13 Large-scale irrigated farming system

The potential and challenges to improve food security, livelihoods and ecosystem management

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Key messages

- The large-scale irrigated farming system (LSIFS) constitutes a complementary addition to other irrigation systems found in Africa. They can be sustainably expanded, particularly in sub-Saharan Africa, to contribute to the attainment of SDGs on ending poverty and hunger and enhancing resilience of production and livelihoods to climate change and other shocks.
- Sustainable expansion that would enable the full social and livelihood benefits of LSIFS to be realized by all gender groups cannot be pursued on a business as usual basis. Lessons learned from sixty years of failures and successes of large-scale irrigation schemes in Africa must be utilized to develop efficient, equitable and ecologically benign LSIFS.
- Strategic priorities to establish well-performing, livelihood-enhancing and environmentally friendly LSIFS include improved water management, distribution and drainage, increased use of renewable energy sources for irrigation and agroprocessing, improved access of women and youth farmers to irrigated land, improved access of all smallholder farmers to finance, irrigation advisory services, input and output markets, empowerment of water users' associations and public-private partnerships to increase investment and improve management of LSIFS.
- Households in well-managed and sustainable LSIFS will be able to escape poverty and improve their well-being through intensification and diversification of agricultural production activities and off-farm income earned from agro-processing and other employment opportunities created through the spillover effects of irrigation.

Summary

The potential of irrigation to improve food security, reduce poverty and promote agricultural growth is widely recognized by governments across Africa. Yet, despite availability of abundant but underutilized water resources, expansion of irrigation has been slow, especially in sub-Saharan Africa (SSA). This chapter reviews the constraints, opportunities and strategic priorities for sustainable development of the large-scale irrigated farming system (LSIFS) in Africa, with an emphasis on SSA. It begins by examining the array of

biophysical, technical, human capital, policy and institutional factors that have shaped the evolution of LSIFS, followed by an assessment of the performance of the system. The assessment indicates that based on productivity, sustainability and human development outcomes, performance of LSIFS has improved over time. But much remains to be done in the area of irrigation water management and distribution, development of new irrigation and business management models, empowerment of farm households and local institutions, and agroecosystem management. Intensification and diversification of agricultural production through irrigation, better water management and improved access to finance and markets, remain the most important pathways out of poverty for households in this farming system. The chapter concludes by discussing the strategic priorities that can be pursued to turn potential into reality and make LSIFS a bridge to improved food security, poverty reduction and agricultural growth in Africa without harming the environment.

Introduction

Irrigation holds great potential for agricultural growth, food security and poverty alleviation in Africa, but its contribution to date has been constrained by a lack of investment to expand the area under irrigation and the poor performance of existing public sector managed large-scale irrigation schemes. In 2013, nearly 243.1 million ha of land was cultivated in SSA. However, the total area equipped for irrigation was 8.2 million ha – only 3.4 per cent of the cultivated area and less than one-fifth of the 39 million ha deemed suitable for irrigation (FAO 2011, 2016a, 2016b). In contrast, irrigation plays an important role in north Africa, where it accounts for 23 per cent of cultivated area. Against this backdrop, the need for investment to develop and use the abundant land and water resources has never been greater.

Investment in economically viable, environmentally sustainable and socially acceptable large-scale irrigation systems can increase agricultural productivity and incomes and lower food prices. Such irrigation systems can also contribute indirectly through increased rural and urban employment arising from the multiplier effects of growth in the rural and urban non-farm economy (Lipton et al. 2003; Namara et al. 2010; Saleth et al. 2003) and by permitting other livelihood activities such as livestock keeping, fish production and small and medium enterprises (e.g. brick making). Case studies of rehabilitated and new large-scale irrigation schemes indicate that these benefits of irrigation are achievable under the right economic, social and institutional environment (Aw and Diemer 2005; IDA 2007).

Overview of the irrigated farming system and subsystems

The large-scale irrigated farming system often co-exists in the same country with medium-, small- and micro-scale irrigated systems (Table 13.1). These systems differ in terms of management (public or private), the primary source of water (surface or groundwater), costs of maintenance and operation, and the implications they hold for food security, livelihoods and the environment.

The focus of this chapter is on the large-scale irrigated farming system (LSIFS). This is usually centred around a public sector irrigation scheme distributing water collected in dams from nearby rivers, over a command area, i.e. area that can be physically irrigated and is fit for cultivation, spreading over thousands of hectares (Figure 13.1). Land is leased out to farmers who cultivate mandated crops (e.g. cotton or rice) in addition to a variety of other crops (Box 13.1).

Figure 13.1 Markala dam, large-scale irrigation infrastructure, Office du Niger, Mali.
Source: Regassa Namara.

Table 13.1 A typology of irrigated farming subsystems in sub-Saharan Africa based on management and command area

Subsystem	*Description*	*Typical command area (ha)*
Large-scale	Public and / or commercial irrigation systems, growing cash crops for export and staple food crops for domestic and regional markets	≥ 1,000
Medium-scale	Community and/or agribusiness managed systems growing staples, fruits and vegetables for domestic, regional and export markets	≥ 100 to ≤ 1,000
Small-scale	Community and/or farmer managed systems producing food and horticulture crops for domestic market	≥ 1 to ≤100
Micro-scale	Farmer managed systems producing staple foods and horticulture crops for urban and peri-urban centres	≤ 1

Box 13.1 A typical household in large-scale irrigated farming system

A typical household in an LSIFS has a family of seven to eight persons, comprising four or five adults and three children. Depending on the size of the irrigation scheme that is at the heart of the farming system, the family owns 4–8 ha of irrigated land and about 1–2 ha of rainfed land outside the scheme. The family cultivates at least one cash crop (cotton or rice) on the irrigated land in rotation with other crops grown for subsistence (sorghum, wheat, etc.), soil fertility maintenance and fodder (groundnuts or a leguminous forage). Millet and/or sorghum is typically grown on the rainfed land. The family owns about 9–10 TLU (tropical livestock unit). One or two adult household members work outside the farm in nearby towns, requiring the family to rely on hired labour for about 40–50 per cent of the farm work on the irrigated fields. Average crop yields are about 3 t/ha for paddy rice, 1.4 t/ha for cotton seed, 2 t/ha for sorghum, 1.4 t/ha for wheat and 1.9 t/ha for groundnuts. Average crop yields in all cases are well below the potential achievable due to a shortage of irrigation water, inadequate application of fertilizers and pesticides, and limitations due to soil and crop-specific factors. Approximately 80 per cent of total household income comes from crop production, including the portion retained for household consumption; 5 per cent from sales of livestock and livestock products; and 15 per cent from off-farm business. A typical household in this system is able to meet the minimum cereal requirement of 214 kg per capita after paying for production costs.

