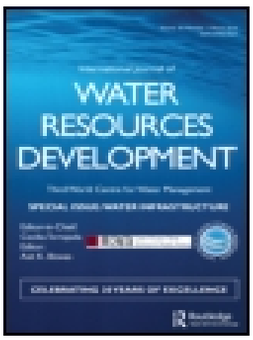

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Exploring the factors causing the poor performance of most irrigation schemes in post-independence sub-Saharan Africa

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ABSTRACT

This article explores the factors causing the current poor performance of most government irrigation schemes in sub-Saharan Africa. The literature review finds that the poor performance is not primarily caused by socioeconomic and biophysical conditions inherent to sub-Saharan Africa. African farmers have adapted to diverse biophysical conditions and expanded or contracted their area under agricultural water management in response to market signals. Rather, this poor performance is predominantly linked to the production systems introduced during colonialism and developments since independence, such as agricultural policies restraining rural economic development, unsuitable irrigation technologies and agricultural practices, and international lending practices and trade arrangements.

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Agricultural water management; farmer-led; sub-Saharan Africa; rural economic development; agricultural production systems

Introduction

Formal irrigation schemes were introduced to sub-Saharan Africa (SSA) by colonial governments in disregard of local socio-economic and biophysical contexts, and primarily to meet interests in export crop production. After independence, governments in SSA continued to develop irrigation schemes with donor backing. These schemes were not driven by farmers' economic interests, nor were they used to enhance production systems for local development (Bjornlund et al., 2020). Rather, the development and management of irrigation schemes were driven by the political and social objectives of governments, and often at odds with farmers' interests. In contrast, the complex agricultural water management (AWM) practices endogenous to SSA were adapted in scale and management to their socio-economic and biophysical environments, as in many places (Bjornlund & Bjornlund, 2019). We use the term 'government schemes' to describe irrigation schemes where the government has a substantial control over their management. The degree and form of government control varies across schemes and countries. In general, government schemes have performed poorly and failed to deliver the promised outcomes (Mutiro & Lautze, 2015). Farmer-led AWM and private irrigation have fared much better; they were often developed on an entrepreneurial basis in response to economic opportunities and

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managed by farmers as both producers and beneficiaries of the system (Bjornlund et al., 2020).

After independence, governments initially focused on the development of large single-crop irrigation schemes for national food sovereignty. However, these did not perform well, and a cycle of decay-refurbishment-decay commenced (Jones, 1995; Racked et al., 1996). This resulted in abandoned or underutilized irrigation infrastructure. For example, there is only 54% utilization of irrigated areas in the Sudano-Sahelian region (Food and Agriculture Organization [FAO], 2016). The focus of development then changed to small schemes driven by social objectives for household food security, but with similar poor outcomes (Pittock et al., 2017).

Investment in government schemes declined in the 1990s, but there has recently been renewed interest by the World Bank (WB) and other lenders. This article argues that planners and funding agencies, at least until the late 1990s, either did not fully understand or were unable to address the socio-economic and political issues that caused the previous failures. Consequently, the lessons of history have been ignored, risking the repetition of past mistakes or limiting the potential benefits from irrigation investment. Thus, it is essential to understand why, despite repeated refurbishments, most government schemes have continued to perform poorly.

Many studies argue that the poor performance is because of issues inherent to Africa's biophysical environment and its people – for example, poor soils, debilitating droughts and floods, labour shortages, ignorant farmers, backward farming methods and small-scale farming systems (Austin, 2008; Tadele, 2017). This article argues that it is critical to understand that this is not the case. Other studies focus on aspects such as high development costs, poor management, lack of rural finance, expensive fertilizer, lack of infrastructure (Inocencio et al., 2007; Molle & Renwick, 2005), uncertain land tenure (Abdulai, 2006; Tiffen, 1985), and lack of farmer organizations (Mercoiret et al., 2007). These aspects do contribute to poor performance, but addressing them individually has yielded limited positive outcomes.

We argue that irrigation scheme developers have failed to understand that irrigation schemes are complex systems. Such systems can only be successful if they operate within the constraints of the water resource (Lankford, 2010) and are part of a functional rural economy that is integrated with markets, transportation, and information systems. Unless schemes are profitable, and farmers' livelihoods are improving – warranting the investment of labour, land and water – schemes will continue to perform poorly and remain underutilized.

The hypotheses explored in this article are that the poor performance of most government schemes post-independence is rooted in (1) the production and trading systems introduced during colonialism and (2) post-independence developments of (a) political systems and policies, (b) technologies and agricultural practices, and (c) global lending and trading systems. We explore these hypotheses by reviewing a broad range of literature. As SSA is a vast and diverse region with agricultural development spanning many centuries, we explore general trends and patterns, rather than reflecting the nuances of development across the region.

The article is structured as follows. The first section provides evidence to support our argument that the poor performance of most government irrigation schemes is not primarily related to issues inherent to Africa's biophysical environment and its people.

This argument is supported by a description of the main AWM systems endogenous to SSA (Appendix 1) and their adaptation and expansion in response to European demand. The second and third sections describe the colonial production systems and post-independence agricultural policies and irrigation developments. Hypotheses 2a, 2b and 2c are explored in a fourth section drawing on the second and third sections and the companion article by Bjornlund et al. (2020).

African AWM as adaptive and productive systems

AWM systems are understood as planned human interventions to control and distribute surface and subterranean water for agricultural purposes to meet community objectives (International Commision on Irrigation and Drainage, 2002). AWM may comprise land equipped for irrigation, including canals, dykes and weirs (FAO, 2016). Complex AWM systems existed across Africa when the first European maritime traders arrived on the west coast of Africa (Figure 1). This ability to manage and manipulate water was critical for SSA's communities, as the increased productivity of AWM could support denser populations and more complex societies. Appendices 1 and 2 provide an overview of the diversity and sophistication of these systems.

Adaptation of endogenous AWM systems to external opportunities and market changes

This section illustrates how AWM systems in SSA were expanded during the 1700s and 1800s to produce crops for export to Europe and to respond to changing market conditions, such as terms of trade, tariffs and competition.

Export demand was initially driven by European traders on the west coast of Africa. Trading posts supplied rice and maize to the sugar plantations on Sao Tomé and Principe Islands, and later to the North Atlantic slave trade (Havik et al., 2018; Knight, 2010). Demand increased in the late 1700s to supply agricultural raw materials (e.g. gum, rubber, cocoa, palm oil and peanuts) to Europe's emerging industries, which stimulated local African economies and the expansion of SSA's endogenous AWM systems (Law, 2002; United Kingdom Parliament, Accts. & Papers, 1879). Inter-regional trade in local produce also increased as the export economy grew, including goods such as red peppers, kola nuts, livestock, and manufactured products such as textiles, leather goods and iron hoes (Lovejoy, 1980a). As few urban centres existed, most daily staples remained locally produced (Inikori, 2013).

High export commodity prices and favourable terms of trade during the 1800s improved economic conditions in the second half of the nineteenth century (Figure 2). This meant that local economies were receiving more for exports relative to imports, creating surplus revenue to invest in agricultural production. On the Gold Coast, for example, African merchants generated substantial revenue from palm oil, with exports rising from 350 tons in 1829 to 1,050 tons by 1848 (Reynolds, 1974). Following the European financial crisis of the 1880s and the transition to the colonial single-nation buying regimes, the terms of trade and the commodity prices received by African farmers declined. To offset the lower prices, the volume of goods exported was increased (Table 1; Figure 2), and African farmers became increasingly specialized (Bjornlund et al., 2020).

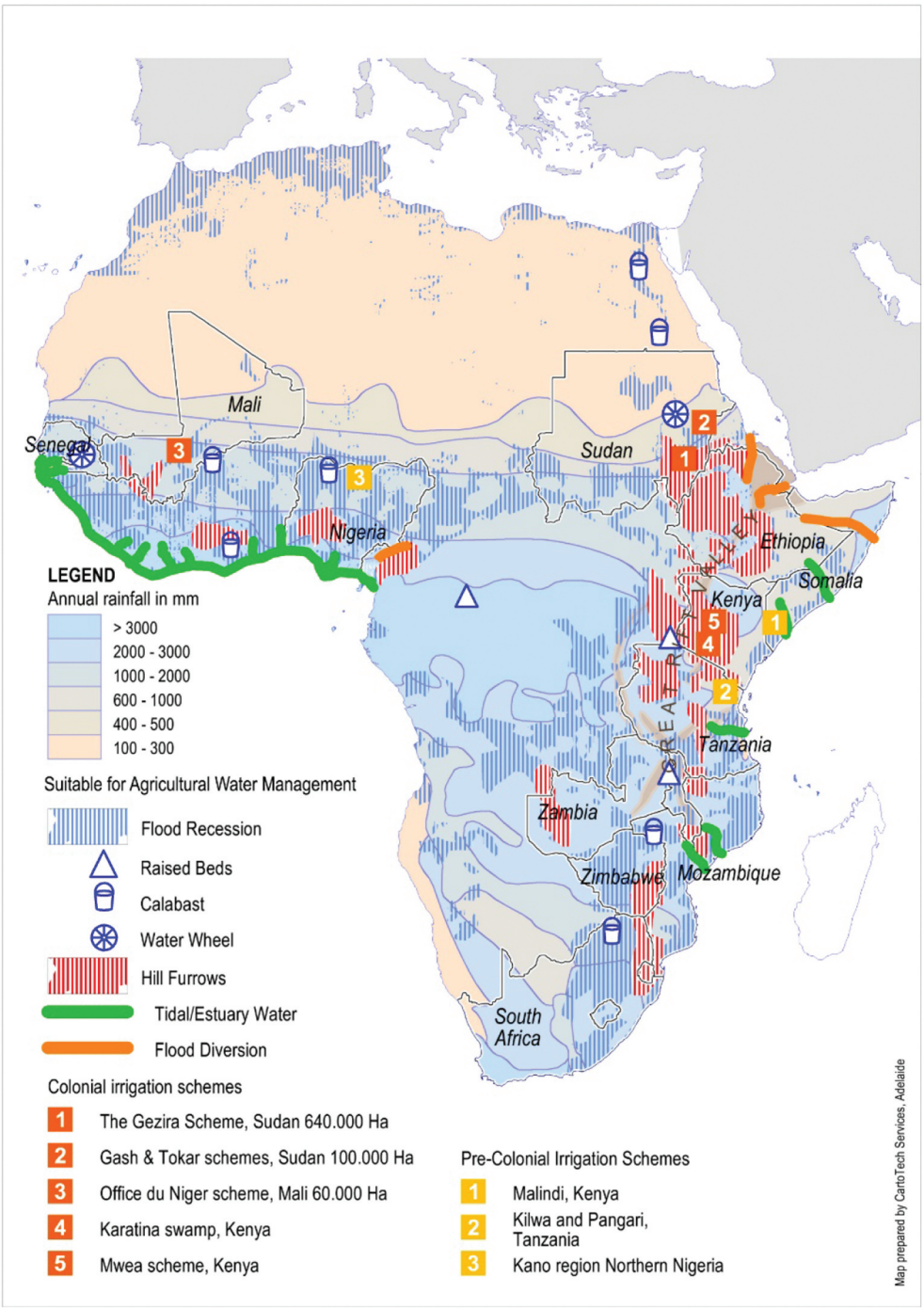

Figure 1. Agricultural water management and precolonial and colonial irrigation schemes (compiled by the authors based on Appendices 1–3 and You et al., 2011).

