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206

Working Paper

The Link between Small Reservoir Infrastructure and Farmer-led Irrigation: Case Study of Ogun Watershed in Southwestern Nigeria

Adebayo Olubukola Oke, Olufunke O. Cofie and Douglas J. Merrey

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Collaborators

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Contents

Acronyms and Abbreviations

ADP	Agricultural Development Program
FGD	Focus group discussion
FLI	Farmer-led irrigation
Ha	Hectare
Mm^3	Million cubic meters
OORB	Ogun-Osun River Basin
RA	Reservoir area
SEED	Safety Evaluation of Existing Dams
SR	Small reservoir
SSA	Sub-Saharan Africa

Summary

There are over 900 small reservoirs (SRs) constructed by the federal and state governments for rural water supply and irrigation across Nigeria. Many of them are currently not performing to their full potential. The Ogun-Osun River Basin with four sub-watersheds (Ogun, Osun, Ona and Sasa) has many SRs. The Ogun sub-watershed is a major hydrological basin with over 25 small dams and reservoirs constructed under various government programs. These reservoirs, however, are poorly maintained and poorly managed and lack the required institutional and governance structures to ensure realization of their potential. Nevertheless, farmer-led irrigation (FLI) practices are growing around these reservoirs as farmers have taken over the structures (albeit informally) through private irrigation efforts such as investing in water lifting, conveyance and crop production practices.

This study evaluated the condition and utilization of 20 SRs in the Ogun sub-watershed to answer several questions: What are the prevailing issues responsible for the low productive use of the SRs? How does the state of hydraulic infrastructure, maintenance and management affect overall productivity? How can water productivity be enhanced? What is required to improve the productive use of these SRs? This paper reports on the state of selected reservoirs and makes recommendations to achieve more sustainable management of these resources.

Five major issues were investigated: the dams' structural elements and reservoir capacities; maintenance and management of the dams, including institutional and governance structures; agricultural and irrigation practices; agronomy and farming systems; and marketing and related socioeconomic issues. The research methods we followed included field and infrastructure assessments, focus group discussions and key informant interviews with the relevant stakeholders.

The capacities of the reservoirs included in our study ranged from 0.09 million cubic meters (Mm^3) to 2.025 Mm^3, with 90% of the reservoirs having less than 1 Mm^3 capacity. The combined capacity of these SRs was 9.75 Mm^3 with a total irrigable area of 152 hectares (ha), of which 97 ha (64%) are currently cultivated largely by FLI actors. Eroded and overgrown embankments, fractured spillways, sedimentation and high levels of weed infestation were observed in these reservoirs. Overall, 70% of the SRs are in a poor state and need urgent revamping. Although about 80% of the 780 farming households in the study area are currently active in irrigated crop production, they face many constraints, including limited irrigation management capacity, extension support and access to necessary inputs. Farmers themselves coordinate the management of these reservoirs on an ad hoc basis. Most of them consider irrigated agriculture profitable, especially as they can produce during the dry season when vegetables command better prices. However, the poor state of the dam structures and reservoir storage limits the advantages that can be derived from irrigation.

To sustain the SRs' storage capacity, overhauling the dam spillways and embankments and dredging the reservoirs are critical solutions. Furthermore, inefficient irrigation practices resulting from low technical capacity, inadequate irrigation equipment and the challenge of securing a good return on investment in the context of poor market access are the other issues that need to be addressed. Building the capacity of farmers in irrigation management practices is important for the success of FLI efforts. There is also a need to strengthen the governance of reservoirs with appropriate and inclusive institutions. The current level of haphazard and poor coordination makes these reservoirs unsustainable. The existing farmer cooperatives and commodity associations can be reorganized to serve as water user associations to coordinate water allocation, utilization and reservoir management. There is also a need for a support mechanism for farmers to access resources such as agricultural inputs, finance, markets and technical support. This can be achieved by creating an enabling environment for public-private partnership arrangements with private sector actors, improving the extension services, and cooperation among the stakeholders. The potential of SRs to support smallholder irrigation in the Ogun sub-watershed is high, provided a more sustainable approach is employed, especially by strengthening the capacity of water users to take firm ownership of the systems.

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Introduction

Agricultural Development in Nigeria: A Historical Perspective

Nigeria has implemented several initiatives to improve food production and agricultural productivity. These are initiatives taken by government institutions themselves or in partnership with various development partners (Chukwuemeka and Nzewi 2011). While some of them are focused on deploying smallholder irrigation technologies, others address other forms of agricultural and rural infrastructure development. These agricultural productivity-focused interventions include programs such as Operation Feed the Nation (1976), Green Revolution (1979/80), the Directorate of Food, Roads and Rural Infrastructure, River Basin and Rural Development Authorities (1987), and the World Bank-assisted Agricultural Development Program (ADP), which commenced officially in 1972 in Northern Nigeria, and very recently, the National Fadama Development Project (1990).

The ADP was first rolled out in the 1970s and 1980s (Ogbalubi and Wokocha 2013; Auta and Dafwang 2010). It was the first major practical demonstration of an integrated approach to agricultural development in Nigeria. It focused on improving agricultural extension systems and water and irrigation infrastructure, especially for smallholder irrigation. The World Bank-funded ADP project was formally launched in 1972 in Northern Nigeria while activities were implemented in Funtua, Gusau and Gombe by 1974. The project expanded to the central (Ayangba and Lafia in 1977 and Ilorin in 1980) and southern parts of Nigeria (Ekiti-Akoko in 1981 and Oyo North in 1982) with acclaimed success in promoting small-scale irrigation practices. The program adopted an integrated rural development strategy (Ogbalubi and Wokocha 2013; Daneji 2011). The success of the first phase of this program in the selected states led to the launch of multi-state programs across Nigeria. The first multi-state agricultural development project (MS ADP-1, loan no. 2733 UNI of USD 162 million) was appraised in May/June 1984 with the broad objective of improving smallholder farm incomes (Chukwuemeka and Nzewi 2011; Ogunjimi and Adekalu 2002). This period of the ADP heralded massive deployment of tube well or wash-bore smallholder irrigation practices in multiple watersheds in Northern Nigeria, where irrigation using shallow groundwater was feasible (Adelodun and Choi 2018). Similarly, in the southern states where the possibility of using tube well technology is remote—within the Ogun watershed, for instance—several small dams and reservoirs for irrigation and rural water supply were constructed under the Oyo North Agricultural Development Program (Chukwuemeka and Nzewi 2011; Daneji 2011).

While private irrigation based on tube wells proved a huge success in parts of Northern Nigeria (Adelodun and Choi 2018; Moro and Onoja 2006), major limitations have hindered the small dams and reservoirs constructed under the ADP as a result of poorly equipped, or even absent, irrigation infrastructure such as headworks and conveyance structures. This was similar to the challenges observed with large-scale irrigation schemes (Enplan Group 2004) and has contributed to the poor use of small reservoirs. However, the ADP initiative—jointly supported by the World Bank and the Federal and State governments of Nigeria—increased the interest of smallholder farmers in the deployment of private irrigation practices, especially outside the irrigation schemes. Recent investments in the National Fadama Development Project (phases 1-3), following in the path of the ADPs, have emphasized support for private smallholder farmers and related agricultural support (Adelodun and Choi 2018). These efforts have increased smallholder farmers' adoption of private irrigation technologies—farmer-led irrigation—even around the small reservoirs constructed under ADP.