Sources: Guvele (2001); Mather and Kelly (2012); World Bank (2000).

As shown in Figure 13.2, the large-scale irrigated farming system is found in Egypt, Sudan, Mali, Nigeria and Somalia. There are significant additional unmapped areas of irrigation in Morocco and other countries. The areas surrounding these LSIFS also support other livelihoods such as livestock rearing and fishing. The map, however, does not show the myriad small-scale irrigation systems that are embedded in some of the other farming systems covered in this book.

Table 13.2 provides basic data on the LSIFS. The system covers approximately 46 million ha and supports a total human population of 124 million, of which 86 million are located along the Nile Delta and River in Egypt. About 48 million in the LSIFS are directly involved in agricultural production. Despite the farming system's potential, almost 58 per cent of the rural population lives in extreme poverty. The farming system has relatively good market access compared to the other farming systems, but access to services – extension, credit, insurance, etc. – varies from low to medium.

North Africa contains approximately 5 million ha of LSIFS, concentrated in Egypt and Sudan and, to a lesser extent, Morocco. The Nile Valley schemes have dominated Egyptian farming for thousands of years. In contrast, although the Gezira Scheme in Sudan (Box 13.2) is famous, rainfed cropping and pastoralism dominate the Sudanese agricultural sector.

Figure 13.2 Distribution of large-scale irrigated farming system in Africa.

Source: GAEZ FAO/IIASA, FAOSTAT, Harvest Choice and expert opinion.

Table 13.2 Basic system data (2015): large-scale irrigated farming system

Item	*Data*
Total human population (million)	124
Agricultural population (million)	48
Total area (million ha)	46
Cultivated area (million ha; % of total area)	11.7; 25
Irrigated area (million ha; % of cultivated area)	8.0; 69
Total livestock population (million TLU)	23
Major agroecological zone	Tropical warm arid
Length of growing period (average, days; core range, days)	47; 0–90

(continued)

Table 13.2 (continued)

Item	*Data*
Access to services (low/medium/high)	Low to medium
Distance to 50k market (average, hr; core range, hr)	3.8; 0–4
Agricultural population density (persons/total area; persons/cultivated area)	1; 4.1
Livestock density (TLU/total area; TLU/cultivated area)	0.49; 1.9
Standard farm and herd size (cultivated area/household; TLU/household)	1.3; 2.6
Extreme poverty (% of rural population)	58*

Source: Refer to Table 2.4.

*For sub-Saharan Africa only.

Box 13.2 Challenges and emerging opportunities in the Gezira LSIFS

The Gezira irrigation scheme in Sudan was formally established in 1925 by the colonial authorities with the aim of growing cotton as a cash crop over a command area of approximately 126,000 ha. Since then the scheme has grown in size and complexity. It currently encompasses a command area of 924,000 ha that is leased out to about 130,000 tenant farmers. The population of farmers and their families is about 1 million. There are also about 150,000 seasonal labourers who together with their families add another 1 million to the population of the farming system. Another 1 million people supply goods and services, meaning that approximately 3 million people rely on the scheme and associated farming system for their livelihoods.

Some of the initial challenges that tenant farmers faced included top-down management and administration of irrigation water, restrictions on crops that could be cultivated, and low agricultural yields which in turn led to low incomes. To address these and other challenges, the government passed a new Gezira Scheme Act in 2005, which among other things allowed: freedom of crop choice; farmers' right to dispose of their freehold or leasehold land through sale, mortgage or assignment; the establishment of water users' associations (WUAs); and the participation of the private sector in the provision of commercial services to farmers. However, these reform measures have not resulted in marked improvements in agricultural productivity. WUAs lacked the capacity and know-how to actively play a role in the management of irrigation operations at the field canal level. Also, despite the freedom of crop choice, farmers until recently struggled to find a suitable alternative crop to replace cotton as a cash crop.

In 2010, the Japan International Cooperation Agency (JICA) introduced rice into the farming system on a trial basis. Although rice is a latecomer to the farming system, it is already being hailed as a portent of better times, because with good yields, it has allowed farmers to almost triple their incomes.

Sources: CFI 2013; World Bank 2010a.

Trends and drivers of change across the large-scale irrigated farming system

Population, hunger and poverty

Over the period 2000–2010, human population in the LSIFS in SSA increased from about 25 million to approximately 32 million people, representing an average annual compound growth rate of 3.2 per cent. Increasing population pressure and low agricultural productivity have led to the persistence of hunger and poverty in SSA and made food security a key priority for many African governments. These pressures have also brought about a change in the orientation of LSIFS in many SSA countries – from systems designed to produce cotton fibre for export, to systems focusing on staple food production in an attempt to ensure food self-sufficiency. However, due to poor irrigation water management, inadequate extension services support and government control of input and output prices, aggregate agricultural output and farmers' incomes remained low until price and institutional reforms were introduced in the 1990s.

The increase in population has also led to increased fragmentation of land on many LSIFS. Families who were originally allocated about 8 ha of land in the Office du Niger irrigation zone in Mali have had to subdivide the land among their children. At the same time, there is increased demand for irrigated land by farmers already in the scheme and those willing to join (Mather and Kelly 2012).

Also, diets are changing as a result of urbanization and income growth. There is increased demand for horticulture products – vegetables, fruits and spices. This growth in demand, both domestically and externally, is promoting horticulture production on medium- to large-scale irrigated farming systems in a number of African countries including Egypt, Morocco, Ghana, Ethiopia, Kenya, Nigeria and Zambia.

Furthermore, the growing phenomenon of rural-urban migration appears to be drawing family labour away from LSIFS (Box 13.2) across Africa in the same way as it affects other non-urban farming systems.

Natural resources and climate

In SSA, agricultural water resources are relatively abundant but underutilized due to inadequate water storage and irrigation infrastructure. FAO (2011) estimates that average agricultural water withdrawals are 1.3 per cent of renewable water resources and groundwater use is less than 20 per cent of renewable supplies, indicating significant scope for surface water and groundwater development. Other studies, for example Pavelic et al. (2012) and MacDonald et al. (2012), have shown evidence which indicates that groundwater is the largest and mostly widely distributed store of freshwater in Africa.