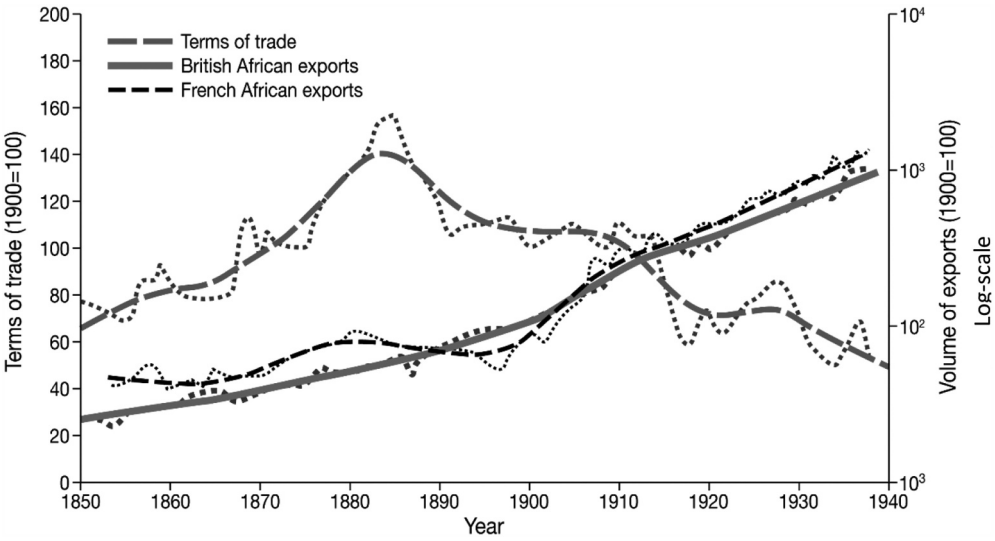

Figure 2. Sub-Saharan Africa terms of trade and British African and French African exports between 1850 and 1939. Source: Frankema et al. (2018). Notes. Smoothed trend excludes South Africa, Mauritius, Madagascar and Reunion, based on 1900 = 100. Terms of trade is the price received for exported goods compared to prices paid for imported goods.

Table 1. Decomposition of export growth in British and French West Africa, 1850–1929. Source: Frankema et al. (2015).

	Annual growth of purchasing power of exports	Price contribution to annual growth	Volume contribution to annual growth
British West Africa			
1850–1885	3.8	46%	54%
1885–1929	5.5	−24%	124%
French West Africa			
1850–1885	5.0	72%	28%
1885–1929	2.0	−123%	223%

Three processes facilitated the increased export production in West Africa: increases in cropping (both AWM and rainfed) and grazing areas by 40% and 30%, respectively; intensification of water management (Goldewijk et al., 2017); and increased migration of labour to production areas (Brooks, 1975). As a result, the area equipped for irrigation in tropical Africa increased by 720% during the 1800s (Goldewijk et al., 2017). Production systems were intensified; for example, maize that had been grown for centuries as a vegetable was adapted to a field-grown cereal crop in the 1800s. This extended the cropping season by several weeks in the humid forest zone, encouraging forest clearance and the expansion of cocoa production in Ghana (McCann, 2007).

Creating large AWM systems required inter-community coordination for substantial manipulation of the biophysical environment. Examples include the development of tidal rice production on the west coast of Africa and inland rivers. Importantly, these were local initiatives, with the benefits staying locally and African traders facilitating the transactions

between producers and shipping companies. These systems were established, managed and regulated by the communities, using customary laws of obligations, rights and benefits.

As external conditions changed, farmers adapted their production. In the 1830s, peanut production in West Africa expanded rapidly to meet demand from Britain and the Americas. When the US imposed tariffs to protect local growers in 1841, West African traders lobbied for the removal of French import restrictions. Consequently, the tariffs on whole peanuts were reduced, but tariffs on peanut oil remained to protect French processing interests (Brooks, 1975). West Africa also became a major supplier of palm oil to Europe. When the Suez Canal opened in 1863, palm oil prices fell as the supply from South-East Asia increased. West African farmers responded by diversifying their production: for example, Gold Coast farmers aggressively adopted rubber production, which increased 2,500% between 1884 and 1898 (Dumett, 1971). However, prices declined after 1910, when inexpensive, high-quality rubber was produced in South-East Asia. The Gold Coast farmers again demonstrated their flexibility and changed to cocoa production, with Ghana becoming the largest producer in the world (Vos, 2008).

In some places, changes in the control of trade meant that the demand for certain products ceased, and the economic base and the society disintegrated. For example, in response to demand for rice and spices, Swahili merchants invested in several large precolonial irrigation schemes in the coastal valleys around Malindi in Kenya and on the islands of Pemba and Zanzibar (Nicholls, 1971; Ngigi, 2004) (Figure 1; Appendix 3). These schemes supplied coastal city-states, with spices also being exported (Vernet, 2009). But this trade had ceased by the late nineteenth century, after the establishment of the East Africa Protectorate, as European merchants increasingly relied on supply from the Indian Ocean islands to avoid the Swahili merchants (Prakash, 1996). Cotton grown under the Sokoto Caliphate (now part of Nigeria, Burkina Faso, Niger and Cameroon) supplied a significant textile industry in Kano, which supported Arab trade across the Sahara (Lovejoy, 1978, 1980b). Products such as Benin cloth were traded by Europeans between coastal ports along the West African coast (Johnson, 1978), which illustrates the value of the commercial market for African products. When Britain colonized the area in 1903, they removed the Arab merchants and textile producers, and thereby the economic foundation of the rich Sokoto Caliphate. The caliphate disintegrated, and the population dispersed (Lovejoy, 1978).

Substantiating the argument

Different and often sophisticated AWM systems evolved across SSA to meet local demands for food, manufacturing and trade as part of diverse livelihood strategies. These systems were sufficiently productive to support large populations, with diverse occupations and hierarchical social structures. These complex societies could undertake long-term planning, investment and regional organization of labour. Production systems had internal feedback mechanisms that drove decision-making, management, and ultimately efficiency. Farmers processed this information as a community and decided how to manage the season, with individual households acting accordingly.

Communities were actively involved in the development and management of production, consumption and trade. They experimented and refined their practices over time, enabling them to expand and intensify crop production under AWM in response to

European demand. This adaptation continued despite fluctuating market conditions and competition, with farmers and African traders initially benefitting from external trade. On the strength of this evidence we argue that the biophysical environment and the people of Africa are not the primary cause of the poor performance of most government schemes in SSA.

Colonial institutionalization of export production in SSA and its legacy

This section describes the colonial administration's institutionalization of export production, which has impacted the economic performance of government schemes since independence. This provides the evidence to substantiate Hypothesis 1. The drivers of irrigation expansion and production changes are first considered. This is followed by a summary of two large-scale irrigation schemes, which introduced production systems that have continued to influence government schemes since independence. A third section explains how European agricultural advisors dismissed local AWM practices and knowledge. This resulted in a focus on irrigation schemes during the period of developmental colonialism, which is explained in the fourth section.

Drivers of irrigation expansion and production changes

During the colonial period, agricultural export production in SSA became institutionalized and entrenched as part of a dual economic system that separated the export and domestic economies. This separation was set in motion in 1884, when Africa was partitioned into separate European colonies to protect European economic interests and social stability and prevent competition between the European powers over resource access. The US Civil War was pivotal in triggering this process, as it necessitated the shift of cotton production from the US to Africa, India and Latin America. European powers were keen to secure the supply of low-cost cotton, and other inputs to expand their industries (Beckert, 2004; Calhoun, 2012; Isaacman & Roberts, 1995). As a result, the African export economy focused on the production and trade of a few crops in single-buyer markets supplying the colonial powers. The export economy drove the expansion of irrigation and changes to production systems during the colonial period (Figure 2). Enforced by colonial administrations, export production continued to increase despite declining terms of trade (Austin, 2009). The domestic economy and markets declined due to expatriation of the revenue from the export economy; closure of manufacturing industries; discouragement of inter-regional trade; disruption of local food production and livelihoods (Worboys, 1988); and payment in provisions rather than cash for domestic and farm labour on plantations and settler estates. Hence, farmers could not invest in improving the productivity of food production for local needs.

In western Africa and the Sahel, production of export crops was already well established and managed mainly by African producers using endogenous AWM systems (Apoare, 1882). Colonial governments used several strategies to secure industrial inputs: investing in infrastructure to produce and transport export crops, including irrigation schemes, railroads and ports; granting 'company concessions' to European companies and settler estates; securing the labour supply through taxes and corvée labour obligations; and enforcing export-crop production on communal land in collaboration with local

chiefs (Austin, 1984; Bassett, 1988; Bjornlund et al., 2020; Hinds, 1986). These strategies significantly increased the area under export crop production: for example, the acreage under cocoa in Ghana increased by 800–1,000% between 1919 and 1959 (Harwitz, 1964). While some expansion was on new land, the reallocation of land and labour resources from local food to export production also took place.

In eastern and southern Africa, colonization was dominated by the arrival of European settlers, and Africans were often removed from their land. In many locations, colonial governments gave preference to settlers to supply the export market (Bjornlund et al., 2020). But in Uganda and Malawi, settlers were not granted protection, and the economic outcome for individual farmers, whether settler or African, depended on their ability, the commodity market and access to resources (Frankema et al., 2014). Public and private investments in irrigation infrastructure were used to support sugar and cotton production and increase the agricultural area (Appendix 4). Smaller private settler irrigation schemes and estates were typical in southern Africa and played a significant role in crop intensification and the establishment of higher-density settlements in the remote interior (Visser, 2013).

In general, the focus on export crops denied local industries value-adding opportunities. Jobs and skills acquisition arising from industrial technology and manufacturing took place in Europe rather than Africa. The colonial administrations were also wary of local industrial production. This would have made the colonies economically more self-sufficient and created a class of skilled workers, which colonial administrations might not have been able to subdue (Clarence-Smith, 2004). By-products that could have been used to improve farm income and develop the rural economy were also exported, for example oilcakes, which improve livestock fodder and increase the volume and quality of milk and meat. This lack of integration of the agricultural output into value-adding processes contributed to stagnated productivity in African farming systems.

Higher European demand for agricultural raw materials resulted in substantial expansion of the area under agricultural production, with estimates of 136% and 74% increase in cropping land and pasture, respectively, between 1900 and 1960 (Goldewijk et al., 2017), and an increase of 700% in the area equipped for irrigation in SSA (Appendix 5). Early colonial expectations of irrigation were high, and irrigation schemes were proposed in a range of situations, including in Tanganyika near Lake Victoria in 1910 (Haldemann, 1957), and the Scarcies in Sierra Leone in the 1920s (Richards, 1986). However, few dams for irrigation schemes were developed in non-settler regions, as only cotton and sugar production justified the expense (Figure 3). In the early colonial period, additional demand was met through expanding or improving existing AWM systems (Roberts, 1996; Appendix 6). AWM therefore underpinned the colonial production system in western Africa and was supported by colonial governments through small-scale funding under native administration acts. This produced some beneficial outcomes; for example, the Mopti region of Mali was assisted to construct traditional submersible dykes, canals and sluice gates to control the flow of water onto 10,000 ha of rice (Roberts, 1996). Smaller village systems (40–200 ha) in Sokoto Province in Nigeria were further developed to expand the area supplied with water or improve drainage to manage waterlogging and floods. As these were improvements rather than total water control, the villages retained management. The changes improved health and nutrition for the villages during the dry season (Nwa, 2003).

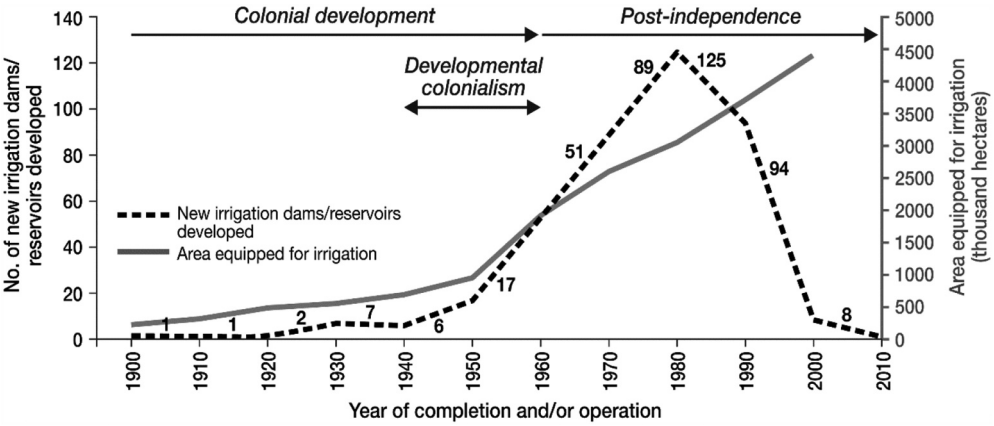

Figure 3. Trends in large dams and reservoirs for irrigation development in sub-Saharan Africa (adapted from FAO, 2016) and estimate of area equipped for irrigation (source: Freydank & Siebert, 2008).