Government Irrigation Schemes and Emerging Farmer-led Irrigation

In most sub-Saharan African (SSA) countries, large-scale irrigation schemes have been the major focus of government investments in irrigation development (Woodhouse et al. 2017; NEPAD 2003). Nigerian governments too have invested more in large-scale irrigation schemes (Adelodun and Choi 2018). In these schemes, the land is usually allocated to farmers for commercial or smallholder production with a centralized water management system (Kyei-Baffour and Ofori 2006). However, the performance of large schemes has not been commensurate with the investment costs over the years (Inocencio et al. 2007; Alam 1991; Kortenhorst et al. 1989). By 1990, Nigeria had over 162 large dams and pumping infrastructure projects with a capacity to irrigate up to 725,000 ha, which was less than 20% of the total irrigation potential. Most of these large dams are not equipped with adequate irrigation infrastructure (Frenken 2005). Presently, developed and actual irrigated areas are estimated at 139,128 ha and 95,289 ha, respectively (Irrigation and Drainage Department 2021).

While the global discourse on the performance of large-scale irrigation schemes continues, there has been renewed interest in small-scale irrigation development in SSA, and specifically in West Africa (de Fraiture et al. 2014; Woodhouse et al. 2017). In 2016, the government of Nigeria proposed a three-phase plan to increase the cultivable irrigation command area by developing irrigation infrastructure to serve 500,000 ha of land by 2030 (Suleiman 2017). The plan was to add 100,000 ha during 2016-2020, 170,000 ha during 2021-2025 and 225,000 ha during 2026-2030. This requires a projected investment of more than Nigerian naira (NGN) 1.5 trillion (USD 4.14 billion) over 12 years (Suleiman 2017). This is not the first time that such huge investment plans have been made in the irrigation sector of Nigeria. Past investments failed to achieve their intended objectives (Enplan Group 2004) because, among other reasons, the primary users of the irrigation infrastructure were not engaged in the design of irrigation systems and most of them did not have sufficient capacity to use such large systems efficiently and effectively (Woodhouse et al. 2017).

On the other hand, small dams with small reservoirs (SRs) are often used for multiple purposes in several SSA countries (Ayantunde et al. 2016; van de Giesen et al. 2004). Sometimes, the category of SRs also includes big 'dugouts' in West African countries such as Ghana and Burkina Faso, and 'tanks' or 'ponds' in India, Sri Lanka or China (Ayantunde et al. 2016; Roost et al. 2008; Sugunan 1995). These structures are often constructed either by governments with assistance from development partners as part of development initiatives or directly by farmers themselves (Woodhouse et al. 2017; Abric et al. 2011). In SSA, including Nigeria, SRs refer to small dams 5-15 m in height (from foundation to crest) or those with a capacity of less than 3 million cubic meters (Mm^3) (Saruchera and Lautze 2019; Keller et al. 2000) or a surface area of 1-100 ha (van de Giesen et al. 2008). There are thousands of SRs throughout SSA (Saruchera and Lautze 2019), including in West Africa. Roost et al. (2008) documented a 'pond' with a storage capacity of up to 16.6 Mm^3 as an SR in China. In India, some 208,000 SRs irrigate 2.3 million ha (Palanisami et al. 2011).

Several benefits of SRs have been documented across Africa, including irrigation water supply, livestock watering, domestic water supply and local employment (Saruchera and Lautze 2019). Among these uses, farmer-led irrigation (FLI) is predominant. Unlike the management of large irrigation schemes, which is not under the control of farmers, FLI gives small-scale farmers a driving role in respect of water management for crop production, choice of irrigation methods, decisions on crop type and management of their investment (Woodhouse et al. 2017; de Fraiture and Giordano 2014). Farmer-led irrigation allows farmers to drive investment in the development of water sources (groundwater and surface water), improvement and/or expansion of irrigated land area, and influencing decisions on the location, purpose and designs of irrigation initiatives. Farmer-led irrigation practices around SRs allow farmers to be independent in water use and develop the capacity for productive uses with a positive impact on farmers' livelihoods (Venot et al. 2012; Abric et al. 2011). The major benefits of SRs include ease of access to water and operations with fewer technical complexities compared to large irrigation dams (Liebe et al. 2007). With SRs, farmers have more freedom in their irrigation operations, crop choice, irrigation technologies and institutional arrangements. The contribution of informal FLI practices outside public schemes has often been overlooked and hardly integrated into mainline irrigation planning (de Fraiture and Giordano 2014). Yet, they provide employment and improved livelihoods for many people. Wisser et al. (2010) estimated that water stored in SRs around the globe could increase global cereal production by 35% through supplemental irrigation.

Exploring FLI Practices Around Small Reservoirs

Despite the documented importance of SRs in SSA, efficient management of these systems has been a major challenge. The high potential of FLI has not been adequately captured in national irrigation planning and development initiatives, including SRs. The reasons, as observed by de Fraiture et al. (2014), are that FLI practices around SRs are poorly organized, limited by poor reservoir management, ineffective institutional structures, and unregulated operation. Thus, in Burkina Faso, farmers managing such irrigation structures are likened to 'irrigation pirates' who are not regulated but use water as they consider needed. There are over 900 SRs across Nigeria (Owusu et al. 2022). Farmers undertake off-season small-scale irrigation more flexibly than they do in large irrigation schemes even though some of these SRs are neglected (Suleiman 2017), resulting in poor maintenance, dilapidated structures and complete abandonment in some instances. In Nigeria, a typical SR system is a small dam with a reservoir intended to provide rural domestic water supply and small-scale irrigation. This does not include individual farmers' water storage dugouts or excavations, which are often not documented because they are very small and informal. Since the Ogun watershed is within the basement complex geological formation, groundwater-based irrigation is not feasible because of the depth to the water table (Nwankwoala 2015; Okeke et al. 2011). Hence, farmers are interested in using SRs and other surface water resources. Generally, there is a dearth of information on the state of Nigeria's existing large and small dam structures.

This study evaluated the utilization of SRs for irrigation. Some of the questions we examined were: What is the motivation for FLI activities springing up around SRs? What is the state of these structures, and what is required to overcome constraints limiting their productivity? How are farmers' irrigation activities—irrigation methods, water uses, agronomic practices and related socioeconomics, including market access—sustained? How does the state of hydraulic infrastructure and its maintenance and management affect the activities of irrigators? What are the immediate actions required to improve the productive use of SRs and strengthen irrigation activities within the Ogun watershed? This paper reports the state and status of selected SRs in the Ogun watershed within the Ogun-Osun River Basin and makes recommendations to enhance the water productivity and sustainable management of these resources.

Study Approach

Study Location: Ogun-Osun River Basin Hydrological System

The Ogun-Osun River Basin (OORB) covers a large part of southwestern Nigeria. The geographical area delineated as the OORB is about 45,155.9 km², covering the whole of Osun, Oyo, Lagos states and a part of Ogun. The basin is underlain by basement complex formation with an undulating terrain of a dendritic network of rivers and streams, some perennial, others seasonal. The OORB is divided into four major watersheds (Figure 1[a]), of which the Ogun watershed is the largest with an area of approximately 23,044.7 km², about 51% of the OORB. The others are Sasa (6,407.7 km²), Osun (9,295.8 km²) and Ona (6,407.0 km²) (Oke et al. 2013). The OORB comprises two major river systems: the Ogun and Osun. The Ogun watershed is drained mainly by the Ogun River, with the Ofiki, Oyan and Ona rivers as the major tributaries. The Oyan and Ofiki start in the north and flow southward. The Ona River drains the Ona watershed covering the Ibadan metropolitan area and discharges into the Ogun River. Other tributaries of the Ogun include the Opeki, Ose, Oso and Awon rivers.