With expansion of irrigated area and new land investments growing apace within the perimeters of some of the irrigation schemes that support LSIFS, water availability may soon become a problem. Analysis of this situation in the Office du Niger (Sidibé and Williams 2016) suggests that if the current water management system based on a flat rate per hectare pricing is maintained, aggregate water demand for irrigation may exceed the average annual water availability in Markala dam, with negative consequences for environmental flows and the possibility of conflicts among different water users.

Increasing climate variability and climate change pose both a challenge and an opportunity for LSIFS. According to some predictions, greater variability in precipitation will significantly affect surface water across a quarter of the continent (De Wit and Stankiewicz 2006), implying a possible reduction in water availability for irrigation. But the possibility of more frequent extreme weather events such as floods and droughts, suggests that water storage and irrigation may provide an opportunity for capturing and utilizing flood water that would otherwise have been lost, to mitigate the effects of drought and improve agricultural production.

Energy

In some LSIFS, energy is needed to pump water into canals to irrigate planted fields. Rising fuel, electricity and pump maintenance costs since the late 2000s have disrupted water supply to farmers on such LSIFSs. For instance, in Ghana, the inability of several large-scale irrigation schemes to pay their electricity bills has led to the shutdown of water pumping operations and supply of irrigation water to farmers, leading to a loss of household income. The option of using solar and wind power to lift water is being explored in many countries and has progressed much more rapidly in small-scale irrigation systems compared with LSIFS. A private sector company in Ghana, Integrated Water and Agricultural Development Ghana Limited (IWAD), which has established a large-scale irrigation scheme involving neighbouring farmers, has installed a 0.5 megawatt solar power plant with a mini grid to supply renewable energy for irrigation on both the nucleus and nearby smallholder farms and other agro-processing applications (http://cms.iwadghana.com/).

Human and social capital

On many LSIFS during the 1960s to 1990s, water resource administration and irrigation management were handled by government employees who were mostly engineers. These professionals lacked training in the broader environmental and socioeconomic issues that are essential to making irrigation beneficial to farmers. Apart from limited capacity, frequent funding cuts and political interference curtailed the ability of available staff to perform necessary operation and maintenance activities, collect relevant hydrological, meteorological, water supply and distribution data, and provide adequate irrigated farming support services to farmers. These shortcomings contributed to the failure of many large-scale public irrigation projects during this period, as they were caught in a vicious cycle of infrastructure disrepair and poor performance which also impacted negatively on farm households. But the failure has also spurred capacity strengthening in many irrigation management agencies, for example in Kenya and Tanzania.

From the 1960s to the 1990s, land allocation in many LSIFS failed to incorporate gender considerations and this exacerbated existing imbalances in resource allocation for women. For instance, land allocation often favoured male household heads, thus cutting women out of irrigated land ownership except as labourers for the household heads (van Koppen 1998). Although gender-based farming practices where men and women cultivate separate fields are common in many parts of SSA, this reality was often ignored, resulting in gender inequity in access to land and water resources (IFAD 2007).

However, in recent years, these omissions have gradually been corrected with impetus for change coming from national strategic initiatives such as the Poverty Reduction Strategy Programmes (PRSPs). These programmes, which emphasize the link between poverty and gender, together with the gender strategies of donor agencies, are increasingly promoting women's empowerment as a means of reducing poverty and food insecurity. With this new perspective and lessons learned from failed irrigation projects, issues of gender equity and poverty alleviation are now being addressed through capacity building and securing of greater access rights and control over resources for women and poor vulnerable people. But efforts to ensure that women have access to land in LSIFS or are members of WUAs and their management committees have not entirely succeeded. Local norms regarding gender and other elements of social stratification still prevent women and marginalized groups from having full control over land and full decision-making powers over resources. Due to poor access to finance, women still experience serious problems in mobilizing sufficient labour to make the most of the potential benefits that irrigation offers.

Science and technology

Plant breeding and agronomic research have contributed to increased crop yields in LSIFS. High-yielding germplasms coupled with inputs such as fertilizers, pesticides and herbicides, and improved water availability at the field level have raised yields of rice, cotton, wheat and sorghum (Figure 13.3).

In addition, market reforms launched as part of the structural adjustment programmes in the late 1980s and early 1990s in many SSA countries initially provided incentives to farmers. For instance, in Mali, such reforms, including the abolition of the monopoly

Figure 13.3 Irrigated rice farming, Karfiguela irrigation scheme, Burkina Faso.

Source: Regassa Namara.

on rice milling and marketing by the Office du Niger (the government management agency), allowed rich farmers and entrepreneurs to introduce simple technologies (small threshers and dehullers) for post-harvest processing of rice in rural areas close to the farms. This encouraged farmers in the Office du Niger to increase rice production as they no longer had to travel long distances and incur huge transport costs to mill their rice. The machines also reduced the workload of women by saving them the tedium and long hours of pounding paddy for the family meal. Entrepreneurs sensing a new business opportunity and the need to reduce the percentage of broken grains produced by the simple threshers and dehullers, subsequently introduced relatively more sophisticated rice-milling technologies, thereby spawning an off-farm small and medium enterprise industry in the rural areas (Barry et al. 2009).

Research studies have shown that satellite images, remote sensing and earth observation decision-support tools can be used to analyse the performance of LSIFS and support the development of performance-enhancing solutions that can improve irrigation water management and ultimately benefit farmers (Borgia et al. 2012; Hamid et al. 2011). These new tools increase access and capacity to collect data in a systematic, detailed and comprehensive manner on a vast array of variables, including water storage and distribution patterns, evapotranspiration, crop yields, droughts and flooding. They also allow monitoring of environmental factors in near real time.

Trade and markets

Profound changes in domestic, regional and international markets are creating new opportunities for production and trade in horticulture commodities. These changes, driven by rising incomes, faster urbanization and technological advances are increasing demand for high-value horticulture products such as fruits, vegetables and spices. There is evidence that high-value markets catering for domestic consumption are the fastest growing in many SSA countries. Neven and Reardon (2004) reported that from the mid-1990s, supermarkets in Kenya grew at 18 per cent annually and reached one-fifth of the overall food market in cities by 2002. In South Africa, supermarkets held 55 per cent of the national food retail market in the early 2000s. Williams (2011) estimated that Africa's export of horticultural products grew at an average annual rate of 10.7 per cent between 1990 and 2008, double the average annual growth rate of traditional African agricultural exports during the same period. This growth in markets for horticultural products is promoting a range of small- to large-scale irrigated horticulture systems across Africa. In the LSIFS of Office du Niger where rice production predominates, mango, onions and potatoes are providing a second out-of-season cash crop for farmers. With technical assistance from foreign companies and donors, farmers in this LSIFS have started to access export markets.