Cotton schemes with European investors and control

Several irrigation schemes were developed to enforce the production of long-staple cotton for European industrial weaving, rather than the short-staple cotton traditionally grown on rainfed land for home spinning or local industries (Figure 1; Appendix 3). Two large, centrally controlled schemes were the most important: the Gezira Scheme in Sudan, and the Office du Niger Scheme in Mali. Detailed information about these schemes follows, as their production model set post-independence government schemes on a path-dependent course. These case studies illustrate how the objectives of the externally funded and controlled schemes were at odds with farmers' livelihood strategies.

The Gezira Scheme

A British cotton syndicate operated the Gezira Scheme from 1898 to 1951 and was backed by the colonial administration, as it increased export revenue. Traditionally, tenant farmers would have received a share of the production. However, the syndicate introduced profit sharing, which farmers could not physically verify; it was open to manipulation, and mistrusted by the farmers (Bernal, 1997). Gaitskell (1959) estimated that traditional crop sharing would have reduced the syndicate's profit by 70%.

Gezira's farmers were subjected to a rigid production system, which dictated crop rotations, inputs and sales (Ertsen, 2006; Robins, 2013). Before colonization, farmers were mainly pastoralists (sheep) but also grew a few crops, such as short-staple cotton and cereal, in a mixed production and labour allocation system. The syndicate introduced a tenant and cropping system, which forced the traditional pastoralists to become croppers and to reallocate most of their labour to cotton production. Cotton was labour-intensive, creating labour shortages for land preparation for subsistence crops (millet and sorghum) and livestock activities. These changes reduced farmers' livelihood options, farm viability and food security (Bernal, 1990; Shaaeldin, 1986). Further, irrigation in the dry climate caused salinization, and the use of canals as night-storage dams caused waterlogging and brought malaria and bilharzia (Keiser et al., 2005). When the scheme was expanded to

460,000 ha in the 1920s, it became necessary to recruit tenants and slaves from other regions, creating resource conflicts and disrupting social cohesion.

The depression of the 1930s revealed the risk of relying on one cash crop in a single-buyer system. Global cotton prices plummeted, and production was simultaneously reduced by a locust plague and bacterial blight. The syndicate ensured that farmers received little of the diminishing profit and refused to change the fixed crop rotation. Hence, farmers' debt increased, and many starved. While farmers with large livestock herds could focus on more profitable activities and pay subcontractors to do their cotton work, others had no alternative and abandoned their land. The syndicate argued that this was because the farmers were lazy and incompetent (Daly, 1991; Voll, 1981), rather than responding rationally to oppressive economic conditions (Gaitskell, 1959). Permanent and seasonal migrants from western Sudan were either subcontractors or took over the abandoned land (Wallach, 1988), creating further social problems (Mollan, 2008).

The Office du Niger Scheme

In West Africa, short-staple cotton was widely grown in rainfed upland areas, intercropped with rice. However, France wanted long-staple cotton. As this cotton variety could not be intercropped with rice, farmers were advised to establish single-crop, long-staple cotton production, leaving soil exposed to erosion. When soil erosion occurred, farmers were instructed to create bunds for soil conservation, requiring labour the communities did not have. Hence, farmers reverted to the short-staple cotton.

The Office du Niger scheme was established on the floodplain, with a system of tenant farmers, so that the production of long-staple cotton could be enforced. A secondary objective was to supply rice to Senegal so farmers there could focus on peanut production for the French oilseed industry (Becker, 1994). A pilot project started in the 1920s, and in 1931 the French government approved funding for the development of 960,000 ha to be managed by a semi-autonomous agency. Farmers were initially voluntarily recruited from villages 10–40 km away. New villages were constructed, and farmers received individual land tenancies. Chiefs and other community leaders directed production, commanded labour, collected taxes and managed social issues.

The scheme was beset by problems from the early stages. The pilot project and the potential expansion plan were unrealistic, and the scheme never had more than 60,000 ha under irrigation. Farmer mortality was high, due to malnutrition caused by changing from a diverse diet (sorghum, millet, cowpeas, peanuts, livestock and fish) to a high-starch, low-protein diet (maize). An oppressive system was enforced: farmers had to be in their fields during certain hours, could not engage in other livelihood activities (e.g. fishing and weaving) and could not sell their harvest to outsiders, even when the prices offered were much higher. Those disobeying might be physically punished or have their rations cut, fishing nets confiscated or woven cloth destroyed (Couture et al., 2002; Van Beusekom, 1989).

Even before the French approved the funding, 30% of the farmers had fled the pilot project. Voluntary settlements ended in 1934, and five villages 150 km away were forcefully resettled at the scheme. Another 15% left when forced labour was abolished in 1946 (Van Beusekom, 1989). While some concessions were made, including raising the price of cotton and distributing free rice and millet (Van Beusekom, 2000), the scheme

never delivered the promised exports. As with Gezira, there was a fundamental conflict between the scheme's objectives of securing the supply of long-staple cotton and farmers' livelihood strategies. Hence, the farmers did not collaborate, and the system failed. This highlights the importance of the motives behind externally controlled irrigation schemes and their influence on livelihoods.

Colonial agricultural advisors' dismissal of endogenous AWM and agricultural practices

The agricultural officers who advised the colonial offices in Britain and France were based in Europe. Generally, they had a poor understanding of agricultural production and water management in SSA and failed to realize how well local farmers understood their environment. They viewed farmers as backward, ignorant, irrational and conservative, as they did not understand the sound and logical reasons for local practices, such as the use of manual labour in humid forest zones where tsetse flies ruled out the use of draught power (Filipovich, 2001; Willis, 1909). When an influenza epidemic in Sierra Leone in 1918 caused a shortage of harvesting labour and therefore of food supplies, the British colonial office concluded this was due to substandard agricultural practices. However, the Indian agronomist subsequently invited to teach rice production found that farmers were innovative and careful seed collectors, and that yields were better than in Madras (Pillai, 1921). A decade later, farmers in southern Sierra Leone again demonstrated their capacity to adapt and improve as they quadrupled their rice production between 1929 and 1934 to compensate for lost kola nut exports (Stockdale, 1936).

Many agricultural officers who had worked on the ground in Africa for many years realized it was essential to build on local and successful AWM experiences. However, it was the colonial advisors' notion of African farmers' need for advanced technologies that influenced decisions (Richards, 1985). This is still reflected in the language used in funding applications.

Acceleration of irrigation planning under developmental colonialism

In eastern Africa, land alienation reduced Africans' ability to produce food. Similarly, in western Africa the pressure for increased production of export crops reduced the land available for food production. Illustrating these pressures, exports to France increased six-fold between 1871 and 1934, and exports to Britain increased eight-fold between 1887 and 1937 (Figure 2). The focus on export production at the expense of local food security resulted in endemic malnutrition in both West and East Africa during the 1920s and 1930s (Robins, 2013; Worboys, 1988). To increase productivity, colonial administrations invested in research, including rice research in Sierra Leone in 1934 (Richards, 1986) and the British campaign in the 1920s to introduce maize into eastern Africa (Forshey, 2008).

By 1940, reports of widespread poverty and hunger in the colonies reached Europe, coinciding with the colonial powers' struggle to maintain support for their empires. To give colonialism political legitimacy and a 'human' face, Britain and France introduced 'developmental colonialism'. In both nations' colonies, investments were made to increase food production, public expenditures per capita to improve health and welfare quadrupled between 1940 and 1955, and aid increased (Chafer, 2002; Cogneau et al.,

2018). But given the perception of AWM held by the agricultural advisors in Europe, investments were made in irrigation schemes rather than improving and expanding AWM.

Investment proposals were evaluated by governmental panels of academic experts in areas such as agriculture, economics and administration. However, they had neither experience in Africa (Hodge, 2007) nor understanding of the biophysical environment and the problems faced by the farmers. This resulted in poor planning and engineering, wasted expenditure, and irrigation projects not achieving the envisaged outcome (Carstairs, 1945). These processes institutionalized the importing of the developed world's expertise and solutions that were unsuitable for the problems of African farmers (Sally & Abernethy, 2002). Developmental colonialism marks the start of public project spending, and substantial increases in investment in dams and new irrigation schemes (Figure 3; Appendix 6). This further consolidated the path-dependent process of irrigation development, which continued after independence. However, no investments were made in supporting farmers by investing in research, demonstration plots, processing facilities and market connections.

The development of three resettlement schemes in Kenya in the 1950s illustrates how poor performance was perpetuated by modelling management on the Gezira scheme. The three schemes (Mwea, Hola and Perkerra) totalling 18,200 ha (Ngigi, 2004; Obara, 1984) were distant from markets and incorporated top-down enforcement of rice monocropping, water control and marketing; small land allocations; disciplinary actions; and the removal of customary owners without compensation (De Wilde, 1967; Veen, 1973). The result was unviable farms, poor performance and absenteeism.

The Scarcies polder rice irrigation scheme in Sierra Leone is a 1940s example of engineering that was unsuited to the local context. The local AWM system in the estuaries relied on tidal surges to push brackish water into the fields during the growing season to limit weed growth. The polders prevented this. As farmers did not have spare labour for weeding, rice growing became unviable, and the scheme failed. Had the engineers sought local knowledge, this could have been avoided (Richards, 1986). In other circumstances, poor planning resulted in significant wasted expense and financial losses. For example, the first refurbishment of the Office du Niger scheme received CFA700 million in 1953, but the redesign failed to address the unviable economic structures, and the scheme lost CFA139 million between 1953 and 1955 (Toussaint et al., 2008).

Post-independence agricultural policies and irrigation developments

This section describes the post-independence policies and unprofessional lending practices which contributed to the poor performance of most government schemes. The first section focuses on the early stages of independence, and the second on post-2000 developments. The discussion provides evidence to support Hypotheses 2a and 2b.

Early stages of independence

Independence for most African colonies came in the 1960s. Many aspects of the colonial legacy continued to influence the performance of agriculture and irrigation developments. Colonial state boundaries were maintained, creating 'artificial' nations where the population

had neither a collective identity nor the aspiration of shared nationhood. The new nations were left to deal with the financial burden of overcoming 80 years of colonialism and a lack of investment. Land, forest and water resources were vested in the state, and land titles only existed in the export sector for settler properties and foreign plantations (Toulmin & Guèye, 2003). For the remaining farmers, there were no formal mechanisms that allowed them to gain ownership of their share of communal land, and therefore no way to transfer their share to another farmer. Without legal title, security for lending for long-term investment to improve agricultural production was not available. The colonial legacy resulted in greater competition and conflict over land and water resources.

Governments were ill-equipped, under-resourced and unprepared to handle the difficult processes of restructuring the dualistic agricultural economy and developing a domestic food production sector with publicly accountable organizations and institutions. Funding was required to establish government services in rural areas, processing and storage, and a transport and distribution system with access to regional African markets (Cox & Niegi, 2010). There was also little food production and demographic data to inform policies (Gardner, 2012). In particular, the legacy of African farmers' ingenuity and ability to adapt AWM practices was dismissed in favour of the Western technologies espoused through European education systems, and hence not factored into agricultural policies. As national budgets remained dependent on a few export crops, revenue was subject to international market fluctuations, making long-term planning difficult.

There were no political leaders or civil servants capable of establishing viable national economies or managing the development of self-reliant, functional and autonomous societies (Bloom et al., 2006). The well-educated elite claimed political control after independence. They had a vested economic interest in the export sector and little incentive to change the dual economy (Bjornlund et al., 2020). They used their position to gain control over large farms and directed government-subsidized inputs to these farms (McCann, 2007). This alienated rural communities, as these farms were created by acquiring and amalgamating land, without compensation, from functional farming communities (Bates, 1981). The elite also had interests in capital-intensive and large-scale infrastructure projects, such as irrigation (Tiffen, 1985). Their businesses benefitted from the supply contracts, such as for cars and accommodation and payments to facilitate contracts, and they used their influence to recommend suppliers. As land and other resources were vested in governments and their allocation controlled by the political elite and chiefs, mining companies and infrastructure developers had a keen interest in pleasing local politicians so that their proposals were accepted. The WB and other lenders, therefore, inadvertently supported nepotism and corruption as part of doing business (Heilbrunn, 2004; Warf, 2017). This further entrenched corruption and increased transaction costs, and still hampers development today.

Despite the official transition to a Western-style democracy, old kinship loyalties remained, and nepotism influenced many African nations more broadly. In rural areas, people voted as instructed by the chief, which helped maintain an elite focused on urban political and economic interests. The consequence was conflicts of interest between the political elite and farmers, dependency on loans, aid and subsidies, and resource conflict and violence between user groups (Boussard et al., 2006).