There are a few large dams within the Ogun watershed. These include the Ikere Gorge Dam (565 Mm³) constructed on the Ogun River in the north, and the Oyan Dam (270 Mm³) on the Oyan River just before it discharges into the river in the middle of the Ogun watershed. These two large dams were originally designed for hydroelectricity generation, irrigation and water supply to cities and communities within the Ogun watershed. The Oyan Dam also serves the purpose of flood control. At the time of this study, the Oyan Dam supplied water to Lagos and Ogun states, while the Ikere Gorge Dam was not being used for any of its intended objectives. The other large dams within the OORB include the Asejire Dam (32.9 Mm³) on the Osun River and the Eleyele Dam (7.0 Mm³) on the Ona River. These two dams are the principal sources of treated water to the Ibadan metropolitan area. Currently, they do not serve any irrigation purposes or contribute to hydroelectricity generation.

In addition to these four large dams, there are several SRs within the OORB. The highest concentration of SRs (more than 25) is in the Ogun watershed (Figure 1[b]). These SRs were originally constructed for rural water supply and small-scale irrigation.

Climate and Crop Production in the Ogun Watershed

The climate in the Ogun watershed is tropical, characterized by marked wet (April-October) and dry (November-March) seasons. Temperatures range from 21 °C to 34 °C, while annual rainfall varies between 1,500 mm and 3,000 mm (Ogunsola and Yaya 2019; World Bank Group 2023). Vegetation in the watershed is characterized as rainforest in the south, transiting to guinea savannah in the north. Farming is predominantly smallholder and rainfed. The main crops are root and tree crops such as cassava, yams, cocoa, plantains, cashew, oil palm and rubber (FAO 2021; Okolo 2006). There is also significant production of arable crops including maize, soybean, cowpea, tomatoes, pepper and vegetables. Irrigated agriculture accounts for only a small fraction of the crop production in the Ogun watershed. A few farmers practise small-scale irrigation in the valley bottoms—called *fadama*—and along riverbanks to produce vegetables and maize. Crop production is increasingly being challenged by climatic variability, including rainfall fluctuation, early cessation of rains and lack of certainty of sufficient rainfall for late (dry) season production (Ladan 2014). This has created more interest in irrigated crop production using surface water and groundwater resources, especially the rivers, streams and SRs, which hitherto had been abandoned. Of major importance is the development of farmer-led irrigation around the SRs. The challenge of low productivity of these SRs is the subject of this study.

Study Framework and Scope

Twenty SRs in the Ogun watershed were surveyed for this study (Figure 1b), focusing on six major aspects: (i) the structural elements and reservoir capacities of the dams; (ii) maintenance and management; (iii) governance; (iv) agricultural water management practices; (v) agronomy and farming systems; and (vi) marketing and related socioeconomic issues (Figure 2).

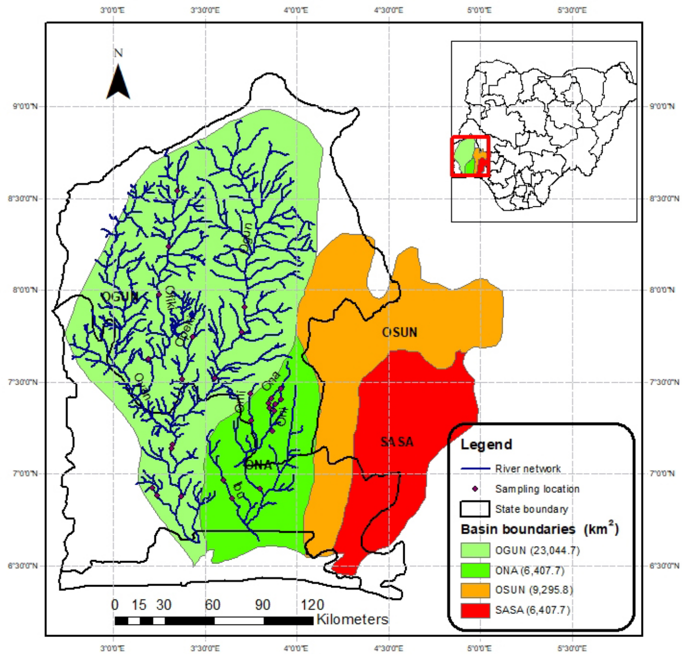

Figure 1(a). Watersheds within the OORB.
Source: Oke et al. 2013.

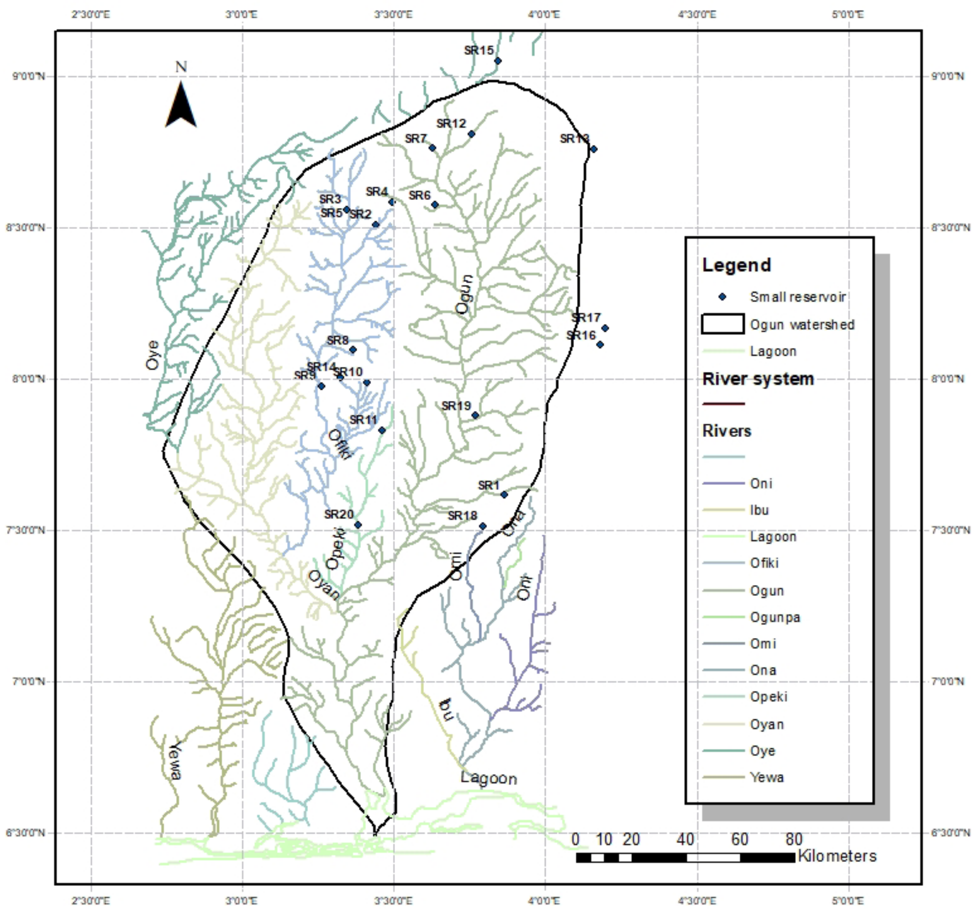

Figure 1(b). The Ogun watershed with the studied small reservoirs.
Source: Authors.