Policies and institutions

Since the mid-1990s, many governments in Africa have initiated market reforms initially focused on market-oriented liberalization to 'get prices right' and later on 'getting institutions right', including introduction of participatory approaches to irrigation management and devolution of irrigation management to WUAs. In recent years, there has been increased interest in the question of how to make markets work more effectively for the poor. Many PSRPs and associated economic development strategies and policies have placed high priority on stimulating increased market participation by poor farmers through improving their access to markets and involving them in viable value chains.

These initiatives have created opportunities for farmers in LSIFS. Freedom of crop choice, removal of price controls and liberalization of produce marketing have allowed farmers to diversify and grow a range of new crops which they are now directly marketing. Reform of the previous top-down approach in design, operation, implementation and maintenance of large-scale public irrigation schemes has permitted farmers to form WUAs, which has given them a voice in water and irrigation operations management (Table 13.3). In addition, many governments in Africa have invested in land reforms to give greater tenure security to farmers (see Aw and Diemer 2005 for the case of Mali; and Gezira Scheme Act 2005 for Sudan). In some cases, within these reforms, there has been an emphasis on improving the rights of women to own land. As a result of these institutional and market reforms, there is emerging evidence in a number of countries that previously underperforming large-scale public irrigation schemes (e.g. Office du Niger in Mali) are becoming financially sustainable and highly productive irrigation systems with concomitant benefits to farmers (Aw and Diemer 2005; Barry et al. 2009).

Although government and donor investments in large-scale irrigation schemes declined sharply from the 1990s to the mid-2000s due to poor cost-benefit returns and rising concerns about the environmental and equity impact of large dams, currently there is renewed interest in large-scale irrigation schemes. This is partly driven by the recent surge in food prices and the associated risk of food insecurity to millions of vulnerable poor people. To date, the Global Agriculture and Food Security Program (GAFSP), a fund that was launched in April 2010 to support country-led efforts to fight hunger and poverty, has awarded grants totalling US$430.5 million to eleven SSA countries to improve water management and irrigation as part of an overall agricultural and food security improvement programme.

SSA is also experiencing a new post-colonial wave of large-scale land acquisitions (LSLAs), predominantly by foreign investors, for the cultivation of biofuels, food crops and flowers. The drivers of these foreign direct investments (FDI) in agriculture are numerous and varied and have been extensively reviewed (Cotula et al. 2009; Von Braun and Meinzen-Dick 2009; World Bank 2010b; Zoomers 2010). Recipient governments have welcomed FDI and viewed it as a way of transforming their poorly performing agricultural sector through the infusion of capital, modern technology and infrastructure, including irrigation. Many of these LSLAs explicitly or implicitly include control and management of water in their contracts. The water dimensions of these LSLAs and their impacts on food security, local livelihoods of smallholder farmers and the surrounding ecosystems are only now beginning to be examined. Kizito et al. (2013) and Williams et al. (2012) found that in Ghana and Mali, LSLAs resulted in loss of access to land and associated water rights by a large number of poor farmers. This directly affected their ability to feed their families and earn income. But there are private sector firms with long-standing engagement that are leasing land from local communities for agricultural production using inclusive business models such as outgrower schemes or revenue sharing arrangements that satisfy both local demands, including increased income for farmers, and investors' interests.

Increasingly, new investments are being implemented through public-private partnership models, for example, in Ethiopia, Ghana, Nigeria and Tanzania. These are relatively new initiatives and there are several variants. In one model, the public sector invests in and owns the irrigation infrastructure but outsources the operation and maintenance to the private sector (World Bank 2013). In another model, public land is leased out to a private sector investor who develops the irrigation infrastructure and operates, either directly or indirectly, through third party nucleus services to hundreds of emergent local farmers who are apportioned plots on the newly developed land. This is the model being piloted by AgDevCo, a private sector, social impact investment company, together with Ghana's Ministry of Food and Agriculture to develop Babator, a 4,500 ha farm in Northern and Brong-Ahafo regions for commercial rice production.

The drivers and trends in the LSFIS are summarized in Table 13.3.

System performance

Productivity

Cereals account for approximately 50 per cent of the harvested irrigated area in SSA (FAO 2005a). Across SSA (and north Africa), irrigated land represented about 3 per cent (33 per cent) of total harvested cereal land but accounted for 9 per cent (75 per cent) of total cereal production in 2006 (FAO 2011). This demonstrates the potential of irrigation to boost agricultural production and food security.

In SSA, rice is the main cereal on 25 per cent of the harvested irrigated area, with other cereals, including wheat, maize and sorghum, covering 24 per cent of the same area, but wheat and rice are the dominant irrigated staple crops in the north African countries in the Nile River Basin. Until the late 1990s, irrigated rice yields achieved by farmers on LSIFS in SSA were generally low (about 1.6 t/ha). This has been attributed to unreliable water supplies, poor water control and management, low input use, poor agronomic practices and difficulty in accessing profitable output markets (World Bank 2007).

However, emerging evidence suggests that rice on LSIFS has the potential to achieve high yield and to be competitive in local markets if farmers have good access to irrigation water, and use adequate inputs and crop management practices (Nakano et al. 2011). For instance, Table 13.4 shows paddy yield ranging from 1.3 to 4.3 t/ha, partly reflecting varying farmer access to water. It also shows that irrigated rice can offer a competitive price in local markets if water access is good (US$299 per tonne in Doho and US$302 per tonne in Chokwe) relative to the international price of rice (US$275–335) in the survey year. However, prohibitive local transport costs can easily change the picture.

The variability in performance of large-scale irrigation schemes evident in Table 13.4 remains an issue across SSA. Borgia et al. (2012) analysed the variability in three large-scale irrigation schemes in Mauritania using field level observations and satellite images. They found great intra-scheme variability, with irrigation intensity varying on a scale from 0 to 1 and yield ranging from 0.4 to 7.0 t/ha in a single scheme. Analysis of the water distribution patterns within the scheme indicated that variability in irrigation water supplies and drainage were the main sources of variable yield and irrigation intensity. The evidence from this study and that of Nakano et al. (2011) suggests that finding lasting solutions to the physical, technical and organizational factors that underlie non-uniform water distribution patterns will be important in raising productivity of irrigated rice and incomes of farm households on large-scale irrigation schemes. Equally important will be access to markets for inputs and outputs, and good road infrastructure and transport systems.