A political focus on urban rather than rural development

The newly independent countries were mainly focused on urban politics, despite having agrarian economies (Berry, 1984). Urban residents had more political influence because they were more concentrated, more visible and better able to articulate their opinions and dissatisfaction (Sandbrook, 1982). While the political elite benefitted from exporting commodities, they also focused on economic policies that would gain urban political support, reduce the dependence on food imports and save foreign currency. Policies were designed to ensure urban food security and low food prices to reduce the wage pressure on urban businesses and improve living standards for urban consumers (Adam, 1977). This was achieved in two ways. First, securing lower prices by: maintaining an overvalued exchange rate (making imported food cheaper); not protecting local production with tariffs (making local food more expensive); operating government-controlled marketing organizations to mandate the price of staples, often at or below production cost (Bates, 1981); and subsidizing farm inputs for large farms (reducing the cost of production). Second, securing supply by intensifying the production of staple food through consolidating land into large farms, and building large government irrigation schemes to produce staple crops.

These policies were detrimental to farmers and overlooked the economic links and investment opportunities between agriculture and other sectors of the economy. They also undermined the incentive for the private sector to invest in marketing, food processing, storage, agricultural supply chains, transport infrastructure, mechanization, and financial and legal services (Paugam, 2015; Smit, 2016). Such investments could have created non-farm jobs and increased agricultural production, farm income and rural economic development (Eicher & Staatz, 1985), supporting the viability of irrigation schemes. Because of this lack of investment, crops often spoilt in the fields or during post-harvest storage and transport, as they could not reach markets. The shortfall in meeting urban demand was met by imports. Higher urban incomes increased the demand for high-value products such as processed food, meat, vegetables and fruit (Paugam, 2015). With the right policies, economic incentives, infrastructure and market information, this demand could have created opportunities for local farmers and national economies; instead it was met by food imports, putting pressure on the balance of payment (World Bank, 1981).

Lack of investment in rural economic development limited the economic viability of rural communities, causing high rural outmigration and greater population pressure in urban centres. As urban centres grew, demand for cereals (rice, maize and wheat) increased, which sparked local and international interest in investment in large-scale irrigation for cereal production for food sovereignty in the 1960s and 1970s (Figures 3 and 4; Appendices 5 and 6).

Irrigation and the development path for SSA

There have been two broad and simultaneous attempts to increase SSA's food production and agricultural productivity: capital-intensive agronomic practices and irrigation schemes. Neither of these interfered with the land allocated to the commodity export sector, and both favoured Western-influenced modern technology and practices.

Productivity increases were sought by establishing large commercial farms rather than investing in traditional AWM systems. This reflects the view that the technologies and farming practices used by small-scale farmers were the core of the problem (Borlaug,

1970). The US funded research on rice, wheat and maize to increase yield and food production and win the minds and stomachs of the newly independent countries. The research focused on attaining higher yields on large-scale mechanized farms using large amounts of expensive inputs (fertilizer, pesticides and hybrid seeds) and double cropping under perennial irrigation. This capital-intensive package of Western science became synonymous with modern farming and was first introduced in Asia and subsequently into SSA. This approach was not appropriate for SSA's small-scale farmers due to inadequate infrastructure and a lack of market access, supply chains, affordable fertilizer and capital.

From the 1950s to the 1970s, the WB's position was that the public and private sectors should play different roles in economic development – see Hodd (1987) for details about the WB Group and the International Monetary Fund (IMF). To enable the public sector to play its role, the WB provided governments with loans to build public infrastructure to attract the private sector to invest in production, marketing and distribution of agricultural and industrial products. In the 1960s, the WB's investment strategies for creating economic development and supporting national economies were based on a simple model (Zoellick, 2010) with four inter-related steps: Step 1, increasing agricultural productivity and production; Step 2, generating surplus for sale, thereby increasing economic activity in rural areas, and creating jobs, tax revenue, export earnings and an improved trade balance; Step 3, integrating the agricultural sector into the national economy to generate demand for non-agricultural products and support local manufacturing, the service sector and job creation; and Step 4, providing raw materials for industrial production, local consumption and export (Timmer, 1988).

Irrigation was the primary component for increasing productivity in the WB model, and capital was essential for irrigation development (Inocencio et al., 2007). Hence, most WB lending for agricultural projects funded the construction of dams for large-scale irrigation (Jones, 1995; Figures 3 and 4). It soon became apparent that this strategy was unsuccessful in generating the productivity increases necessary for the WB model to work. This might reflect an Indian study from the 1950s, which found that 41% of yield increase was attributed to fertilizer and only 27% to irrigation (FAO, 1981). Despite the WB auditing office's reporting in the mid-1960s that these developments would not be viable, the lending continued. The economic policies of African governments undermined the success of the WB model, as they made farming unprofitable (Kpundeh & Riley, 1992). The WB's willingness to keep funding could be questioned on economic grounds; however, it must be seen in the context of US economic interests in African resources and the Cold War, which created a desire to link developing countries to the Western world. This led to unprofessional lending practices without accountability (Stiglitz, 2004), including rent seeking, corruption, and the funding of projects that Horowitz and Salem-Murdock (1993) described as Cadillac projects with a 2CV engine. From 1950 to 1993 the WB financed close to 400 dams and irrigation schemes in Africa totalling 3.7 billion constant US dollars (Jones, 1995; Figure 3). These developments consolidated the path-dependent course from colonial times and perpetuated Africa's problems.

Development costs were a contributing factor to the debt burden created by irrigation schemes in SSA (Inocencio et al., 2007). The average cost of new irrigation projects in SSA in the 1980s was US$14,500/ha versus US$6,600/ha in South-East Asia. In the remote Turkana region in Kenya, costs were as high as US$63,000/ha (Rosegrant & Perez, 1997),

providing an extreme example of the cost of politically motivated developments. For rehabilitation, the average cost was US$8,200/ha in SSA compared to US$2,300/ha in South-East Asia. The higher costs were due to lower economies of scale, with large SSA schemes smaller by a factor of three; greater distance to ports; few navigable rivers; and lack of transport infrastructure and services. Hence, irrigation budgets included the construction of access roads, housing for staff, electric grids and public services. While Inocencio et al. (2007) argue that the cost in SSA was not statistically higher than in South-East Asia – after adjusting for these factors and excluding the schemes with the most corruption – the high cost has influenced the economic future of SSA countries. Importantly, the need for many of these investments can be directly linked to the colonial legacy of providing infrastructure for export crops rather than local distribution. As most materials and services for establishing irrigation schemes were imported, rent seeking and corruption have further increased the development cost.

Not until the 1980s, after many SSA countries defaulted on payments, did funding start to dry up. A consensus emerged among irrigation professionals that irrigation schemes were not simply a matter of concrete and water, and most solutions were associated with governance (Kpundeh & Riley, 1992). The WB therefore started to focus on small-scale irrigation schemes and implementing water user associations in existing schemes (World Bank, 1988). This might have improved conditions in some schemes but did not address the lack of market integration. Jones (1995) argues that the rationale was that small could not go as wrong as large. Further, some argued that the participatory element was mainly to transfer the cost of maintenance to farmers (You et al., 2011). Consequently, neither large nor small government schemes kick-started Step 1 of the WB model. In combination with the lack of rural economic development, Steps 2 through 4 did not eventuate (Dorward et al., 2004). Large debts are an additional legacy, which were partly caused by US lending and monetary policies (Bjornlund et al., 2020) but also partly by domestic policies (Greene & Khan, 1990). These debts eventually sent the young nations into bankruptcy and have burdened future generations of Africans with the repayment of unproductive loans.

Farmers' livelihood strategies at odds with the objectives and characteristics of large government schemes

Large government schemes were developed, particularly in the semi-dry Sahelian zone in Sudan, where dry conditions and access to the Nile favoured cotton production, but also in Mali and northern Nigeria (Adams, 1985; Adams & Carter, 1987) (Appendix 6). The objective of most schemes established after independence was to address social and political issues caused by the earlier focus on the export economy and the neglect of the domestic economy.

These schemes were capital-intensive. They were typically larger than 3000 ha and comprised storage, diversion, conveyance and distribution works, plus embankments for flood protection where required (Underhill, 1990). Their governance and production arrangements usually followed the Gezira model, with fixed irrigation schedules and infrastructure; external management by government officers without local knowledge or trusted credentials and accountable to a government agency rather than to the farmers (Zwarteveen, 2008); prescribed production of staple crops that were subject to price control; and land and labour allocated to a single crop. These characteristics made it difficult for

farmers to make a profit, and inter-scheme conflicts arose as trust was not established. As a result, farmers' traditional diverse livelihood strategies were at odds with these characteristics, and they were reluctant to pay fees and participate in scheme maintenance.

Drijver and Marchand (1986) considered the economic scenario for farmers under AWM compared to allocating all their labour to rice production on the Office du Niger scheme (Table 2). They found that farmers were better off with the traditional diversity of income and food sources. While rice-only farming produced eight times as many calories and 50% more protein than AWM, the produce from AWM was more varied in nutritional and economic value. The potentially higher profit margin (4%) from growing rice alone was insufficient to buy the forgone nutrition and other non-farm benefits. The associated risk was high and borne by the farmers. When the canals on the Office du Niger were functional, farmers could be coerced to focus on rice production, but they would not maintain the canals; the scheme became underutilized, and a cycle of rehabilitation-decay-rehabilitation commenced (FAO, 2016).

A scheme's location often influenced the viability for farmers, and many were on floodplains and distant from urban markets. This, combined with poorly developed infrastructure, made market access difficult and costly. Lack of milling and storage facilities prevented farmers from receiving optimal prices for rice, and cheap food imports into urban markets depressed prices (Adams & Grove, 1984).

Irrigation supplied from a dam offers the opportunity for two cereal crops, but farmers would only utilize this option if it provided the best economic outcome. Most farmers in the Sahel had mixed livelihood activities, including livestock, and transplanting dry-season rice conflicted with taking livestock to distant pastures. As the potential income from livestock was greater than a second rice crop, very little double cropping happened. Hence, the feature of irrigation that made it superior to AWM was not viable for farmers without simultaneous investment in processing and intensification of livestock production (H. Bjornlund et al., 2017).

Resettlement schemes were implemented in the 1960s, for example Mbarali, Madibira and Dakawa in Tanzania. These schemes had large diversion infrastructure and lined main canals, with the objective of providing rice for the urban market. They were managed by state agencies, with farmers as paid labourers, and depended on government support.

Table 2. Comparison of traditional agricultural water management in the Niger Inner Delta and the Office de Niger Scheme, 1978 (adapted from Drijver & Marchand, 1986).

	Inner Niger Delta					Office de Niger	
	Meat	Milk	Fish	Rice[a]	Total	Rice[a]	Total
Total weigh (t)[a]	10,372	118,454	100,000	78,400	–	100,000	–
Weight (g/100 m^3 water)	44	506	427	235	–	5003	–
Value (Malian francs per 100 m^3)	18	202	171	23	414	550	550
Protein yield (g)	8	17	77	18	119	190	190
Energy yield (Kcal)	83	318	401	853	1656	13,749	13,749
Cost of Input for 100 m^3 (Malian francs):							
Fertilizer (50 kg/ha)	0	0	Very little	0	–	11	Risk for farmers
Management	0		Very little	–	–		120
Services	0	0	Very little	Very little	–	84	
Oxen, ploughs	–	0	–	Very little	–	25	
Profit margin per 100 m^3 (Malian francs) = value – input:					414		430

[a]The total weight of rice is based on 1978 averages of 1.4 and 2 t/ha for the Inner Niger Delta and Office de Niger schemes, respectively.

This support ceased in the 1990s, and the schemes collapsed (Kadigi et al., 2012). Some schemes were privatized, while others were given to the farmers, assigning them management and economic responsibility (Stirzaker & Pittock, 2014). As the farmers had often been resettled from very different areas, several issues arose; they either lacked irrigation experience and knowledge of local soils or failed to develop the trust and cooperation required for collaboration.

Economic issues for farmers in small schemes

Two types of small government schemes were developed: expanded and upgraded existing AWM systems; and new schemes with social objectives such as resettlement and subsistence food production. The latter were on newly cleared land, often with poor soils and in remote locations (Harrison, 2018). Most of these schemes struggled, as viability in irrigation schemes with a subsistence orientation but no subsidies is an oxymoron; farmers could not pay irrigation fees or buy inputs if they ate what they produced. These costs and household expenses – school fees, transport and other essentials – required cash.