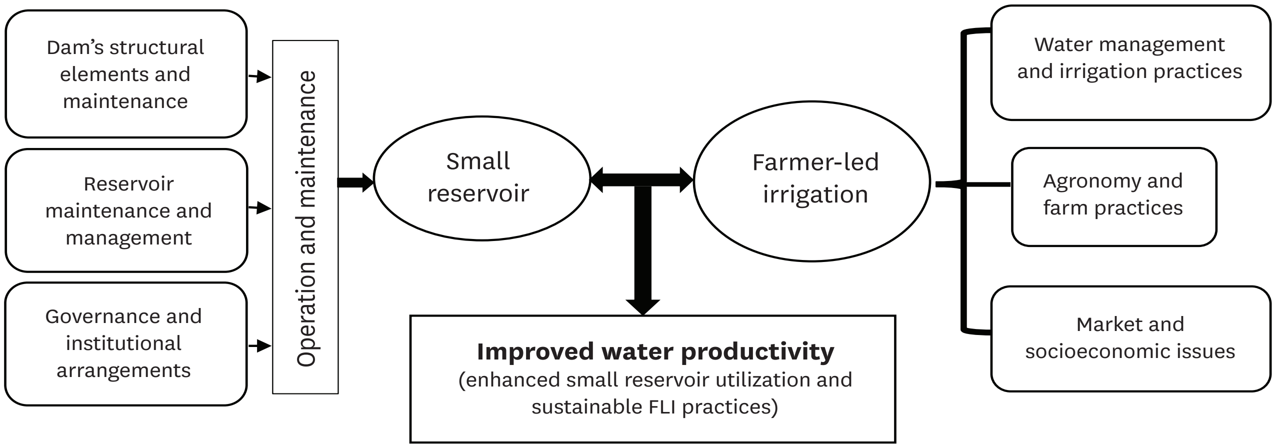

Figure 2. Framework for the evaluation of the productivity of farmer-led irrigation (FLI) around small reservoirs.

Dam Structural Assessment

An evaluation of the dam structures (embankments and spillways) and reservoir design and current capacities was conducted following the 'Safety Evaluation of Existing Dams' (SEED) procedure (USBR 2000). The SEED protocol includes site inspection, physical examination of structural elements, appraisal of dam management records, where available, and rating of the defects and failures observed. Table 1 presents the three categories of structural observations recorded and their ratings. The level of growth of vegetation in the reservoir was estimated during field observation and reported as a percentage of the original reservoir area (RA).

During field inspection, we identified the available water conveyance systems (either as pipes or open canals) and water lifting, distribution and other irrigation equipment, whether constructed by the government or provided by the farmers themselves.

Table 1. Rating and assessment of different structures in the SRs.

State of hydraulic structures (spillway and embankment)			
Rating	State	Description	Remarks
0	Very poor	Destroyed, shattered; vegetative growth has taken over; failed due to erosion; in a complete state of disrepair.	Major and extensive rehabilitation required.
1	Poor	Erosion of banks; shattered; vegetative growth minimal; not in a complete state of disrepair; minimum repair required.	Major but not extensive rehabilitation.
2	Fair	Very minimum vegetation and silt; not in a state of disrepair; minimum clearing needed; structure still intact.	Minimum repair required.
3	Good	No vegetation; minimum clearing and removal of sediments needed without any need for rehabilitation.	Clearing of vegetation and sediment required.
4	Very good	Nothing to repair; no vegetation; just minor sediments in conveyance canals.	Nothing to clear.
5	Excellent	The structure requires no repairs.	Perfect state as constructed
Description of observed failures (such as piping, cracks, seepage)			
N	Low	High	Very high
None	Sparsely noticed	Very much noticed but not threatening	Highly noticeable and threatening

Assessment of Agricultural and Water Management Practices

In each of the 20 SRs studied, focus group discussions (FGDs) were conducted with an average cluster of ten farmers (Figure 3). Thus, 200 farmers participated in the FGDs across the SRs. A structured interview instrument guided the FGD. The information collected from stakeholders in interviews and FGDs was collated and analyzed using descriptive statistics.

Irrigation management practices were assessed, including irrigation methods and level of irrigation experience or capacity to use various irrigation practices. Past training or access to relevant training, access to technical support from input suppliers and extension agencies, perception of access to water and constraints to resource deployment were assessed. 'Capacity' here refers to experience based on field-level training on basic irrigation practices such as surface irrigation and use of pumps.

Agronomy, Farm Practices and Socioeconomic Issues

In each SR, access to land, support services, tillage equipment, major crops cultivated, agricultural inputs, credit system and access to extension services were investigated. The market for irrigated produce was identified. Farmers' perceptions of the profitability of irrigation practices were examined, and the existing institutions and governance structures for managing the SRs were observed.

Figure 3. A focus group discussion at the Ilero SR within the Ogun watershed.

Findings and Discussion

Capacity of Small Reservoirs

The main characteristics of the 20 SRs we studied are presented in Table 2. The reservoir capacities ranged from 0.09 Mm³ to 2.025 Mm³ and the combined capacity was 9.75 Mm³. Nine (45%) of the SRs had less than 0.3 Mm³ storage capacity, six (30%) were within 0.30-0.59 Mm³, two (10%) within 0.60-0.99 Mm³ and three (15%) had more than 1.0 Mm³ (Figure 4). Thus, 85% of the investigated SRs had less than 1 Mm³ capacity. Their combined potential irrigable area was 192 ha, of which 115 ha (60%) were under cultivation. The irrigable command areas of the SRs ranged from 5 ha for SR5 with a capacity of 0.09 Mm³ (which was estimated to serve 25 smallholder farmers) to 20 ha for SR1 with a capacity of 2.025 Mm³ (estimated to serve 100 smallholder farmers). The findings for potential irrigable land and area under cultivation show that the available irrigable command area has been fully utilized in SR8, SR12 and SR17; in fact, more land has been opened up for irrigation in these SRs (Table 2). This shows a high utilization of reservoir water in contrast with the other SRs. The average landholding of the irrigating farmers ranged from 0.05 ha to 0.8 ha, among the 675 farmers practising irrigation. This pattern of Ogun watershed farmers using SRs with a capacity of 1.0 Mm³ or less for irrigation is similar to the pattern seen in the rest of SSA (Skinner et al. 2009; Saruchera and Lautze 2019). Oke et al. (2015) have also reported that there is good potential across small rivers in southwestern Nigeria for water storage using small structures.

Table 2. Details of the small reservoirs in our study and their potential irrigation benefits.

SR no.	SR name	Capacity (Mm³)*	Potential number of farmers*	Number of farmer households practising irrigation	Irrigable area (ha)*	Estimated area under irrigation (ha)	Average holding (ha/household)
SR1	Alabata	2.025	100	40	20	10	0.25
SR2	Ago Are	0.30	50	25	10	6	0.24
SR3	Irawo	0.30	50	0	10	0	0.0
SR4	Oje Owode	0.29	15	30	3	6	0.20
SR5	Ago Amodu	0.09	25	0	5	0	0.0
SR6	Sepeteri	0.28	50	20	10	8	0.40
SR7	Ogbooro	0.319	30	10	6	8	0.80
SR8	Ilero	0.30	50	35	10	15	0.43
SR9	Iganna	0.17	40	10	8	5	0.50
SR10	Ilua	0.128	50	10	10	3	0.30
SR11	Ado Awaye	0.20	50	0	10	0	0.0
SR12	Igboho	1.20	50	20	10	10	0.50
SR13	Igbeti	0.923	50	15	10	4	0.27
SR14	Okeho	0.818	60	35	25	8	0.23
SR15	Kishi	0.30	50	20	15	10	0.50
SR16	Ibapon (under construction)	0	0	0	0	0	-
SR17	Ikose	0.580	75	400	15	20	0.05
SR18	Akufo	0.110	50	5	10	2	0.40
SR19**	Fasola	0.220	15	0	5	0	0
SR20	Eruwa	1.20	-	-	-	-	-
Total		9.753	860	675	192	115	

Notes:
* *Source*: Oyo State Agricultural Development.
** SR19 is a concrete dam; SRs 1-18 are earth dams.