Table 13.3 Evolution of the large-scale irrigated farming system (LSIFS) in response to various drivers

Drivers	*Trends*	*Implications for LSIFS structure and function*
Population, hunger and poverty	• Increased population growth and incidence of hunger and poverty • Rapid urbanization and changing diets • Increased rural-urban migration	• Shift from production of cotton fibre for export to staple food crop production for domestic market • Production of horticulture crops • Reduction in family labour input on-farm
Natural resources and climate	• Abundant irrigable land and water resources • Increase in natural resource degradation	• Potential for expansion of irrigated area • Reduced agricultural productivity; increased environmental externalities
Energy	• Rising fuel (petrol and diesel) and electricity cost • Introduction and increasing importance of renewable energy (solar and wind)	• Disruption of water pumping and supply to farmers • New opportunities for water lifting and agroprocessing
Human and social capital	• Limited human capacity in agencies managing irrigation operations • Gender bias in land allocation and in membership of WUAs	• Poor service delivery to farmers • Poor representation of women as owners and farmers of irrigated plots and in irrigation management decision-making
Science and technology	• Improved availability of germplasm and inputs (fertilizers, herbicides, etc.) • Availability of new data-gathering and decision-support tools	• Increased yields, but regular access of all farmers to inputs remains problematic • Improved service delivery to farmers in the long run
Trade and markets	• New opportunities for trade in high-value horticulture products in domestic and export markets	• Income-earning opportunities for farmers
Policies and institutions	• Decentralized governance, including different forms of participatory irrigation management (PIM) and irrigation management transfer (IMT) to WUAs • Market reforms, including abolition of price and marketing controls	• Mixed results in terms of irrigation water availability at field level and maintenance of irrigation infrastructure • Provided incentives for farmers to diversify their production activities and market their products directly

Table 13.4 Yields and returns in large-scale rice irrigation schemes in five sub-Saharan African countries

Country, location and water availability	*Uganda*		*Mozambique*		*Burkina Faso*			*Mali*		*Niger*	
Data	*Doho 2007*		*Chokwe 2007*		*Kou Valley*	*Sourou*	*Bagré*	*Niono*	*N'Débougou*	*Say2*	*Daibéri*
					2005–06			*2005–06*		*2005–06*	
	Facing main channel	*Not facing main channel*	*Receive enough water*	*Do not receive enough water*	*Deteriorating access to water*	*Fluctuating access to water*	*Improved access to water*	*Improved access to water*	*Improved access to water*	*Fluctuating access to water*	*Deteriorating access to water*
Sample size (number of households)	111	177	144	32	78	40	30	49	50	60	50
Current irrigated area (ha)	1,000	–	4,000	–	1,400	3,200	1,885	–	11,757	186	295
Mean paddy yield (t/ha)	3.2	2.7	2.2	1.3	3.2	3.6	3.2	3.2	3.1	4.3	3.6
	(1.3)	(1.7)	(1.2)	(1.0)	(0.7)	(1.7)	(1.2)	(1.6)	(1.3)	(1.5)	(1.2)
Net return (US$/ha)	671	506	143	29	564	368	166	1,000	983	438	361
Profit (US$/ha)	377	203	35	−73	–	–	–	–	–	–	–
Unit production cost of milled rice (US$/tonne)	299	358	302	407							
Rice grade/type	International rice price (US$/tonne f.o.b.) in survey year										
Thai 2nd grade#		335							291		
Thai A1 grade		275							219		
Pakistan 25%		290							235		
Vietnam 50%		313							255		

Source: Nakano et al. (2011).

Note: data in parentheses are the standard deviations of mean paddy yield.

Sustainability

Economic dimension: costs and returns

The economic sustainability of LSIFS depends not only on improving the agricultural productivity but also on keeping the cost of construction and operation and maintenance of irrigation infrastructure low. Based on an irrigation project database compiled by the International Water Management Institute, Inocencio et al. (2007) showed that for a sample of 314 large- to medium-scale projects implemented in developing countries from 1965–2000, the unit total cost of new construction projects in SSA was on average twice as expensive as in non-SSA. For rehabilitation projects, the unit total cost in SSA was almost three times as high as in non-SSA. However, SSA projects that were deemed successful, because their rate of return at completion was 10 per cent or more, did not have unit costs that were significantly different from unit costs in non-SSA.

The study found that unit costs varied inversely with project size indicating a scale economy. Other key factors found to influence costs included community participation, type of irrigation infrastructure, type of crops grown and concurrent use of surface and groundwater. Projects where farmers made a large capital contribution and managed irrigation systems or shared management with a government irrigation agency recorded significantly better results in terms of keeping costs down and improving economic returns. Irrigation infrastructure designed for staple cereals showed higher unit costs and lower returns than those designed for horticulture, vegetables and fodder crops. This was partly because the heavy irrigation infrastructure such as dams, reservoirs, sluices and canals used in the irrigation of staple foods (such as rice, wheat and maize) is much more costly than the lighter infrastructure used in the cultivation of non-cereal crops. Furthermore, the declining price of cereals from the mid-1980s to mid-2000s resulted in reduced profitability relative to horticulture and vegetable crops that experienced strong demand growth. Irrigation systems that concurrently used surface and ground water performed better than those that did not.

With respect to economic returns, Inocencio et al. (2007) found that externally funded projects from the 1970s up to 1984 performed poorly due to high unit costs per hectare leading to low or negative rates of return. However, projects implemented after 1985 have fared better. A number of factors influenced performance. First is the reduction in the unit total cost of irrigation projects. Failed projects (those with rates of return below 10 per cent) had, on average, total unit costs per ha four times those of 'successful' projects (those with rates of return above 10 per cent). Second, projects where high-value crops can be produced and sold profitably do better. This is confirmed by the thriving horticultural production for export by smallholder irrigators in Kenya, Ethiopia and Zambia.

Across SSA, lessons learned from these studies are already being put to use in new irrigation projects. More recent projects are avoiding the over-sophisticated and unduly complex infrastructure of earlier projects and are often decentralized and farmer-driven, with higher farmer contribution leading to lower unit costs (Aw and Diemer 2005; IDA 2007).