A range of factors in small schemes influenced farmers' economic outcomes. While small government schemes had different governance structures, water schedules were often determined by a government agency and inflexible. In some countries, including Mozambique and Zimbabwe, the production of staples (mainly maize) for food security was mandatory. However, the low market value of these staples made irrigation unviable (H. Bjornlund et al., 2017). Where farmers had more cropping choices, they could produce a mix of vegetables. But they then needed to navigate demand and transport their produce to market to realize an economic return. In many cases, farmers produced the crops they were most familiar with, leading either to low prices for crops that stored well (e.g. cabbages) or oversupply and spoilage of more perishable crops (e.g. tomatoes). While Dtmzthe (1997) finds that small schemes less than 5 km from a market have better sales opportunities, local markets can only absorb limited volumes of a commodity before prices fall and production becomes unviable. Commercial production and participation in domestic and regional markets were not part of governments' vision, and extension officers were not trained in economic and market analysis, so they could not help farmers identify viable enterprises based on urban demand for high-value crops or value-added products (Vorley, 2013).

The policy-driven objectives of the schemes meant the focus was on irrigated crops as the final product, rather than a more holistic approach to support farmers' economic opportunities, for example, growing fodder to improve livestock production and quality. Small plots and the lack of market and processing opportunities made it impossible for farmers to make a living from irrigated crops. Hence, they supplemented irrigated farming with other activities, including rainfed cropping, livestock and off-farm work. This often resulted in sub-optimal resource allocations from an irrigation productivity perspective (H. Bjornlund et al., 2019). As off-farm work opportunities were limited due to lack of rural economic development, men often worked far from the farm, leaving women and children to manage production. As small-scale irrigation schemes did not meet farmers' economic needs, the schemes deteriorated and became underutilized.

Detrimental impacts of resource allocation and irrigation schemes

As a result of poor hydrological understanding, the construction and management of large dams have had adverse economic impacts on downstream farmers. For example, the Manantali Dam (Mali), was constructed in the 1980s for hydropower and to irrigate 50,000 ha. However, it dried up 320,000 ha of flood-recession farming, depriving 100,000 farmers of their land and livelihoods. Environmental impacts were also created downstream; groundwater resources and riverine forests were damaged, and an area with a low incidence of water-borne disease became one of the worst-infected in Africa (Horowitz & Salem-Murdock, 1993). This project, like many others, not only failed to provide the promised benefits but also contributed to persistent rural poverty.

In Tanzania, the Great Ruaha River was over-allocated. Since the filling of the Mtera Dam in 1994 and the opening of the Kapunga scheme, the river has dried out seasonally (Mdemu & Francis, 2013; Walsh, 2012). Over-allocation is a politically expedient way to reduce tension, as it avoids having to limit access to resources, and project proposals attract funding and political support (Allan, 2006). Over-allocation creates supply insecurity for downstream users, who have no ability to challenge the decision (Molle & Wester, 2009); for example, over-allocation in the Chad Basin resulted in lake recession and the out-migration of millions of people (Office of the Auditor-General for the Federation, Nigeria, 2015; Okpara et al., 2015).

Irrigation development since 2000: is a new paradigm emerging?

Since 2000, WB reports have started to show support for good governance, market integration and improved financial return as essential elements of irrigation projects (Waalewijn et al., 2020). This section discusses the successful Fadama project, which has embraced a systems view and illustrates a paradigm transition in irrigation development; this is a paradigm that requires wider universal acceptance.

The Fadama project, funded by the Nigerian government and the WB, was implemented on fadama land with traditional flood recession AWM and diverse livelihood strategies such as cropping, herding, fishing and harvesting of materials (see Appendix 1 for definition of fadama land). From Fadama I to III the project transitioned from the old to a new paradigm to better meet community needs. Fadama I (1993–99) used the traditional top-down approach, focusing on increasing rice productivity and investing in irrigation infrastructure, tube wells and pumps (Nkonya et al., 2012; Takeshima & Yamauchi, 2012). Crop production increased, but the neglect of post-harvest issues reduced crop prices and increased storage losses, and the exclusion of other resource users created conflicts between croppers, herders and fishers (Babatunde et al., 2008).

These lessons were incorporated into Fadama II (2004–2010), which shifted to a community-driven development approach supporting activities other than agriculture. Following significant progress in the first three years, Fadama III was expanded to all 37 states in Nigeria with fadama land (World Bank, 2007). The project supported user groups, whose members had a common economic interest. The target was to increase real income by 20%. Fadama III utilized a private–public funding model, where the farmers and the project contributed 30% and 70%, respectively, to cover the cost of productive assets such as processing, fishing and irrigation equipment, and buildings (World Bank, 2003). These assets were managed by the user groups to facilitate sharing and revenue

raising; for example, boreholes for watering cattle were shared according to herd size, and processing equipment was hired out in addition to serving user group members' needs.

The project adopted a targeted approach to select participants based on gender, disability, age and specific economic interest groups with different livelihood activities. The average income for participating families increased by 59%. Even for non-participants within the community the increase was 41%, as they also benefitted from improved road and irrigation infrastructure, off-farm work opportunities, access to services, and other public facilities. Non-farm activities contributed the second-largest share of household income for all participants, and farm incomes in neighbouring areas increased by 15% (Nkonya et al., 2012). Therefore, the Fadama III approach supported local economic development through flow-on effects and showed that significant outcomes can be achieved by incorporating all affected resource users and encouraging collaboration between groups with common interests.

The approach of the Fadama project might indicate that a paradigm shift is taking place to integrate irrigation into rural economic development, and that the livelihood strategies of farmers and communities are being considered when designing and implementing new developments. However, while there is evidence of this new paradigm in the Fadama project and in new WB project design (see Ministry of Agriculture, 2010, and African Development Bank, 2018, for projects in Mozambique and Mali), there is limited evidence of similar changes on the ground in projects other than Fadama. The reality is that many governments still focus on large irrigation schemes, and many donors are still willing to fund them. It might still take a long time to learn the lessons of the past.

Non-government development of irrigation

Farmers using AWM methods outside government schemes is one form of non-government development. Whether AWM uses traditional technology or small pumps, it has more recently been described as farmer-led AWM (Beekman et al., 2014). Figures on the extent of this vary widely. For example, FAO (2016) reports 625,000 ha of flood-recession farming in Nigeria, but the size of the commercial rice harvest from the same period suggests that the figure should be 1.5 million ha (Ugalahi et al., 2016). While the FAO (2016) reports that no farmer-led AWM exists in Mozambique, Beekman et al. (2014) report that at least 118,000 ha exists and add that underreporting is common for SSA. Reflecting this, Wiggins and Lankford (2019) argue that most of FAO's estimated 2 million ha (56%) increase in irrigated area in SSA from the 1990s to 2016 was farmer-led AWM. Farmer-led development reflects increased access to cheap technology; small Chinese pumps can be bought for around US$250 and, combined with flexible piping, enable farmers to use water year-round (Scoones et al., 2019).

Discrepancies in the area under AWM raise concern over the estimated potential for irrigation development in SSA, as the land included in the estimated potential may already be cultivated under AWM. Estimates of area vary widely and are difficult to reconcile. You et al. (2011) estimate the potential at 1.3 million ha for large-scale and 6.6 million ha for small-scale irrigation schemes, making a total of 7.9 million ha. Xie et al. (2014) estimate the potential as 30 million ha for motor pumps, 24 million ha for treadle pumps, 22 million ha for small reservoirs and 20 million ha for communal river diversions, for a total of 96 million ha. Figure 4 shows that post-independence irrigation schemes are in areas suitable for AWM production, suggesting that new irrigation schemes, unless

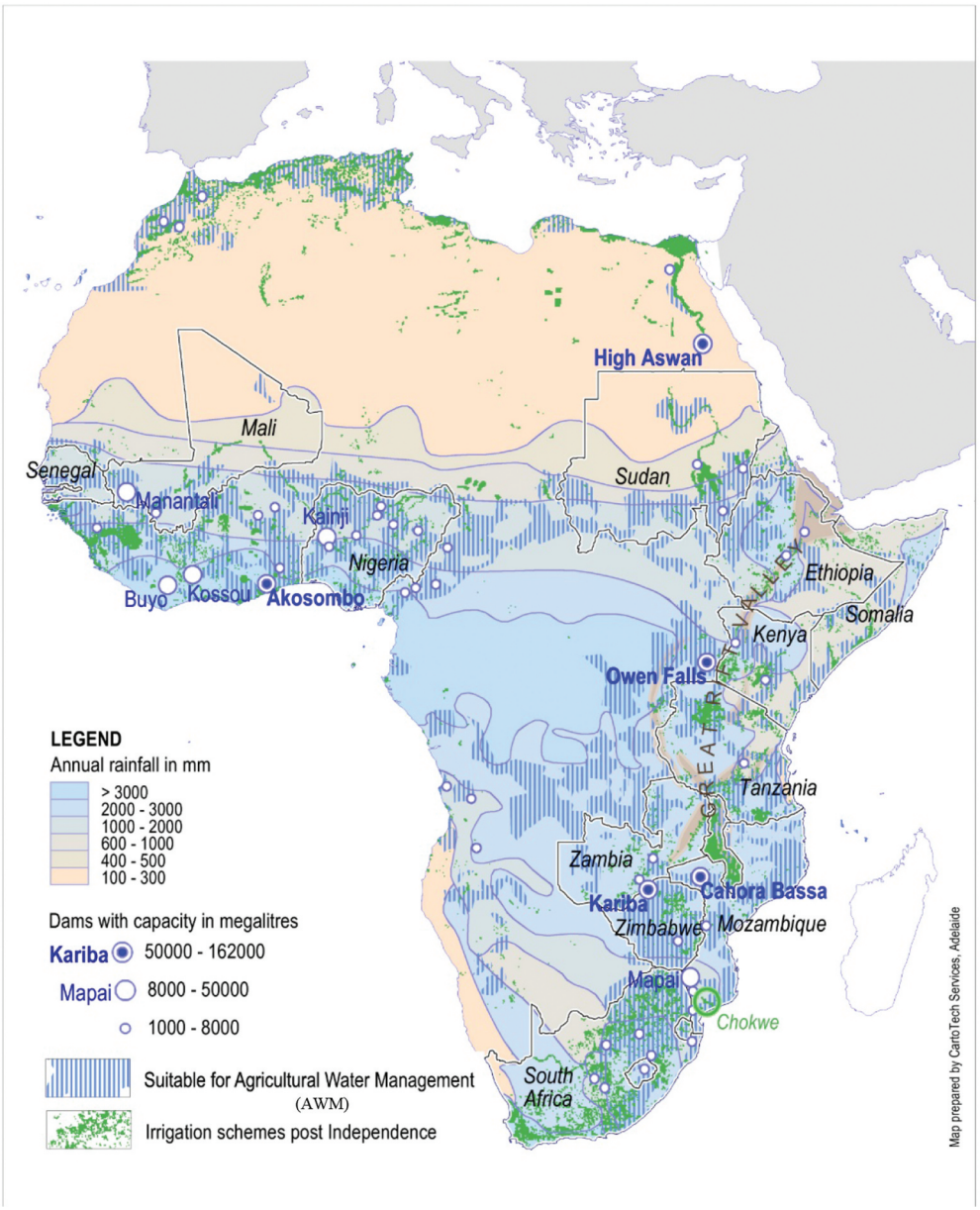

Figure 4. Post-independence major dams and irrigation schemes and area suitable for agricultural water management (map compiled by the authors from Appendix 6 and You et al. (2011)).

groundwater-fed, might encroach on existing AWM systems. This may not be beneficial for existing AWM farmers as they have uncertain property rights and may be at risk of being displaced.

There is emerging evidence that farmer-led AWM and individual small-scale irrigation provide economic opportunities for small-scale farmers. De Bont et al. (2019) document for Mozambique and Tanzania that farmer-led systems are commercial, with crops grown for the market using improved seeds, fertilizers and hired labour. Owusu (2016) found that

farmers in Ghana using small-scale motor pumps to irrigate can generate two to three times higher returns on family labour, which could be increased with better access to inputs. This suggests that flexible micro-credit to overcome liquidity constraints associated with investments, operation and maintenance of pumps would increase productivity and economic returns to farmers. It seems reasonable to suggest that farmer-led and individual small-scale irrigation represent investment and development opportunities in viable production systems. The outcomes of the Fadama project also suggest that public–private partnerships to support farmer-led AWM can produce positive economic outcomes. Hence, farmer-led AWM and private irrigators might provide viable alternatives to government schemes (World Bank, 2018).