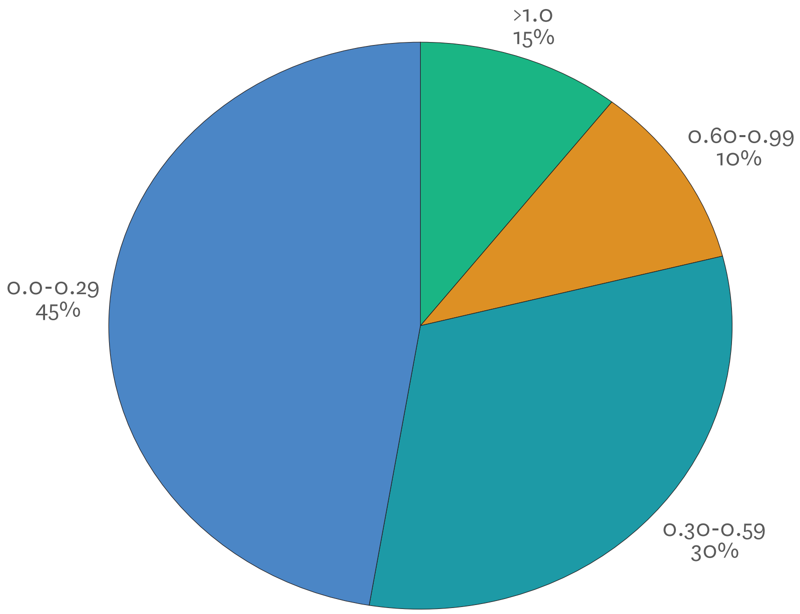

Figure 4. Chart representing the distribution (%) of small reservoirs according to storage capacity (Mm³).

State of Dam Embankments and Spillways

Nineteen of the 20 small dams we studied in the Ogun watershed are earth dams built with a clay core. The one exception, SR19, has a concrete embankment built on a foundation of rock outcrop across the impounded stream. The embankments we inspected showed that their construction had followed the basic earth dam protocols (Stephens 2010). However, the embankments were degraded to different degrees, which may affect the structures over time. There has been no history of overtopping or dam failure in the catchment over the past years of operation, which suggests a sound matching of spillways with net flow. However, the embankments of some of the SRs were poorly maintained. The embankment is the core of a dam; it is the element that keeps the reservoir in shape to hold the water force. When it is poorly maintained, it could become a safety challenge over time. Figure 5 shows that the state of SR embankments was rated poor for three SRs, fair in another four SRs while the rest were in a good condition.

Some of the practices followed by the farmers were observed to worsen the degradation of the embankments. In some cases, farmers had dug 10-30 cm deep trenches on the embankments to pass water hoses while pumping from the reservoir for crop irrigation downstream, a practice that may degrade the embankments (Figure 6). There was thick growth of shrubs and small trees (Figure 7) on the embankments of most of the SRs. Plant roots create crevices which increase piping or water movement within the earthen embankments (Table 3). In addition to a high level of erosion and gully formation on the downstream side of the embankments, cracks and seepage were observed at the toes and shoulders of the spillways and embankments of some of the dams (Figures 6-11). About 40% of the structures showed a high level of cracks in the spillways and seepage from the embankments. In this respect, our study supported the findings of Lukman et al. (2011), who highlighted poor slope protection, erosion-beaching, vegetative growth, debris burrows or animal burrowing as unusual conditions on the upstream and downstream sides of an embankment. These require monitoring and prompt attention as part of embankment maintenance. Our direct observations and the responses of stakeholders showed that maintenance of these SRs has been neglected for a long time.

The poor state of the spillways impacted the storage capacity and performance of the reservoirs. In 19 out of the 20 SRs surveyed, the most common spillway type seen was the uncontrolled side channel, stepped spillway. The spillway widths in our study ranged from 10 m to 25 m. SR17 (Ikose) has an uncontrolled open ogee crested spillway, 20 m long; it is equipped with three intake gated pipes and three low lift pumps to feed a conventional treatment plant for public water supply. At the time of the study, the treatment plant had been out of operation for the past ten years. The spillways in the worst state were found in Ago Are (SR2), Oje Owode (SR4), Iganna (SR9) and Ado Awaye (SR11). The SR11 spillway was not completed, which led to further deterioration. The poor state of the spillways affects the water level in the SRs. On average, water levels were found to be lower than the designed levels because of spillway leakages. Only the Sepeteri (SR6) spillway structure was in an excellent state.

These faults are among the problems identified in Enplan Group (2004) and confirmed by Lukman et al. (2011). These problems are common among SRs across West Africa; for example, Agyare et al. (2008) observed that neglect of dams and reservoirs is a major problem in Ghana owing to dwindling funds as the number of SRs increases.

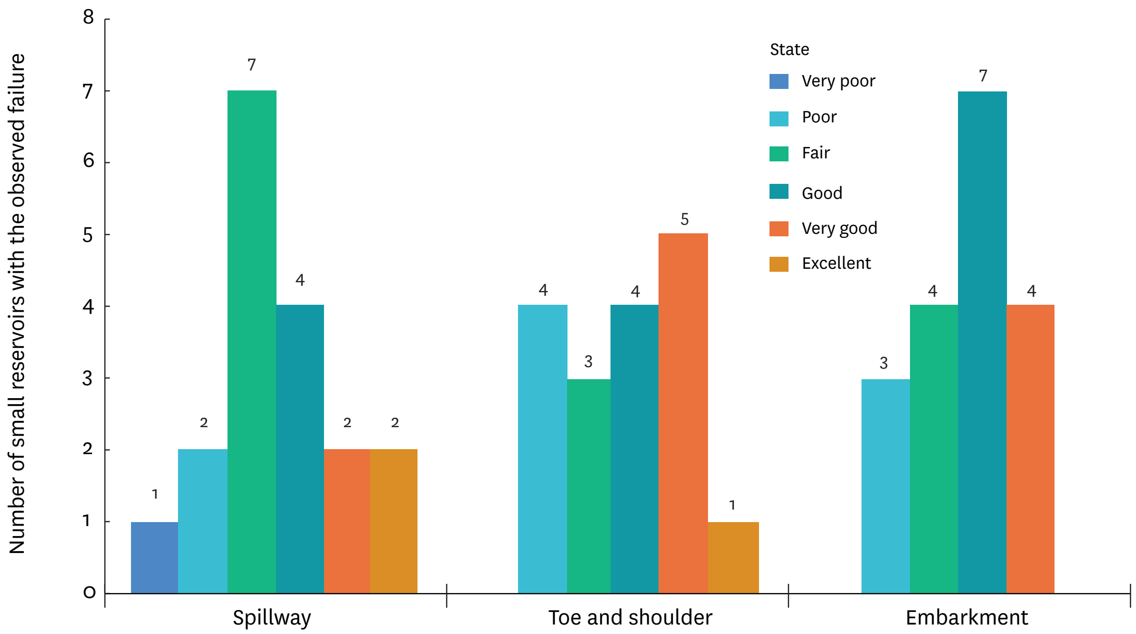

Figure 5. Ratings given to the state of dam elements.