Environmental dimension: salinization

Irrigation-induced salinization is a growing problem in several LSIFS resulting in extensive areas of land being taken out of productive use and threatening the productivity of other farming systems downstream. In the mid-1990s at Chokwe LSIFS in Mozambique, salinization led to the loss of about 5,000 ha out of a total of 30,000 ha (World Bank 2007). Recent estimates in the same system are that 10,000 ha are rendered unusable due to salinization. Evidence of irrigation-induced salinization or threat of salinization has also been reported in Wonji/Shoa scheme in Ethiopia (Ruffeis et al. 2010), Office du Niger (Barry et al. 2009), Vaalharts scheme in South Africa (Verwey and Vermeulen 2011), and Chali and Bahi schemes in Tanzania (Kiunsi 2006). While the technical problems that have led to irrigation-induced salinization in each of these systems are context specific, they include one or several of the following factors: poor on-farm water management such as overirrigation and poor drainage control; poor construction, operation and maintenance of irrigation canals leading to excessive seepage; inadequate or lack of system-wide drainage infrastructure; and poor quality of construction, operation and maintenance of drainage facilities where they exist.

These technical problems, as pointed out by Umali (1993), often have their roots in other policy and institutional failures, for example inappropriate water pricing policies, poor irrigation scheduling, ineffective project planning, monitoring and evaluation, inadequate operation and maintenance budgets, inadequate extension services and farmers' lack of awareness of more efficient water management. However, salinization can also occur within irrigation systems through natural weathering of saline parent material. Barbiéro et al. (2001) and van Asten et al. (2003) provided evidence which suggests that soil salinity in irrigation schemes along the Senegal river valley was not necessarily due to secondary salinization, but rather the manifestation of salt already present in the soil before the establishment of the irrigated rice system. Whatever the cause, irrigation-related salinization imposes severe consequences not only on the farmers and households in affected production areas but also on areas and people downstream. In areas directly affected, loss of land and loss of production mean less agricultural production and income with concomitant strain on farm household food security. Drainage water discharged into rivers increases the salt load of the rivers and makes the river water less suitable for irrigation and other uses downstream.

Apart from estimates of soil salinity and land area abandoned, there is very limited empirical research on field-level and basin-wide economic and environmental impacts of irrigation-induced salinization. This gap in our knowledge will be further examined in the section on strategic priorities for the LSIFS.

Social dimension

UPSTREAM-DOWNSTREAM RELATIONSHIPS

Downstream externalities will occur through the interruption of the downstream transfer of water and sediment which would otherwise take place. This will be compounded if poor water and land management in the irrigation scheme lead to soil erosion and discharge of salt-, herbicide- and pesticide-laden drainage water downstream. Losses may be incurred by households engaged in agricultural production, fishing and firewood collection. The livelihood impacts may be substantial in semi-arid zones where downstream uses of water are critical to the economic well-being of a large number of rural households. Negative impacts on ecosystem services may also result. For instance, in northern Nigeria, construction of dams for large-scale irrigation schemes upstream of the Komadougou-Yobe river basin diverted water from Hadeija-Nguru wetlands downstream, resulting in loss of plant and animal habitat and biodiversity, and negative implications for irrigated agricultural production in the floodplain which was dependent on water from a shallow groundwater aquifer (Barbier 2003; FAO 2005b). Dialogue and cooperation between upstream and downstream users has moderated some of the negative impacts noted earlier. But this needs to be preceded and informed by rigorous environmental impact assessment to establish the scale of the problem and to develop solutions to eliminate or mitigate the worst impacts. Understanding of local interactions and dependencies around the vicinity of large-scale irrigation infrastructure and farming systems will allow a clear linkage between upstream irrigation activities and downstream effects to be established and will facilitate the adoption of an integrated water resources management approach at a watershed level.

PUBLIC HEALTH IMPACTS

A different but related issue concerns the public health problems created by dams constructed for irrigation. In Ethiopia, the construction of small dams in Tigray region increased the spread of malaria, while the spread of urinary schistosomiasis in Burkina Faso has been associated with the increase in construction of small reservoirs (World Bank 2007). Another study reported incidences of schistosomiasis in several large-scale irrigation schemes across Africa: Morocco, Tessaout Amount; Sudan, Gezira Managil; Mali, Office du Niger; Cameroon, Lagdo; and Kenya, Mwea resulting in debilitating health consequences for farming households (Boelee and Madsen 2006).

Apart from inadequate attention to the environmental and health impacts of irrigation projects at the design stage, many of the highlighted problems are also partly attributable to weaknesses in the environmental and health regulatory and enforcement frameworks. Regular monitoring and evaluation and mitigation measures are often not implemented as funds are not budgeted for such activities.

Human development outcomes

Household income, consumption and poverty

In a farm household level study conducted in the Tigray region of Ethiopia, Gebregziabher et al. (2009) analysed the income, consumption and poverty-reduction impacts of three different types of small-scale irrigation systems (earth dams, river diversion and shallow wells). The study sampled 613 farm households (331 irrigators and 282 non-irrigators) using a three-stage stratified sampling and propensity-score matching method to compare the differences between irrigators and non-irrigators. Although the focus of the study is on small-scale irrigation systems (Figure 13.4), the findings are relevant. They found that the overall mean income gain due to participation in irrigated agriculture ranged from US$462 to US$520 per household per annum, which was higher than the income gain estimated for the entire sample. Poverty incidence in the irrigator's group was also significantly lower than that of non-irrigators, which was slightly higher than the regional average for Tigray and significantly higher than the national average. Total household consumption expenditure of irrigators was significantly higher than that of non-irrigators, though the difference was not as large as the difference in income between the two groups. Also, irrigators hired more labour and had lower participation in off-farm activities, reflecting the relative labour absorption potential of irrigated farming compared to rainfed farming. This was particularly so for

Figure 13.4 Small-scale irrigation, East Dangbe district, Ghana.

Source: Regassa Namara.

groundwater irrigators who also had the highest average income level among the three categories of irrigators. The results relating to groundwater irrigators are consistent with results from other developing countries (Shah et al. 2007).

Dillon (2010) assessed the impact of the scale of irrigation on household welfare in Mali, with a sample of 651 agricultural households (283 small-scale irrigators, 56 'large-scale' irrigators[1] and 312 non-irrigators) in the region of Niafunke. The analysis showed significant gains in agricultural production and income for both large- and small-scale irrigators, with larger benefits accruing to the latter. Relative to non-irrigating households, small-scale irrigation had a statistically higher estimated yield of 2.1–2.4 t/ha, whereas large-scale irrigation had a point estimated yield ranging from 941 kg/ha to 1.1 t/ha. With respect to agricultural income, the effect of small-scale irrigation was generally higher, with estimates between US$296 and US$317. Estimates of the effects of large-scale irrigation ranged between US$250 and US$342 and were more variable than those of small-scale irrigation. The effects of irrigation on consumption expenditure per capita were mixed. Although there was an overall positive effect on irrigators of consumption per capita, the effects of large-scale irrigation on consumption per capita were larger than those for small-scale irrigators, despite the larger production effects of small-scale irrigators. The author suggested that the differences in income and consumption effects between the two types of irrigators could be due to lower market engagement by small-scale irrigators compared with large-scale irrigators, with the implication that agricultural surpluses may affect household welfare more slowly if asset, input and food markets are less integrated.

