cumulative effect, as innovators provide examples for others.

Figure 6.1
Three stages of irrigation development



SOURCE: LANKFORD (2003)

Since some farmers or groups have advantages over others in skills, access to funds, political connections and so on, this process will probably differentiate farmers and rural society. Development projects can, of course, exacerbate this, by privileging some farmers or areas over others, when project sites and target participants are defined.

In Stage Three, irrigation becomes significant in the water basin, as substantial fractions of the irrigation potential are taken up – surpassing water capacity in some cases. Systems amalgamate: both the physical irrigation schemes and the human interactions. What may have worked well at smaller scale can become problematic when aggregated.

From an appreciation of these stages emerge policy considerations. In the first stage, policies and public investments to support FLI are largely relatively straightforward. They consist of building roads and other public infrastructure, while ensuring that significant obstacles to investment in agriculture – heavy taxes on output or inputs, high inflation, cross border tariffs, etc. – are remedied as far as possible. Activities include those seen in traditional development projects: investing in infrastructure, training of farmers, organising in groups, etc. For example, Colenbrander and van Koppen (2013) argue for the removal of blocks on the uptake of imported motor pumps for irrigation.

Less straightforward are the challenges of overcoming the lack of access most smallholders have to financial services, heavy plant equipment, inputs and technical knowledge.

As irrigation is increasingly taken up in the second stage, then additional measures to facilitate farmer-led development become appropriate. These include helping farmers raise the performance of their irrigation – see Pittock et al. (2017) – including training, soil moisture monitoring and water scheduling. This helps would-be irrigators to overcome obstacles they face in adopting irrigation, spreading benefits to the poorest within irrigating communities – which may involve distributing small plots to people lacking land (Koopman et al., 2001), and starting to regulate use of water, especially during the dry season and droughts, to ensure water consumption does not exceed supply.

By the third stage more demanding policy challenges are indicated, above all in finding effective ways to regulate water use, assign rights and to mediate any conflicts over water use. Public agencies need to help create institutions and allocate rights (a) to resolve collective problems of water consumption arising from large, coalesced irrigated areas that harm economic sustainability in catchments with substantial irrigation; and (b) to mediate and resolve conflicts between farmers located within and across irrigation systems. The challenges of effective and equitable regulation can hardly be overstated (see Box 6B).

Indeed, so forbidding is the agenda of regulation that an understandable response is to retreat to a narrower focus on, say, irrigation engineering, where the issues appear more tractable. Neglecting the challenges, of course, is only likely to make them all the more daunting when they simply have to be addressed.

The organisations and institutions, the knowledge and data, and the political forums needed to address these issues cannot readily be prescribed: they will need adaptation to national and local circumstances. Moreover, if they are to succeed, they will probably need to evolve. That said, knowing about working models in other catchments and countries can provide inspiration and encourage decision-makers to begin the process of creating the structures and institutions for regulation of water.

It is easy enough to outline a policy agenda, but harder to put it into practice, for the following reasons:

- The stages outlined above are schematic. It may not be precisely clear when irrigation has passed from one stage to another, especially from Stage Two to Three. Moreover, within any country, different timings may apply in different catchments; and catchments may not correspond to administrative divisions. While not impossible to differentiate policy by river basins, this complicates the public task – central agencies tend to prefer standard approaches across the country.

Box 6B The challenges of regulating irrigation

Why is regulation so demanding? The challenges arise from:

The **overlapping scales** that the use of water involves, which go from irrigated fields to water flows in catchments and the functioning of the environment, and on to national concerns over equitable and efficient allocation of water. Issues that arise at more aggregate scale, such as competition for water or impacts on the wider environment, are not necessarily appreciated by water users at smaller scales. An added complication is that formal administrative sub-divisions do not usually correspond to water catchment areas.

The complexities of natural systems that render connections across scales opaque and hard to measure. They tempt local actors to deny responsibility for the distant consequences of their actions: for example, would irrigating farmers accept that their abstraction of water affects wetlands far downstream, leading to loss of wildlife and imperilling the livelihoods of fisherfolk?

Differing time scales between the seasonal rhythms of irrigation and those lagged reactions in natural systems where the full impact of irrigation takes several years before it is apparent and confirmed.

Variations through time in water supply and demand that may require adjustments in policies and the allocation of abstraction rights. It can be hard to detect in the short term whether such variations are part of cycles or represent trends or step-changes, including those that may cross thresholds.

The **politics of first movers** who believe that by dint of their enterprise they have established, de facto, justified rights to water and land – and are likely to be unimpressed by any limits to those rights that the state might later set in the interests of the wider community. First movers, moreover, may be more than averagely influential, and able to organise to defend their interests.