However, African governments have maintained political control over resources without legalized acknowledgement of customary rights (different arrangements and issues exist for land and water, but this is outside the scope of this article). These rights have been widely respected by governments and within communities; however, where governments have an interest in the land, AWM farmers have lost their land and livelihood without compensation, which does not encourage investment in irrigation (Boussard et al., 2006). In other cases, those involved with farmer-led AWM have been neglected or even criminalized, despite AWM being practised prior to colonialism (Ulvila, 1995); for example, in the Uluguru Mountains in Tanzania, attempts were made to evict the farmers (Kusiluka et al., 2011; Lopa et al., 2012; Mussa & Mwakaje, 2013).

While there appear to be opportunities to use public–private partnerships to develop farmer-led AWM, some partnerships could represent risks for local farmers and local development, particularly where the partnerships are between resource-rich farmers or companies (often from another country) and national governments, which have also been referred to as land grabs (Friis & Reenberg, 2010). While these arrangements might increase production, they might also marginalize local farmers and communities, and transfer benefits out of the community.

Exploring the hypotheses

The following discussion is organized to explore four hypotheses: that the current poor performance of government schemes is rooted in (1) the production and trading systems introduced during colonialism and (2) post-independence developments of (a) political systems and policies, (b) technologies and agricultural practices, and (c) global lending practices and trading systems.

Hypothesis 1: production and trading systems introduced during colonialism

During the colonial period, changes were progressively made to focus production systems on export crops at the expense of domestic production, markets and rural economic development. This undermined Africa's ability to invest in industries such as food processing, and technologies to improve rural job availability and intensify production. Aspects of the production system that still influence the performance of government schemes include:

- Prioritization of a small range of export commodities, leaving farmers exposed to volatile markets;
- Consolidation of trade in export crops into a single-buyer system – this made farmers price takers, expatriated economic benefits, and left little for African economic development;
- Separation of the lucrative European-controlled import-export market from the less commercially valuable African-supplied domestic market;
- Focus of investment in agricultural research and transport infrastructure for export crops, increasing dependence on imports at the expense of infrastructure for domestic and regional trade, improved varieties of local crops, and local production of farm inputs;
- Discouragement or prohibition of local manufacturing, regional trade and processing industries, restricting rural development and increasing dependence on imports;
- Provision of Western-influenced agricultural technology and extension to support production, rather than building on local farming practices;
- Development of capital-intensive irrigation schemes with a cost structure unsuitable for farming conditions in SSA; and
- Introduction of a top-down production system characterized by central management; fixed and rigid cropping and water supply schedules; settlements of people from different cultures and communities with or without farming experience; and no mechanisms to resolve conflict between users.

The objectives of colonial production were at odds with the livelihood strategies of African famers and meant that irrigation schemes neither benefited farmers nor supported the development of strong and diverse local economies. This resulted in impoverishment, malnutrition, poor health, and social problems due to forced labour and long-term migration.

Hypothesis 2a: political systems and policies

At the time of independence, the urban elite took control of the political and administrative systems. Many had adopted Western values and norms, and their interests were aligned with colonial administrations. Their Western orientation influenced the policies that were implemented after independence and contributed to the poor performance of government schemes. While policies varied across SSA, the objectives were much the same:

- Fostering food sovereignty to limit imports and save foreign currency by consolidating land into larger units and developing large-scale government schemes for cereal production;
- Supplying cheap food for urban areas to secure votes and to keep wages low by controlling food prices, allowing cheap imports of food, and subsidizing farm inputs and finance for large farms;

- Providing food security in rural areas by allocating small parcels of land to rural households for subsistence farming and developing small-scale government schemes;
- Vesting land in the state with allocation controlled by governments and implemented by the chiefs in rural areas, which encouraged nepotism and corruption when allocating land; slowed the process of change as the farming population voted as instructed by the chief; consolidated land into large units allocated to the urban and rural elite; and created non-transferable use rights for small farmers – this made it difficult for farmers to borrow money, for good farmers to expand, for young farmers and entrepreneurs to start farming, and for others to exit (Bjornlund, 2009); and
- Developing government schemes for social and political objectives, but without securing their economic integration and financial viability – this resulted in land underutilization, and in mistrust which impeded efficient management.

The urban policy focus contributed to a lack of development of transport infrastructure and created a disincentive for private investment in supply channels, processing and distribution networks. Consequently, small-scale farmers' viability suffered. Farm households therefore maintained diverse income streams, allocating their labour and financial resources between multiple activities to maximize total household income rather than prioritizing the productivity of irrigated land and water resources. Hence, both large and small-scale government schemes performed poorly and were underutilized.

Hypothesis 2b: inappropriate technologies and agricultural practices

Several aspects of the technologies and agricultural practices used within government schemes have influenced their poor performance:

- Western agricultural production systems were viewed as modern and more appropriate. This led to the continued transfer of increasingly costly technologies, leaving farmers in government schemes dependent on large quantities of expensive inputs.
- Inadequate hydrological and topographical knowledge of watersheds and floodplains produced inappropriate scheme designs. Large government schemes resulted in villages and farmlands being flooded upstream; hundreds of thousands of farmers, herders and fishers downstream being deprived of the annual floodwater regimes; and environmental impacts (salinization, waterlogging, and waterborne diseases) that reduced productivity.
- The opportunity offered by irrigation to apply water for two annual crops was often in conflict with farmers' other, more lucrative livelihood activities and was not always utilized.

The cost of the technology and the added social complication of managing water supply and maintaining infrastructure must be justified by increased prosperity. Under the conditions discussed under hypotheses 2a and 2b, this did not happen. Farmers could not afford to engage in high-input, capital-intensive farming practices, and the benefits never matched the construction, operation and management costs of the schemes.

Hypothesis 2c: inappropriate lending practices and global trade policies

This section is based on the detailed evidence provided in Bjornlund et al. (2020). Here we only provide key references to substantiate the hypothesis.

The WB and IMF were introduced as apolitical efforts to (re)build the world economy through infrastructure development. Loans initially had long grace periods, fixed exchange rates, and below-commercial interest rates to protect young economies (Stiglitz, 2004).

During the 1960s and 1970s, global agricultural commodity prices declined, and it became clear that the debt levels of African countries were unsustainable. Despite the WB auditing department's finding that half the audited rural developments in Africa failed over the 1965–86 period, the WB continued to approve loans for these developments – that is, without implementing its own recommendations (Toussaint et al., 2008; World Bank, 1965, 1988). During the financial crisis of the 1970s and 1980s, the IMF promoted fluctuating exchange rates and higher interest rates (Stiglitz, 2004) without safeguarding developing countries.

A combination of sharply falling commodity prices after 1980, a rising US dollar, and soaring interest rates meant that 52 African countries went bankrupt in the 1980s (Stiglitz, 2004). Refinancing was subject to the IMF's structural adjustment policies, which demanded that governments stop spending on agricultural projects, social welfare, education, health care and industry, and that they introduce deregulation, privatization and trade liberalization.

As a result, agricultural research was privatized, strengthening the influence of Western science and focusing on crops of economic interest to commercial farmers, rather than responding to Africa's food needs and building on past local successes. These changes weakened the state, and debt drained SSA's countries of the funds necessary for infrastructure investment. The structural adjustment policies effectively prevented governments from implementing policies protecting the agricultural sector and promoting rural economic development.

Under the WTO's free trade policies, SSA countries were prevented from protecting local production from competition. In contrast, the developing world continued to support its farmers, to the extent that African farmers lost their competitive advantage of being the most cost-efficient producers – for example, Benin produced cotton at less than half the cost of US farmers (International Cotton Advisory Committee, 2001). Cotton subsidies in the 2002 US Farm Bill guaranteed US farmers a minimum price of US$0.71 per pound, keeping US production artificially high and distorting cotton prices (Woodward, 2007).

Conclusion

This article argues that the poor performance of many government schemes in SSA is caused by a complex set of factors associated with the production and market systems introduced for export crops and subsequently institutionalized during the colonial period. The focus on commercial export crops ignored existing local expertise, food requirements and markets. The systems introduced by outsiders diverted resources from the locally relevant production systems, which had evolved to meet local needs and to be responsive to opportunities and risk. Decision making was centralized in the colonial systems, and

outside the producers' sphere of influence. The export-oriented production system set post-independence developments on a path-dependent course. The impact of this was compounded by post-independence policies and institutions, which failed to integrate government irrigation schemes into agricultural production and processing industries for domestic and regional markets. Hence, these schemes did not become drivers of wider rural economic development.

These developments have resulted in a lack of institutional flexibility and political will to adapt to evolving external and internal political and economic forces. In this context, farming in government schemes was not profitable for many farmers, and they were therefore unable and/or unwilling to pay for and participate in maintaining the schemes. Hence, the schemes have remained underutilized and have performed poorly, regardless of investment in refurbishment. These findings form the basis for four critical recommendations for donors, policy makers, project designers and other stakeholders involved in developing new irrigation schemes or rejuvenating old ones.

First, irrigation technologies must be designed by Africans for the specific socio-economic and biophysical conditions, and for the benefit, of Africa. Hence, they must be cost-effective and be developed or introduced through participatory processes and the engagement of African farmers. New technologies must be designed for African conditions and not promote expensive inputs the rural economy cannot adopt. This requires the involvement of locally engaged scientists and engineers with an understanding of, and respect for, African production methods and farming conditions. Scientists from developed countries engaging in this process should be embedded in Africa for extended periods to understand the conditions under which their technologies will be used. The articles in this special issue analyze the impact of the use of cost-effective and simple-to-use soil and moisture monitoring tools. They show that improved water management can increase the productivity of existing flood or furrow irrigation systems. However, new innovations are likely to be needed to initiate further improvements, for example, the development of cost-effective technologies for flexible water supply and precision delivery of water along the furrow or the field.

Second, the wider institutional arrangements must be designed so that schemes can evolve in response to changing market conditions, enabling farmers to be profitable and pay the operational cost of irrigation while managing risk. This includes governance structures that allow farmers to react and adapt to the signals of the value chain. Infrastructure is required that can store, process and transport high-quality products to markets in a timely manner. Farmers also need access to better agricultural and livestock advice, inputs, equipment and finance. This requires policies designed to incentivize rural economic development; for example, supermarket chains must source an increasing percentage of locally produced and processed food.

Third, a paradigm shift is required among African politicians, agricultural professionals and other stakeholders associated with farming and government schemes. Farmers must be recognized as capable producers with rational farming practices and be engaged as equal partners in the design and implementation of irrigation schemes and associated processes.

Fourth, lending and trade policies must promote rural economic development, leading to prosperous living conditions for Africans. If this had been the case during the boom in irrigation developments, fewer African nations might have failed. Developing countries

must be allowed to use policies to protect their agricultural sector, as does the developed world. And the EU and US should not undermine local production by dumping excess agricultural produce in SSA.

An encouraging recent realization is that farmer-led AWM production systems and individual private irrigators have been viable despite government policies. These systems have proven resilient as they are rooted in long-standing traditions and a deep understanding of local context. Individual farmers can make quick choices as they are not restrained by external institutions such as inflexible water management arrangements, cropping restrictions at odds with market signals, and rigid supply systems. That these systems can be viable with their own institutions corresponds with Ostrom's description of the collective management of common pool resources. The question is, how can these experiences be integrated into new and existing government schemes to improve productivity? Although there is extensive documentation on how government schemes are managed, there is scant evidence of the social dynamics in informal and farmer-led systems and how they operate in SSA. This is a critical area for future research.

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Appendix 1. Endogenous African agricultural water management systems supplying local markets and trade

This section draws on Underhill (1984) to demonstrate that agricultural water management (AWM) systems were complex and adapted by communities to the local biophysical environments. AWM practices and outputs were part of integrated livelihood strategies consisting of cropping, livestock and non-farming activities, such as fishing, hunting and cottage industries. Importantly, AWM production also supplied local markets and long-distance trade. AWM systems were spread widely across SSA (Figure 2), covering diverse landscapes such as floodplains, coastal areas and highlands (see Appendix 2 for a comprehensive list).