Gender

Evidence from field-level studies and evaluation reports of donor-funded projects demonstrates that the success of irrigation in alleviating poverty will depend on the extent to which issues such as gender and water rights of the poor are taken into consideration (IFAD 2007; van Koppen and Hussain 2007; Zwarteveen 2006). Large-scale projects that improve women's access to land and water have been found to significantly improve household food and nutrition security and incomes (IFAD 2005). Participation by women in WUAs, in areas where women's role as farmers is widespread, has allowed them to articulate their interests and improve their understanding and knowledge of project matters. This has led to their participation in water distribution and maintenance, which, in turn, improved their access to water (Hulsebosch and Ombarra 1995; IFAD 2006).

Strategic priorities for the LSIFS

The availability of underutilized surface- and ground-water resources, the intensification opportunities, and improving access by farmers to input and output markets all suggest that the potential of the irrigated farming system as a whole for improving agricultural growth and reducing poverty remains high. The discussion below explores the way five alternative strategies of intensification, diversification, increased farm size, increased off-farm income and exit from agriculture can lift households out of poverty in LSIFS.

Table 13.5 shows estimated changes over time in the relative importance of the five strategies. With better water management, intensification remains the most important pathway out of poverty for households in the LSIFS. This implies 'more yield per drop' and will entail improving the reliability of water supplies and utilization of the full suite of crop productivity-enhancing measures, including best available germplasm, use of optimal doses of fertilizer and application of improved crop protection practices (e.g. integrated pest management). The evidence presented in Table 13.4 demonstrates that farmers in LSIFS can successfully intensify their production activities. Diversification is feasible where the irrigation management authorities allow this strategy to be implemented. The drive should be to get more value per unit of water, and this can be achieved through switching to higher value crops (fruits and vegetables), integrated farming enterprises (crop-livestock-aquaculture) (Figure 13.5) and addition of agroprocessing to increase value and employment per drop. The practice by many governments of allocating the limited irrigable land under public sector managed irrigation schemes to as many eligible farmers as possible means that increasing farm size will not be a major option in the LSIFS. Improved management and performance of large-scale irrigation schemes coupled with increased agricultural productivity could create off-farm employment opportunities that would increase off-farm income, as described earlier in the case of Office du Niger. For most households, the economic and social benefits derived from owning a plot within an LSIFS make exit from irrigated agriculture unrealistic and there is no widespread evidence of this occurring.

Figure 13.5 Oxen ploughing, Karfiguela irrigation scheme, Burkina Faso.
Source: Regassa Namara.

The question then is: what strategic interventions are needed to make these household strategies work to alleviate poverty? These interventions, summarized in Table 13.6, will be briefly discussed below under the main drivers of the system.

Population, hunger and poverty

In order to guarantee success, new LSIFS investments must be targeted to agroecological zones where population densities are high, where a process of intensification has already

Table 13.5 Relative importance of household livelihood improvement strategies in sub-Saharan Africa

Livelihood improvement strategy	*Extremely poor (2000)*	*Extremely poor (2015)*	*Less poor (2015)*	*Total population (2015)*
% of total ag pop	–	52	48	100
Intensification	3.5	5	3	4
Diversification	2	2	2.5	2.5
Increased farm size	2.5	0.5	2	1
Off-farm income	1.5	1.5	2.5	2
Exit from agriculture	0.5	1	0	0.5

Sources: See Chapter 1, 'Farm household decisions and strategies' and Chapter 2, 'Household strategies'.

started and where market opportunities are emerging. Unlike earlier investments, which paid little attention to measures to increase smallholder farmers' income, they should be planned and designed with poverty reduction and equity as explicit objectives. Undertaking pre-investment socioeconomic and farming system appraisals will allow site-specific social, economic and livelihood factors to be taken into consideration and will provide a good understanding of the way access to water and complementary inputs could be used to assist various household strata to improve their livelihoods. Irrigation is only one of a variety of livelihood strategies for farmers. However, when irrigation schemes are planned, the fact that farmers still cultivate rainfed plots, herd livestock, or engage in off-farm labour opportunities and migration is often overlooked. Without understanding how irrigation fits into other livelihoods strategies, inappropriate recommendations may be made that cannot fit into the labour constraints and multiple aims of different farming households.

Natural resources and climate

The quest to increase area under irrigation will entail development of new LSIFS. For these new schemes, lessons learned from fifty years of irrigation development should be borne in mind. For new irrigation development, the emphasis should be on sustainable intensification of agriculture that minimizes natural resource degradation. Environmental impact assessments within the wider landscape should be conducted during the preparation stage in order to identify alternative designs or mitigation measures. Looking at irrigation development from a watershed management perspective is often not a part of irrigation planning, but it is an approach that is sorely needed. Many schemes frequently suffer from siltation as a result of upstream land use practices. This challenge is also an institutional one as incentives for better land management by upstream users must be devised. Once the LSIFS is operational, monitoring and evaluation of environmental impacts and enforcement of mitigation measures, where negative externalities are created, will be equally important. Farmers' involvement in such monitoring and evaluation exercises will help ensure long-term sustainability.

Most studies predict that impacts of climate change will be more pronounced in Africa than in the northern hemisphere. Given the myriad other challenges confronting the agricultural sector, climate change may become a threat multiplier unless action is taken to improve the resilience of African agriculture. With more frequent occurrence of floods and droughts, irrigation can serve as a buffer against the predicted effects of climate change on rainfed agriculture. Irrigation must be a component of a climate-smart agricultural strategy that also includes proven in-situ soil water conservation methods at the field level.

Energy

A strategic priority going forward is to develop alternative renewable energy sources, e.g. solar and wind power, to pump water on LSIFS and supply electricity for other farm operations. The upfront investment cost of using these energy sources will be beyond the means of farmers and will need to be co-financed through public-private partnerships. In the long run, use of these energy sources will lower operational costs and will also contribute to a cleaner environment.

Human and social capital

Men and women farmers and farmer groups need training that is oriented to their specific constraints, challenges and needs. But the training required extends beyond simply managing, operating and maintaining irrigation schemes. Continuing training in skills ranging from leading and marketing their own organizations and businesses to record keeping will be critical for long-term success.