- As set out in Box 1A, irrigation is an unusually extensive and deep change for agriculture. It can throw up a wide array of demands and challenges. For public agencies, this creates heavy demands on their capacity and for coordination across agencies.
- The temptations of dysfunctional policy are clear. Politically, large schemes with highly visible irrigation works can satisfy the need to be seen to be acting decisively, to modernise and to transform. Focusing on engineering alone can be satisfying in reducing a potentially wide and complex agenda to something more focused. Treating social issues as the failings of 'conservative' or 'traditional' farmers who need to be instructed in new ways is all too tempting.
- Last but not least, for some policy functions, good working models are not obvious. This applies above all to regulating resources, assigning rights and mediating disputes.

Calls for **a more comprehensive approach to irrigation** policy are well founded. Responding to President Obama's call for the 'right irrigation' in SSA, Lankford (2009) recommended taking a comprehensive approach that uses a mixture of technologies, builds on local capabilities, brings sound engineering know-how, is supported by a range of other services and acknowledges other water needs within catchments.

To do all this is not easy. One approach to bring stakeholders together to address issues that affect them is the agricultural innovation platforms, field tested in Southern Africa (Box 6C).

In summary, the policy challenges of FLI are substantial. Moreover, the challenges can be quite varied, ideally requiring tailored approaches to different schemes. While ideal, that is rarely possible for most public agencies in LICs.

Policy successes with FLI are either scarce or not documented. A prime need is to have working models of policies that have been evaluated as effective, at least in given circumstances.

Box 6C Agricultural innovation platforms for irrigation: the Southern African experience

Action-research was carried out for six irrigation schemes in Mozambique, Tanzania and Zimbabwe. Innovation platforms were pioneered.

These brought together all stakeholders in the value chain, from irrigators to supply chain traders to public agencies. They got them to talk about the things that mattered for them, with diagramming to provoke deeper reflection on underlying causes and processes, and to identify ways to improve the system. Subsequent actions were monitored to promote learning and adaptation.

Success was seen in:

- Watering frequency and use. By measuring water applications, farmers came to water one-third as often – thereby saving time and water, with less fertiliser washed off the land.
- Crop yields were as much as three times greater.
- Farmers at the tail end of the systems got more water, and more land was irrigated – helping reduce conflicts.
- Farmers learned from their own experiences and saw how they work to resolve problems.

Irrigation schemes that had been seen as problematic, with farmers unenthusiastic, were revived.

SOURCES: BJORNLUND ET AL. (2017), PITTOCK (2017), VAN ROOYEN ET AL. (2017)

Gender and policy

Those who see irrigation as an arena where patriarchal norms tend to prevail recommend two initial steps to taking a more gender-sensitive approach. One is to see that many irrigators are women farmers, the other is to recognise that women may have different priorities and perspectives on irrigation. For example, women are more likely to see an irrigated plot as a reliable provider of food for the household; they are more likely to prioritise forms of irrigation that produce food more dependably.

This does not mean that women farmers do not see market opportunities and cannot benefit from extra cash earnings, just that they do not see that as having priority over feeding the family. Reflections on women's perceptions, however, need to be appreciated within their setting of time and circumstance, rather than being the representation of some fixed, determined differences in outlook of men and women. Women's views will vary as circumstances change and as time passes (Zwarteveen, 2010)

Beyond these considerations lie the practical needs of women as irrigators: ensuring that they have access to land and water, to technology and technical advice, to support services and inputs. And that all of these are tailored to women's circumstances of limited labour time and capital. A major challenge is to make sure that women's rights and interests are reflected in regulations and governance of irrigation, especially in situations where men's voices and interests are assumed to have priority (Domenech and Ringler, 2013).

6.3 Further research needs

A review of the literature on irrigation in SSA reveals persistent gaps in evidence necessary to form a better understanding of the subject. Priorities include:

- Improving the data available that records areas under irrigation, for what crops, with what technology, and operated by which farmers. While this may not be easy to record accurately, better estimates – reliable to, say, plus or minus 20% – could be made than is the situation currently, where official data may understate the extent of irrigation by an order of magnitude. More ambitious would be to estimate the water abstracted by irrigation, how much reaches plants, and how much is returned to the catchment or aquifers.
- Drawing on better data, then reviewing irrigation's sustainability by analysing outcomes, including crop production, water consumption externalities on downstream water security, energy use and social costs, such as exclusion of the poorest.
- Building on the previous point, benchmark performance across different types of irrigation systems, enabling policy-makers to understand how different technologies (e.g. treadle, drip, large, small) compare across the registers of water, land, energy and finance.
- Similarly, the above data collection and reviews could then form the basis for assessment of irrigation's contribution to creating decent jobs, reducing poverty, and improving food and nutrition security.
- Documenting and evaluating experiences of collective action, regulation, allocation of rights and mediation in respect of water to provide more insight into what is effective and under what conditions.
- All of the above need to increase attention to gender issues, given the low visibility of women as irrigators in most studies to date.

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