Figure 6. Erosion of the embankment of the Oje Owode Dam (SR4).

Figure 7. Shrub growth on the embankment of the Ago Are Dam (SR2).

Figure 8. Failed spillway of the Ado Awaye SR (SR11).

Figure 9. Cracks in the side of the Alabata SR (SR1) spillway.

Figure 10. Cracks in the spillway at Igbeti (SR13).

Figure 11. A break in the embankment of the Akufo SR (SR18).

Table 3. State of hydraulic structures and observed failures in small reservoir (SR) dam structures.

SR no.	SR name	State of hydraulic structures[a]			Observed failure			State of reservoir area (RA)
		Spillway (0-5)	Toe, shoulder (0-5)	Embankment (0-5)	Piping	Cracks	Seepage	
SR1	Alabata	2	1	4	Low	Low	Very high	15-20% of RA lost to reeds. Overgrowth of shrubs on embankment.
SR2	Ago Are	1	1	3	Low	High	High	40% of RA lost to vegetation, siltation is evident.
SR3	Irawo	2	4	4	None	Low	Low	Vegetation problem is minimal. Overgrowth of shrubs on embankment.
SR4	Oje Owode	2	1	1	High	Very high	Low	10-20% of RA lost to reeds. Vegetation problems, embankment in a poor state with overgrowth of shrubs.
SR5	Ago Amodu	3	3	2	Low	Low	High	30% of RA lost to vegetation.
SR6	Sepeteri	5	4	4	None	None	None	In good state. Embankment has shrubs.
SR7	Ogbooro	2	2	2	Low	Low	Low	Minimal vegetation problem. Embankment being eroded, overgrowth of shrubs.
SR8	Ilero	4	3	3	Low	Low	Low	About 10% of RA lost to vegetation. Embankment compromised with overgrowth of shrubs.
SR9	Iganna	1	1	1	Low	High	Low	25% of RA lost to vegetation. Embankment compromised.
SR10	Ilua	2	2	1	Low	High	High	20% of RA lost to vegetation. Embankment compromised.
SR11	Ado Awaye	0	0	2	Low	High	High	Reservoir is in good state, embankment in good condition.
SR12	Igboho	3	3	2	High	High	Low	Minimal vegetation problem. Embankment in a fair state.
SR13	Igbeti	2	2	2	High	High	Low	15% of RA lost to vegetation. Embankments compromised.
SR14	Okeho	2	3	3	High	Low	High	25% vegetation problem, siltation and overgrowth of shrubs on embankment.
SR15	Kishi	3	4	3	Low	None	Low	Minimal vegetation problem. Reservoir is in a good state.
SR17	Ikose	5	5	4	Low	Low	Low	Reservoir in a good state. Embankment is sound.
SR18	Akufo	3	3	2	Low	Low	High	15% of RA lost to vegetation. Embankment in a fair state with some growth of shrubs.
SR19	Fasola	4	4	3	Low	Low	Low	Reservoir silted and vegetation problem very high
SR20	Eruwa	3	4	4	Low	Low	Low	Reservoir in a good state. Embankment is sound.

Note:
[a] The rating and assessment of different structures has been defined in Table 1.

Irrigation Infrastructure and Equipment

Small reservoirs provide an opportunity for year-round agricultural production, which can significantly contribute to smallholder farmers' livelihoods. Seventeen of the 20 reservoirs in our study have intake and pump houses, but none had a functional pump for water lifting. Ninety percent of the reservoirs had no network of canals or other field irrigation infrastructure such as conveyance systems (pipes or canals) for irrigation activities. This is because, primarily, the reservoirs were intended for domestic water supply. This makes water conveyance from the reservoirs for the purpose of farmer-led irrigation a difficult task. At reservoirs SR1 and SR17, a few pipe networks were installed by the government but were inadequate for the potential cultivable command area (Table 2).

Types of Smallholder Water Conveyance Practices

A fraction of irrigable land under cultivation in reservoirs SR1 (25%) and SR17 (10%) was equipped with a network of conveyance pipes and hydrants for irrigation water supply. There were two types of water conveyance systems in these SRs:

1. *Gravity-based pipe conveyance*. Reservoir SR1 has more water stored for irrigation but inadequate water infrastructure limits farmers' access to the water. The pipe conveyance, designed to take advantage of gravity from the intake gate, consists of a system of pipes and hydrants at the irrigation water points. The network was planned to irrigate 2.5 ha (Figure 12). However, the system does not impart enough water pressure beyond about 200 m downstream of the dam. The main problem is the pressure loss along the line; hence there is reduced flow as distance increases from the dam. However, a major advantage of gravity-based pipe conveyance is that farmers do not have to bear the major costs of operation and maintenance and energy for pumping. However, farmers beyond the viable area do not have sufficient water unless they invest in a booster pump. By improving the design, or by installing a low-energy booster pump, more areas can be brought under cultivation over and above the 2.5 ha that are currently being irrigated. This solution is being explored by a few farmers who on their own have bought small pumps to boost the discharge. More of the stored water could be put to use if the needed conveyance infrastructure including access to pumps for water lifting and distribution is engaged. This will boost FLI practices around these SRs.

2. *Pump-operated pipe conveyance system*. The pipe conveyance system at SR17 (2 ha) was designed to be pump-operated. It comprises a 4-inch mainline and 2-inch lateral lines spaced at 20 m. Each lateral line is 50 m in length with five hydrants at 10 m intervals. However, the pump and conveyance system at SR17 has been abandoned (Figure 13) and farmers have resorted to using individual motorized pumps for irrigation. They cannot pool their resources to operate the low lift pump required for the network as the operation and maintenance costs are beyond their capacity. This inability to operate a shared system may also be due to a lack of cooperation among the farmers. However, they operate small pumps for their own farms while abandoning the shared network—a phenomenon also observed in Ethiopia (Dessalegn and Merrey 2015).

Experience with the use and management of these two conveyance systems suggests the following:

- Well-designed pipe conveyance systems based on gravity can serve the needs of irrigators within SRs. This pipe conveyance option almost completely eliminates the evaporation and water losses associated with open canals and field channels.

- Even in areas where a gravity system cannot serve fields far from the reservoir, with adequate mainline size, low-energy pumps could boost pressure and improve discharge.

Figure 12. The intake end of SR1 (left) and the gravity-based pipe conveyance system (right).

Figure 13. The abandoned pump-operated conveyance pipe network at Ikose (SR17).

- Joint ownership of the pumping and pipe network may not be effective in a farmer-led system. Operating and maintaining a jointly-owned network can be challenging. Some studies have documented the efficacy of farmers having independent irrigation systems (e.g., DWFI 2018; de Fraiture et al. 2014).

- Some of the SRs indeed have more stored water available for crop production. However, there is an economic water scarcity that is associated with the energy and infrastructure needed to pump and distribute water. By and large, irrigation is energy-limited. Introduction of low-cost renewable energy solutions could address some of these challenges.

3. *Direct pumping using small petrol pumps*. In the case of SRs without conveyance structures, farmers depend entirely on their own water pumps and hose reel for lifting and conveying water to their farms. Farmers said they find the use of petrol engine-powered 5.0-6.5 hp surface pumps (Figures 14 and 15) most feasible, as has also been observed by Frenken (2005). No farmers use buckets or watering cans. Individual investment in pumps is increasingly common, as it is in other West African countries (Merrey and Lefore 2018; de Fraiture et al. 2014). Van de Giesen et al. (2008) observed that SRs have huge advantages, including improving water availability at the village level. These advantages, however, will be fully realized when they are properly managed with adequate ancillary infrastructure.