Years of structural adjustment programmes, partly implemented to curb public expenditure, have decimated the agricultural extension systems in many countries. The hard choice facing governments is either to rebuild and strengthen the national extension services or create the enabling environment for private sector and NGO intermediaries to step in and provide the needed extension support services. Whichever model is chosen, extension agents with relevant skills and expertise are needed to engage with communities in the design, operation and maintenance of irrigation infrastructure, and with farmers on efficient water use for irrigation and storage and marketing of irrigated crops. Research capacity and training in neglected aspects of irrigation management – water economics, social and institutional analysis, hydrology, hydrogeology, geographic information systems, remote sensing, meteorology, low risk cropping systems – will need to be strengthened in order to create a critical mass of professionals that can coordinate and manage the expected expansion of irrigation and enforce regulatory measures.

Science and technology

Informed policy, management and investment decisions depend on availability of fact-based evidence. At national and field levels, there is a need to improve the measurement, monitoring and evaluation of agricultural water resource availability, distribution and use. In gathering this data, African countries need to go beyond the traditional methods of data collection that rely on field assistants going from one field or household to another. Investments need to be made in hardware, software and personnel required to apply various remote sensing and earth observation decision-support tools to irrigation management.

In order to make use of the available but underutilized groundwater resources, detailed hydrogeological maps that provide information relevant for agricultural use such as aquifer depth, yield, transmissivity and recharge rates are needed. Various drilling technologies that are suited to different farming systems will also be needed as well as energy-efficient and affordable pumps for lifting water. New technologies and tools to improve water management and water use efficiency will help to enhance agricultural productivity.

Trade and markets

The agricultural growth and poverty reduction potential of the irrigated farming system is constrained by many factors that undermine farm-level profitability, including high input costs and lack of access to credit and markets. Farm-level profitability will be enhanced if farmers are empowered and assisted to operate within viable value chains that ensure access to input and output markets. This will lead to faster growth, higher incomes, and improved food and nutrition security for households in LSIFS. Building value-adding agroprocessing enterprises around irrigation schemes could create additional employment opportunities and linkages to the non-farm economy.

Table 13.6 Summary of strategic interventions for LSFIS

Drivers of LSIFS evolution	*Intervention*	*Implementers*	*Implications for farming system structure and function*
Population, hunger and poverty	• Irrigation investments in agroecological zones with high population densities • Research to understand households' livelihood strategies and where irrigation fits in	• National governments and private sector investors • National governments, private sector investors and research institutions	• Facilitate and provide incentive for intensification • Lead to irrigation recommendations that enhance livelihoods
Natural resources and climate	• Expand irrigation to make use of abundant land and water resources • Adopt a watershed perspective to irrigation planning and implement efficient irrigation water management practices	• National governments and private sector investors	• Increase opportunities for old and new irrigators • Minimize upstream and downstream social and biophysical problems • Increase farm productivity
Energy	• Investment in renewable (solar and wind) energy sources	• National governments and private sector investors	• Lower operational costs • Lower carbon emission
Human and social capital	• Capacity building of farmers • Investment in irrigation-related tertiary education and research	• National governments, private sector investors and research institutions	• Better train farmers to be able to manage irrigation infrastructure and grow irrigated crops profitably and in an environmentally friendly way • Increase capability to undertake research to improve LSIFS
Science and technology	• Investment in new tools and techniques for collection of data required for irrigation planning • Investment in drilling technologies and energy-efficient pumps	• National governments and private sector investors	• Improve predictable supply of irrigation water to farmers
Trade and markets	• Improve access by farmers to finance and markets • Build viable value chains that include farmers	• National governments and private sector investors	• Increase farm-level productivity and profitability
Policies and institutions	• Improve coherence between irrigation, energy and environmental policies • Promote PPPs in LSIFS development	• National governments and private sector investors	• Will provide appropriate and stable incentives to farmers • Expand area under irrigation and increase benefits to farmers

Policies and institutions

While much has been achieved in the way of policy and institutional reforms, much remains to be done. At the national level, irrigation policies need to be better integrated into agricultural growth and poverty reduction strategies. Measures to improve coherence between irrigation, energy and environmental policies are needed to remove ambiguity and contradictory measures and to allow policies to reinforce and complement each other. Continuing land tenure reforms will need to be pursued to ensure women's access to land in LSIFS. Policies and institutional arrangements that will create the right balance between the role of government and roles best performed by other actors – private sector, civil society, farmers' associations – as well as effective coordination and negotiating mechanisms among them will also be needed. In this regard, the new models of public-private partnerships (PPPs) that are being tried out in many countries offer opportunities to accelerate and better manage new investments as well as rehabilitate the dysfunctional irrigation infrastructure that has hampered the growth of many LSIFS. But PPPs in irrigation are relatively new, and especially in the context of SSA, much piloting, learning and evaluation is still required. This should be a priority given the potential payoff.

Conclusions

The potential of LSIFS and irrigation in general to improve food security, reduce poverty and promote agricultural growth is yet to be fully tapped in Africa. The availability of underutilized surface and ground water, the growing demand for staple foods, fruits and vegetables and continuing growth in intra- and inter-regional trade all suggest that the potential of the irrigated farming system to achieve desired objectives remains high.

The analysis presented shows that policy and institutional factors, natural resources, science and technology, and trade and markets have largely shaped the evolution of LSIFS since the late 1950s. Assessment of the performance of LSIFS, based on productivity, sustainability and human development outcomes, indicates that while performance has improved over time, much remains to be done. Predictable water supply, better irrigation management practices at field level and appropriate use of agronomic inputs are needed to raise agricultural productivity and farm profitability and to simultaneously reduce natural resource degradation, including problems of waterlogging and salinization.

Intensification, diversification and increased off-farm income represent feasible pathways for households in the LSIFS to move out of poverty. Strategic priorities to bring about the required change in the farming system include PPPs to increase and better manage investments in LSIFS; improving access by farmers to finance, input and output markets; improving extension support services; reforming land tenure to guarantee access of women farmers to irrigated land; and introducing alternative renewable energy sources for water pumping and other farm operations.

Implementation of these measures and lessons learned from past failures and successes will ensure that LSIFS can play an important role in improving food security, livelihoods and agricultural growth in the years ahead in Africa.

Note

1 'Small-scale irrigators' refer to farmers in a small-scale irrigation scheme of approximately 50 ha, while 'large-scale irrigators' refer to farmers in a community-managed irrigation scheme of more than 300 ha.

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