Floodplains (flood recession)

AWM systems on floodplains encompassed the management of rising and receding floods to extend the area and duration of water inundation and increase agricultural production. This included management of shallow and deep floods in wetland areas. Where required, weirs diverted water via canals to more distant fields, extending the areas that could be planted. As floods receded, overland flow was restricted to ditches or retained by bunds to promote infiltration. These areas could then be utilized for continued production as floods receded (*fadama*/*dambo* or seep-zone systems). The use of bunds also enabled the recharge of groundwater, facilitating supplementary irrigation with lifting devices. Water trapped in depressions created areas with shallow seasonal waterlogging called *bas-fonds* (Turner, 1986). AWM practices also integrated the management of surface and groundwater to simultaneously provide both drainage and supplementary water. For example, in the small valley swamps of Rwanda and Burundi raised beds were used to manage drainage, while sub-irrigation and splash irrigation provided supplementary water (Hekstra, 1983; Sirven et al., 1974).

The livelihoods of millions of people and their livestock benefitted from the annual or biannual flood regimes. Based on generations of experience, farmers selected crop varieties according to the depth, extent and duration of the anticipated flood. In western Africa, farmers managed their crops to secure yields across variable seasonal conditions, employing a complex polyvarietal intercropping system that used nitrogen-fixing legumes to add fertility and enhance yields on poor soils. The requirements and tolerances of different crops and varieties were well understood (Richards, 1986).

Rice was the main crop because of its tolerance to prolonged inundation. Production risk was managed by mixing rice with crops that could tolerate prolonged flooding but performed better with shorter flooding, e.g. red-seeded sorghum (Adams, 1986).

In wetland areas often considered unproductive by Western scientists, communities used a range of shallow and deep-water farming systems. Farmers planted floating rice in areas with seasonally deep floods, such as the inland Niger and coastal river deltas (Linares, 1981). In areas with seasonally shallow floods, crops were planted on raised beds to drain excess surface water, for example in the Cuvette Centrale in the Republic of Congo and the Bangweulu Wetlands in Zambia (Comptour et al., 2018).

Coastal areas (tidal and estuary waters)

In coastal areas, farmers adapted their AWM practices to optimize production for low- and high-rainfall regions (Bos et al., 2006) (Figure 2). Salt-tolerant rice was grown in tidal deltas and mangroves, where seawater was held back by high volumes of freshwater and salt could be leached out of the soil. In West Africa, this practice straddled the Sahel low-rainfall region (e.g. Senegal and Gambia) and the high-rainfall regions (Sierra Leone, Guinea, Liberia and Nigeria). In the low-rainfall region, saltwater could reach up to 70 km inland (Linares, 1981, 2002; Marzouk-Schmitz, 1984). Here, dykes and drainage ditches were constructed to protect the fields from saltwater intrusion and to control the timing, depth and duration of the freshwater floods. Canals directed rainwater runoff to flush the salt out of the soil, and bunds controlled tidal flooding (Agyen-Sampong, 1991; Bos et al., 2006; Davidson, 2015). In the high-rainfall regions, soil was naturally flushed during the growing season and rainfall prevented saltwater intrusion (Adefurin & Zwart, 2016). Mangrove rice growing in eastern Africa, extended up to 50 km inland, as in the river deltas in Mozambique, the Rufiji and Ruvuma River deltas in Tanzania the Tana and Sabaki River deltas in Kenya and the Jubba and Shebelle River deltas in Somalia (Spalding et al., 1997).

Hill furrow and flood diversion in the highlands

Highland areas offered significant AWM opportunities, such as on the Jos Plateau, Nigeria, and the Great Rift Valley encampments (Figure 1). In these fertile and densely populated areas, hill furrow systems enabled a high degree of water management, using terraces, water transfer and control structures. Other systems were used in the steep mountain catchments, where large volumes of water were discharged over a few hours (flood diversion/spate) and recession flows only lasted a few days. For example, weirs were used in the narrow foothill strip between the Ethiopian Highland and the Red Sea to divert floodwaters into bunded field basins (Food and Agriculture Organization & United Nations Development Programme, 1987). These areas were therefore also densely populated.

Appendix 2. Examples of agricultural water management endogenous to sub-Saharan Africa.

	Bioregions, location	Characteristics	Crop grown	Reference
1. Traditional agricultural water management				
1.1 Floodplains				
Rising floods				
Deep floods	Niger River inland delta Sokoto in Nigeria	Planted as the water rises; rice grows in several metres of water and is harvested from boats	Floating rice	Linares (1981)
Shallow water and raised beds and mounds	Seasonal or permanent flooded areas	Sub-irrigation and splash irrigation	Rice and taro	Rwanda and Burundi (Hekstra, 1983; Sirven et al., 1974) Cuvette Province in the Congo Basin, Bangweulu Basin in Zambia (McKey et al., 2014)
Rising water	Inland swamps	Planted ahead of flooding; transplanted when water is 5–10 cm deep		West Africa (Andriesse & Fresco, 1991)
Receding flood				
Dambo/fadama	Floodplains	Various way of slowing down the receding water: bunds, blocked drainage and more	Sorghum, pearl millet, finger millet, fonio, cowpea, tubers	Fadama (Senegal River, Inland Niger Delta, Lake Chad) In West Africa (Adams, 1986; Caillié, 1830) Dambo in Eastern Africa (Turner, 1986; Roberts, 1988) Omo River, Ethiopia (Bassi, 2011) Tana River Kenya, Kilombero and Rufiji River (Beez, 2005; Gilbert, 2016)
Lifting groundwater or river water	Shallow water tables, riverbanks	Extracted by calabash robe buckets or shadoofs through shallows wells 2–3 m deep	Mixed crops	Northern Nigeria (Adams, 1986; Turner, 1984) Volta Delta in Ghana (Chisholm & Grove, 1985) Zambia, Tanzania, Malawi and Zimbabwe (Bullock, 1992)
		Animal-drawn waterwheels	Mixed crops	Sudan (Shaw, 1966)
Water trapped in depressions: *bas-fonds*	Depressions with water trapped	Often labour-intensive (or worked with animals) because of heavy soils and weeds	Millets	West Africa (Mackel, 1973; Turner, 1986; Raunet, 1985)
1.2 Hill furrows				
	Greater Rift Valley and encampment	River diversion and furrows, bunds, some with terracing	Mixed crop and vegetables	Konso highlands, Ethiopia (Hallpike, 1972) Agoro Valley, Uganda (Watson, 1952)
		Banana gardens	Banana	Marakwet, Cherangani, Taita and Pokot Hills, Mbooni Hills Kenya (Davies et al., 2014; Jackson, 1976; Sutton, 1973)

(*Continued*)

Appendix 2. (Continued).

	Bioregions, location	Characteristics	Crop grown	Reference
	Hills and semi-arid plateaus in the Sahel	River diversion and furrows; runoff water and soil conservation; lifting, shadoof; planting pits	Fonio, sorghum, millet, vegetables	Engaruka, Sonjo, Pagasi, South Para Hills, Mt Kilimanjaro, Meru, Usambara, Uluguru irrigation Tanzania (Grove, 1993; Huijzendveld, 2008; Sutton, 1969; Westerberg et al., 2010) Eastern plains, Jebbel Marra, Nuba Hills, Sudan (Critchley et al., 1990) Dowa and Shire Highlands in Malawi; Angonia area of Mozambique, Inianga Range in Zimbabwe; Lyndenburg, Transkai, Bokoni, Drakenberg Escarpment and Zululand of South Africa (Ayers, 1989; Widgren, 2010) Djenne, Dogon, Mali (Ayers, 1989; Widgren, 2010) Jos, Kamaku, Eggon, Tangala Waja,- Plateau, Nigeria (Widgren, 2018) Ader Doutchi Maggia, Niger (Critchley et al., 1990) Hounde, Kassena, Burkino Faso (Widgren, 2018) Atakora, Togo/Benin (Widgren, 2018) Mandara, Cameroon (Widgren, 2018) Escarpments in eastern Angola (Beekman et al., 2014; Tempelhoff, 2008)
1.3 Tidal/estuary water				
	Coastal estuaries, seasonally saline rivers (up to 70 miles inland)	Embankments, dikes, canals, and sluice gates to bar marine water entering the fields, while capturing rainfall for cultivation	Rice varieties	West Africa, the Sahel low-rainfall region (e.g. Senegal and Gambia) and the rainforest region (Sierra Leone, Guinea, Liberia, and Nigeria) (Bos et al., 2006; Carney, 1996; National Research Council, 1996; Pelissier, 1966) Eastern Africa (Spalding et al., 1997)
	Along freshwater rivers	Inland floodplains	Rice varieties	Niger Inland Delta, (Carney, 1996; Linares, 1981)
1.4 Food diversion (spate)	Runoff from highlands	Diversion of flash floods in ephemeral river onto fields	Millet and wheat	Somalia, Eritrea, Sudan and Ethiopia (Sandford, 2013) Northern Kenya (Muthigani, 2008) Cameroon (FAO, 2016)

Appendix 3. Precolonial large schemes, equipped for irrigation.

	Bioregions: location	Characteristics	Crop grown	Reference
Large schemes, 1800s ('large' is based on references)	Swahili plantations	Rising and receding floodwater	Spices and rice	Malindi in Kenya, Pangara (Nicholls, 1971) Kilwa in Tanzania (Ngigi, 2004)
	Sokoto Caliphate (Kano)	Rising and receding floodwater	Cotton and dyes	Nigeria, Sokoto floodplain (Abubakar, 1975; Lovejoy, 1978)
	Coastal estuaries	Tidal waters	Rice varieties	Western Africa, the Sahel low-rainfall region (e.g. Senegal and Gambia) and the rainforest region (Sierra Leone, Guinea, Liberia, and Nigeria) (Bos et al., 2006; Carney, 1996; National Research Council, 1996; Linares, 2002; Pelissier, 1966)
	Seasonally saline rivers (up to 70 miles inland)	Embankments, dikes, canals and sluice gates and capturing rainfall for cultivation		Eastern Africa (Spalding et al., 1997)
	Inland rice-growing areas	Inland floodplains	Rice varieties	Niger Inland Delta, (Carney, 1996; Linares, 1981)
	Runoff from highlands	Flood diversion	Millet and wheat	Somalia, Eritrea, Sudan and Ethiopia (Sandford, 2013) Northern Kenya (Muthigani, 2008) Cameron (FAO, 2016)
South Africa, 1800s	Northern Cape	River diversion schemes	Lucerne	Northern Cape (Visser, 2013)
	Settlement schemes	River diversion schemes	Mixed	South Africa, e.g. Bonnie River Valley (Visser, 2013)
	Sugar plantations	River diversion schemes	Sugar	Plantation in Natal (Lewis, 1990) and Swaziland (Von Maltitz et al., 2018)

Appendix 4. Examples of colonial schemes.

	Bioregion, location	Characteristics	Crop grown	Reference
Centrally controlled	Gezira scheme, 1920s	Dam and river diversion (tenant) scheme, 460,000 ha	Cotton	Sudan (UK) (Bernal, 1997)
	Tokar scheme, 1900s	Dam and river diversion (tenant) scheme, 33,500 ha	Cotton, sugar	Sudan (UK) (Bashier, 2014)
	Gash scheme, 1920s	Dam and river diversion (tenant) scheme, 105,000 ha	Cotton, rice	Sudan (UK) (Bashier, 2014)
	Office du Niger scheme, 1930s	Dam and river diversion (tenant) scheme, 60,000 ha	Cotton, sugar	Mali (Ertsen, 2006; Robins, 2013; Van Beusekom, 1989, 2000)
	Kenya, 1905	Kibwezi and Makindu, connected to Uganda rail link; indentured and soldier settlement	Rice, sugar	Puertas et al. (2005)
	Kenya, 1920s	Drainage of the Karatina Swamp; river diversion, private schemes	Mixed, sugar	Duder (1993) Nyanza Province, Coast Province (Wanyande, 2001)
	Kenya, 1950s	Mwea, Hola and Perkins (tenant) schemes	Rice	Ngigi (2004)
Private/public funded	Zimbabwe	1912–27 dam and diversion, private/public funded	Mixed	Scoones et al. (2018)
Estates	Mozambique	1890s dam and diversion	Sugar	Central Mozambique ((Dubb et al., 2017)
	Zimbabwe	1930s dam and diversion	Sugar	Triangle and Hippo Valley (Dubb et al., 2017)
	Tanzania	1930s dam and diversion	Sugar	Northern Tanzania, (Dubb et al., 2017)
Farmer-managed	Sierra Leone	Scarcies polder rice irrigation scheme	Rice	Richards (1986)
	Nigeria	Village irrigation schemes, 40–200 ha; digging of wells, 1905	Cattle, meat and skins	Sokoto Province (Nwa, 2003) Asiwaju (1982)
	French West Africa	Tube wells for pastoral herders, 1940s; cattle-operated water lift and a Persian wheel	Nurseries, peanuts, vegetables	Sahel (Thèbaud, 1990) Nwa (2003)
	Mali	Submersible dikes, canals and sluice gates, 10,000 ha	Rice	Dia-Tenenkou, Mopti region, Mali (Roberts, 1996)

Appendix 5. Areas equipped for irrigation and under agricultural water management (AWM).