Figure 14. Small pump from the Ikose SR (SR17).

Figure 15. Pumping from the silted Ago Are SR (SR5).

Irrigation Practices

In most SRs, farmers use surface and hose sprinkling irrigation methods (Figure 16). Furthermore, Figures 17-19 show some of the irrigation practices followed within FLI systems around SRs. There were no conventional sprinkler or drip irrigation systems in any of the SRs we studied. In SR6, there was one private farmer with a center pivot (50 m span) for cereal production. This was the only private commercial enterprise seen in any of the SRs. In basin and furrow irrigation, water is released into the basin and allowed to flow along the poorly designed field slope. Irrigation time is based on soil surface dryness without considering crop water requirement or water depletion in the soil profile. Therefore, over-irrigation is common, leading to ponding and uneven distribution of water. Over- or under-irrigation affects irrigation efficiency and water productivity. On the other hand, pressurized hose sprinkling involves considerable drudgery because of the weight of the hose reel under pressure.

We found that the farmers' technical knowledge of irrigation was largely low. Irrigation practices in the study area were based on trial and error or copying other farmers irrespective of differences in crop water requirement. Eighty percent of the farmers in our study mentioned that they had not had any irrigation training through extension services or developmental projects. Leveraging the farmers' willingness to learn from one another and increased capacity building will increase the ability of FLI actors to improve irrigation efficiency even with limited affordable technologies. Where access to water is through individual water-lifting with its associated operational costs, efficient use of water can reduce costs and increase benefits. Therefore, improving farmers' technical capacity could substantially increase water productivity and reduce poverty (Burney and Naylor 2012; Hanjra et al. 2009).

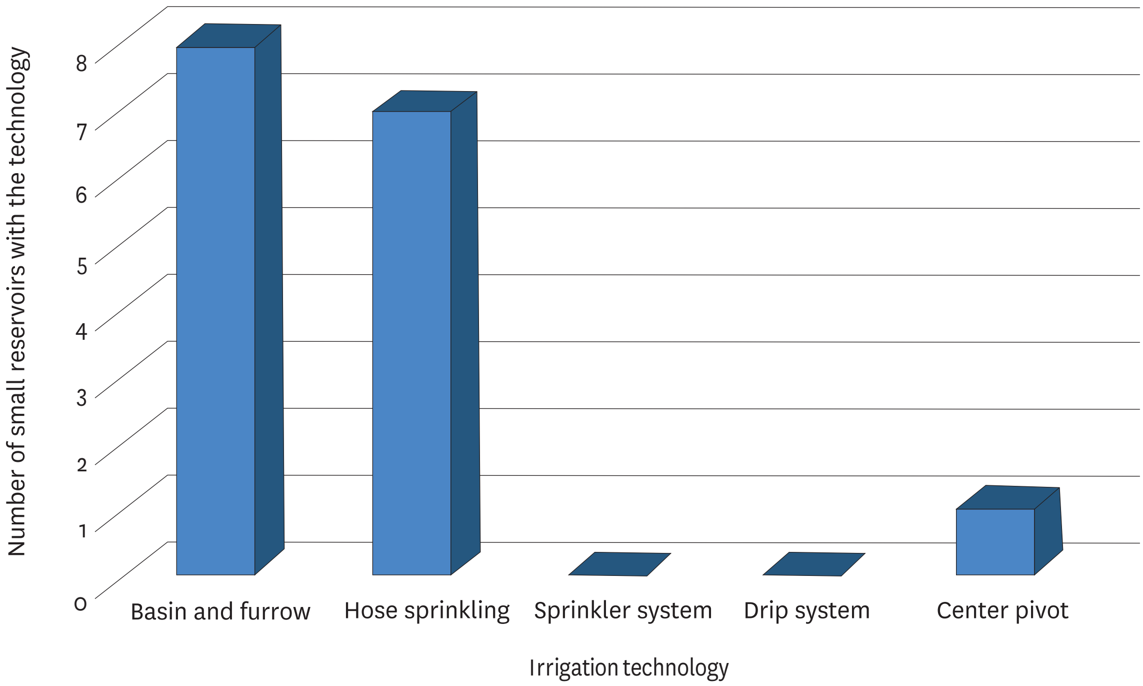

Figure 16. Irrigation methods used in the SRs.

Gender and Inclusive Participation

Men comprised 95% of the irrigators in the Ogun watershed on account of the fact that they have land and access to water and irrigation equipment. At nearly all the SRs, women were predominantly involved as buyers of produce. They buy vegetables, maize and other crops at the farm gate and transport the produce to markets for sale. Although a few (male) farmers did transport their produce directly to markets, most of them depended on women to sell their produce. Women play a major role in fixing the farm gate prices. Their participation in the marketing chain is likely more profitable to them than would be possible if they were involved only in crop production.

Agronomy and Sustainable Production Environment

Major Crops Cultivated in the Small Reservoirs

Vegetables including amaranth (*Amaranthus spp*), jute mallow (*Corchorus olitorius*), ugwu (*Telfairia occidentalis*), okra (*Abelmoschus esculentus*), watermelon (*Citrullus lanatus*) and cucumber (*Cucumis sativus*) are among the major crops produced around the SRs. A few farmers also cultivate off-season maize and rice using supplemental irrigation with residual moisture from late-season rainfall. De Fraiture and Giordano (2014) observed that short-duration crops with low water requirement such as

Figure 17. Okra grown under basin irrigation at the Ikose Dam (SR6).

Figure 18. Maize cultivated under surface irrigation at the Ikose Dam.

Figure 19. Vegetables, okra and pepper grown under pressurized hose sprinkling at the Ilero SR (SR8).

vegetables were of major interest to farmers around SRs. This choice of crops may be related to the high demand for them in the dry season and the good income with minimal investment per unit of land. The freedom to decide what crops will be cultivated based on economic considerations is a major benefit offered by farmer-led systems over major irrigation systems (de Fraiture and Giordano 2014; Burney and Naylor 2012).

Access to Inputs

Access to inputs is critical to achieving high productivity in smallholder systems. Farmers source inputs such as seeds, pesticides and fertilizer from the open market in all the SRs we studied. This makes farmers open to variations in the quality of materials. However, they devised alternative means through partnerships to procure inputs from major suppliers. This reduces the unit price and ensures input quality. The lack of extension services and technical support from government agricultural development officers is a major limitation to improving production. Often, challenges relating to soil fertility, pests and diseases, water quality and access to markets are not readily addressed.

Accessing Finance

The farmers in our study area are directly responsible for financing their activities with no support from the government or other sources. Lack of access to financial support has been a major impediment to increasing farmers' investments in irrigation in SSA (AgWater Solutions 2011; DWFI 2018; Woodhouse et al. 2017; Merrey and Lefore 2018). Farmers, therefore, are making efforts to leverage cooperation among themselves through commodity associations, cooperative societies and such partnerships to address this limitation of lack of access to funding for inputs and equipment. These informal financial support alternatives include joint procurement of inputs and equipment, flexible loan systems and supporting one another with mutual labor or services. This type of partnership has also been observed in Burkina Faso and Ghana (Poussin et al. 2015; de Fraiture et al. 2014), especially for dry-season crop production, which is often profitable. Many more farmers were willing to be involved in irrigation if given proper training and access to support, especially for purchasing motorized pumps. Motorized pumps have been acknowledged as a major boost for farmer-led irrigated crop production around many SRs in West Africa (de Fraiture et al. 2014; AgWater Solutions 2011).