	Equipped irrigated[a] area per country, 1900–2000 (thousand ha) Data from Freydank and Siebert (2008)												Area under AWM (thousand ha) Data from FAO (2016, Table 28)			
	Colonial period						After independence									
Country	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	Increase in area, 1960–2000	Area equipped	Wetland / valley bottom	Flood recession	Total area under AWM
Angola	38	44	50	56	62	68	74	75	80	80	80	6	80	320		400
Benin								20	10	10	12	12	12	7		19
Botswana								1	2	1	1	1	1	7		8
Burkina Faso	1	1	1	1	1	2	4	10	10	20	25	21	25	21		46
Burundi							11	14	14	15	21	10	21	83		104
Cameroon													17	10		27
Central African Republic										1	1	1		0.5		0.5
Chad	1	2	3	4	5	6	7	8	12	16	26	19	30		125	155
Congo Dem. Rep.									7	10	11	11	11	2	1	14
Congo, Rep.								1	1	1	2	2	2			2
Cote D'Ivoire	1	1	2	2	3	3	4	20	44	66	73	69	73	16		89
Ethiopia	10	13	16	19	22	24	27	57	111	260	290	263	290			290
French Guyana								1	1	2	2	2				
Gabon							4	4	4	6	8	4	5			5
Gambia	1	1	1	1	1	1	1	1	1	2	2	1	2	13		15
Ghana	2	3	3	4	4	5	14	15	20	30	31	19	31			31
Guinea	5	7	10	12	15	17	20	50	90	90	95	75	95			95
Guinea Bissau	2	4	7	9	12	15	17	17	17	17	25	8	23	29		51
Kenya	5	6	7	8	9	10	13	29	40	54	85	72	103	6		109
Malawi							1	4	18	20	55	54	56	62		118
Mali	10	12	14	16	18	21	57	61	60	78	236	179	236		440[b]	676
Mauritania	1	4	7	10	13	17	20	30	49	49	45	25	45	33	31	109
Mozambique							7	26	65	105	118	111	118	118[c]		236

(*Continued*)

Appendix 5. (Continued).

	Equipped irrigated[a] area per country, 1900–2000 (thousand ha) Data from Freydank and Siebert (2008)												Area under AWM (thousand ha) Data from FAO (2016, Table 28)			
	Colonial period						After independence									
Country	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	Increase in area, 1960–2000	Area equipped	Wetland / valley bottom	Flood recession	Total area under AWM
Namibia	1	1	1	1	1	1	2	4	4	6	8	6	8		2	10
Niger	2	4	7	9	11	13	16	18	23	66	73	57	74		12	86
Nigeria	3	3	3	3	3	33	185	200	200	230	290	105	293		1500[d]	1793
Rwanda							3	4	4	4	9	6	9	94		103
Sao Tome and Principe	2	3	5	6	7	8	10	10	10	10	10	0	10			10
Senegal	10	20	30	40	49	59	69	78	62	94	120	51	120		30	150
Sierra Leone	1	1	1	1	1	1	1	6	20	28	30	29	29	126		155
Somalia	45	52	60	67	75	82	89	95	125	200	200	111	200		110[e]	310
Sudan	100	163	277	300	396	593	1203	1625	1700	1800	1863	660	1863			1863
Swaziland							32	40	40	45	50	18	50			50
Tanzania							18	38	120	144	184	166	184	117[f]		301
Uganda							2	4	6	9	9	7	9	50		59
Zambia						1	2	9	19	46	156	154	155	100		255
Zimbabwe				2	5	7	20	46	80	109	174	154	174	20		194
Total	241	335	505	571	713	977	1933	2621	3069	3724	4420	2487				
Growth %		39%	110%	137%	196%	305%	702%					129%				

[a]This dataset only refers to 'equipped for irrigation' and does not specify AWM.
[b]FAO (2016) says 60,000 ha, but Dtmzthe (1997) says 440,000 ha.
[c]FAO (2016) says zero ha, but Beekman et al. (2014) say 118,000 ha.
[d]FAO (2016) says 682,000 ha, but Ugalahi et al. (2016) say 1.5 million ha.
[e]Basnyat and Gadain (2009) says 110,000 ha under flood recession, but this is not mentioned by FAO (2016).
[f]Tanzania (FAO, 2016) says 117,000 ha, but counted as irrigated in the country table of the same year.

Appendix 6. Examples of schemes developed after independence and known areas under agricultural water management (AWM).

	Type of scheme	Crop	Issues	Reference
Independence, 1960–2000				
Sudan + 1,270,000 ha	Gravity schemes: Gezira + Managil 870,000 ha New Haifa, Radah and Suki schemes, 310,015 ha Pump schemes: increased to 575,370 ha Gash and Tokar Spate schemes, 132,000 ha Private or cooperative-owned schemes 402,735 ha	Cotton wheat	Area equipped for irrigation 1,851,900 ha, only 54% irrigated. Cotton schemes suffered from poor water distribution, centralized and inadequate management, tenants had lack of economic incentives (de facto farm labour), and single-desk commodity board for cotton were major issues. Severe salinity issues at some schemes due to over-irrigation and inadequate drainage; 500,000 ha beyond rehabilitation.	Mahgoub (2014)
Madagascar + 893,000 ha	Large coastal schemes 780,000 ha are *bas-fonds*, e.g. Lake Alaotra Irrigation Project (1970s) 100,000 ha	Rice	River valleys and low-lying marsh areas with barrages prone to destruction by cyclones. Low productivity due to high input costs, distance to urban markets, lack of capital and poor infrastructure. Government decentralization of power and investment has turned into disinvestment of responsibility, lack of financial support for infrastructure upkeep and investment.	FAO (2016); MAEP (2007); Marcus (2007)
Mali + 179,000 ha	Three large schemes: Segou, Office du Niger and Mopti 167,000 ha Village and private pump 14,300 ha	Rice	Inadequate infrastructure created bottlenecks in the supply system. Of the scheme area of 167,000 ha, 89% is irrigated. Issues: land tenure, supply chain, top-down management, and poor financing. Lack of mechanization creates labour shortages; double cropping is not widespread.	FAO (2016)
	Controlled flood irrigation 190,000 ha Flood recession cropping on 250,000 ha	Mixed	Controlled flood irrigation and flood recession cropping are managed by farmers. Farming systems are labour-intensive, e.g. herbicide spraying for weeds. If less than 5 km from the market these systems are working well and very price-competitive. Research, finance and better infrastructure would improve outcomes.	Dtmzthe (1997)

(*Continued*)

Appendix 6. (Continued).

	Type of scheme	Crop	Issues	Reference
Tanzania + 166,000 ha to 2002 + +14,000 ha to 2013	1,447 irrigation schemes are publicly funded, mainly surface water; 55,000 ha in large schemes, 111,000 in small-scale 190,285 ha in small schemes 117,000 ha are under farmer-led irrigation 27,200 ha rainwater harvesting schemes (AWM)	Tea, coffee, sugarcane, cotton Maize, rice, mixed veg.	The regions with the most irrigation are Kilimanjaro, Morogoro, Arusha and Mbeya. Most non-private schemes have top-down management, and producers are not linked to urban markets, giving production gluts and low prices. Lack of storage facilities, value adding and food processing facilities leave farmers with little profit. Farmer-led initiatives have no water security.	Tanzania (FAO Aquastat, 2016; Food and Agriculture Organization & New Partnership for Africa's Development, 2005)
Zambia + 154,000 ha	126,500 ha commercial irrigated farms: 100,000 ha developed as state farms but privatized in 1980s. Developed areas are on the main highways in Kafue Flats and on the fringe of the Barotse Floodplain Smallholder and resettlement schemes 27,500 ha	Coffee, bananas, tea, sugar	Poor/seasonal roads and missing bridges make commercial agriculture away from main roads difficult and dominated by pastoralists. Large commercial farms, particularly along the Livingston to the Cobber Belt road.	Zambia (FAO Aquastat, 2016; Kuntashula et al., 2004)
	Estimated 100,000 ha of small-scale flood and flood recession farming	Maize and veg. Cattle Cassava, rice, veg. Cattle	Small-scale African farmers lack capital, transport, input and access to markets. Resettlement schemes fraught, with local elite acquiring land. Diminishing water inflows from Congo and Angola affect size of flooded area, and dams reduce downstream flow.	
Zimbabwe + 154,000 ha	In the 1960s, the White minority government financed dams and smallholder schemes to stem rural-to-urban migration After independence (1980), continued to finance smallholder schemes Wetland and *dambo* cultivation estimated at 20,000 ha	Maize and veg.	Top-down, government-managed smallholder schemes with prescriptive cropping calendars prevented entrepreneurship. Credit and loans for groups of farmers were available but little used, as farmers had not build trust in the White minority government. Policy emphasis on maize, lack of capital and inputs give farmers poor economic return.	Zawe et al. (2015)

(*Continued*)

Appendix 6. (Continued).

	Type of scheme	Crop	Issues	Reference
Somalia + 112,950 ha	Spate irrigation on the floodplains of the Shabelle and Juba rivers: irrigated areas developed with barrages and distribution canals (one on the Juba, 1980s, four on the Shabelle from the 1920s, two from the 1950s and three in the 1980s); 112,950 ha under controlled irrigation and 110,000 ha under flood-recession before civil war		Somalia has the highest interannual variations of rainfall in Africa. Widespread environmental degradation and unmaintained dykes allow uncontrolled floodwaters to destroy infrastructure and inundate scarce cultivated land and settlements. Weak political and administrative management and failure to address access to water, fuelling conflict and civil war in 1980s–1990s. Only 100,000 ha of the equipped areas was cultivated in 2018.	Basnyat and Gadain (2009)
Nigeria + 105,000 ha	Public schemes 104,500 ha, of which 34% is irrigated Privatized sugar scheme, 5,600 ha not producing Private small schemes 128,000 ha Flood-recession (*fadama*) cropping 682,000 ha, of which 55,000 ha are equipped in the lowland (FAO, 2016). Farmer-led hill irrigation, e.g. Jos Plateau (acreage not available), initially lifting water with shadoof, (1982) now with pumps	Mainly rice Sugar Diverse: rice, fishing, livestock and cropping Rice, maize, cassava, peanuts, veg.	The public irrigation schemes are old; 84% use pumps; their infrastructure requires rehabilitation and in some cases total replacement of pumping and other equipment. Poor management led to farmers pumping from supply canals outside scheme boundaries, e.g. 3,000 ha outside the Hadejia Jamaare scheme. Most farmers do not pay for water. Charges are too low to meet the cost of water delivery, which contributes to the cycle of poor services leading to lack of willingness to pay. The information flow between policy, planning and budgeting for public irrigation is dysfunctional and ineffective. Most often policy directives are not matched by corresponding budgetary allocations. Data on operation and maintenance, farm inputs, yields, and cost of produce are limited and unreliable. At the scheme level, there is no clear direction on crop production because there is no effective linkage between agriculture and water. The Fadama project invested in improvements for different user groups, e.g. fishing nets, milling and improving farmers' income. Produce mainly taken to markets within Nigeria (Lagos, Kano, Kaduna, Imo State) but also to neighbouring countries, such as Chad and Niger. A major issue is market access and market control by middlemen, reducing farmers' return.	Adelodun and Kyung-Sook (2018); Nigeria National Committee on Irrigation and Drainage (2015); Pasquini et al. (2004)

+: schemes established since independence.