Marketing

Access to markets is critical to achieving the potential economic benefits of smallholder irrigation. Most farmers sell at farm gate prices, which do not support sustained production. That is because there is a glut of perishable crops in the limited local market where everybody sells, and few farmers have the means to transport their produce to the city. This situation discourages investment in improved irrigation systems. Although this does not mean that there are no markets for the produce (e.g., vegetables in the dry season), the challenge of logistics to access markets, which often are in distant cities, remains the main concern. Woodhouse et al. (2017) observed that poor market access remains a major limiting factor in increasing the economic productivity of small-scale irrigation systems. Nkoka et al. (2014) observed that farmer-led furrow irrigation development in Tsangano, in northern Malawi, increased rapidly under the influence of informal regional market links for the sale of potatoes in Malawi, Zambia and even Tanzania. In Accra also, good markets for horticultural products drive urban and peri-urban smallholder vegetable production using wastewater (Drechsel and Keraita 2014). Good market access enables a higher return on investments.

Reservoir Management

Interagency collaboration, or the lack of it, affects the management of small reservoirs. Thirteen (70%) of the dams in our study are owned by the Agricultural Development Program, while five belong to the Water Corporation of Oyo State (Table 2). This is because the primary focus of these SRs was rural domestic water supply and limited irrigation. This partly explains why there is limited irrigation infrastructure in some of the SRs. One of the SRs (SR6) is under the management of the Federal Government's Ogun-Osun River Basin Development Authority (OORBDA) which has the mandate to develop irrigation potential within the basin. However, except where there is a clear understanding among farmers that the dams are the property of the state government, and barring the occasional visit by officers from the Ministry of Agriculture or the Oyo State Agricultural Development Program (OYSADEP), farmers are directly in charge of various operations, irrigation activities and conflict resolution within the SRs.

There is a huge institutional and governance structural gap and a lack of integration among the stakeholders within the SRs. There are no formal platforms, mechanisms or structures for the engagement of stakeholders in reservoir management. There are no specific management principles, such as public-private partnerships, participatory irrigation management or water user associations and no arrangements for water abstraction. Farmers take water as they see fit. There is no regulation or control of over-abstraction and no policy to protect against abuse or any effort toward increasing water productivity. Ease of operation is one of the advantages of SRs, which explains why without the presence of any technical institution, farmers employ simple water lifting and application methods (Ayantunde et al. 2016). This 'lift as you need' regime allows irrigators the freedom to use water as needed; there is no check on the volume of water used, nor any monitoring of the reservoir storage level. Expectedly, water levels decrease during the dry season, but the reservoirs do not dry up. This situation, however, may become worse when more farmers become active irrigators. Farmers believe that the reservoir will get replenished in the wet season even if there is over-abstraction. The situation calls for an integration of agricultural water users and other actors and governance structure/institutions to ensure joint decisions on safe and sustainable use of water from the SRs, removal of abuses and guidance against over-abstraction.

With a possible increase in demand from other water uses, such as domestic water supply and livestock watering, there is potential for conflict. These other users lift water using buckets and tankers. Informal structures such as cooperative or commodity associations currently coordinate issues among the water users. The overall aim of these associations is to offer the needed support and facilitate government assistance to their members to improve water use. These associations currently maintain equity and lead conflict resolution when needed. These groups could be restructured to operate a participatory water and irrigation management arrangement around the SRs. They can become water user associations to exercise more oversight on abstraction and water allocation. They can also become platforms for disseminating improved water management technologies, knowledge sharing, facilitation of capacity building and conflict resolution among water users. Developing and supporting these structures is key in improving FLI practices around SRs.

Conclusion and Recommendations

Currently, the productivity and profitability of irrigated agriculture in the Ogun watershed are very low. The potential of SRs to support FLI is high. However, a more sustainable approach is needed for the management of SRs and to strengthen farmers' capacities. Although the government of Nigeria is planning to increase national irrigation commands by investing in the development of large-scale schemes, the experience from the Ogun watershed shows that creating sound and sustainable inclusive governance structures around existing water structures, revamping the existing small reservoirs and supporting FLI around them through a combination of capacity strengthening, access to resources, bridging the logistics gap between production systems and markets are key factors that could contribute substantially to irrigated crop production. With the increasing need for climate change adaptation strategies to improve the resilience of farming systems, more farmers are now showing an interest in irrigation, especially use of water resources within their domains.

To strengthen the resilience of smallholder farmers and to minimize the constraints to their investment and production, we make the following recommendations.

1. *Strengthening coordination and management among water users*. The weak institutional and governance structure around all the SRs is very evident. There is an urgent need to strengthen synergy and partnerships among the various actors and key institutions to ensure a strong platform for coordination, management and control of activities around the SRs. The water users currently include irrigators, livestock pastoralists and domestic water tank owners. Presently, water lifting is done without recourse to long-term sustainability of the structures. There is a need for a platform to better manage the volume of water lifted from these reservoirs and ensure that allocations to different users are done in a coordinated and sustainable way. This could be achieved by transforming different commodity associations into water user associations to adopt and implement sustainable management of the SRs. In addition, governments should consider developing long-term support programs to strengthen local communities' efforts to manage their SRs (Owusu et al. 2022).

2. *Repair and maintenance of dam structures*. To ensure that the structural health of the dams is kept intact, there is an urgent need to repair the embankments and spillways of most of the dams. This is necessary to halt the observed degradation that may eventually lead to collapse of these dams if unchecked. A joint approach could be promoted among all the stakeholders to agree on how these structures will be continually protected from the observed abuses. This could be accomplished if farmers and other water users around the reservoirs took more ownership of the systems. They currently take the lead in using the system, but it will be beneficial if they develop a mindset to be responsible for system maintenance rather than expect government intervention.

3. *Revamping of reservoirs*. Restoration of the storage capacities of these SRs will ensure that water is available for irrigation and other demands and for possible expansion of the irrigated area. While this may be capital-intensive, one approach would be to, first, support farmers to focus on cultivating downstream of the reservoirs rather than upstream to reduce the sediment load in the reservoirs. Although small reservoirs are of small capacity by design, proper estimation and water balance are required to ensure that the objectives (domestic supply, irrigation and sundry uses) of the reservoirs are realized over a reasonable year even at small capacity. The reservoirs we studied have suffered from neglect and require flushing or dredging to recover lost reservoir volumes and removal of aquatic weeds. It is also important to control grazing and tillage activities upstream to reduce sediment release into the reservoir. Second, intervention and support from both government authorities and nongovernmental organizations will be required. Over time, it is expected that the farmers will operate the reservoirs so that storage capacities are protected.

4. *Capacity building in efficient irrigation practices*. To improve irrigation practices and water productivity around the reservoirs, there is a need to build the capacity of farmers. Irrigation methods can be improved with training and extension services. The numerical strength and capacity of the extension systems should be reviewed to provide further training where necessary. Thus, a multilevel capacity-building effort across various actors—water users, governing institutions, extension service providers—may be required. Some of the problems relating to the management of the structures, such as digging over the embankment, poor management of intake pipes, and planting in the reservoir during low periods, can be corrected with better training. There is also a need to re-orientate farmers and other water users toward better water management practices.

5. *Improved watershed management and control of practices causing degradation of reservoir infrastructure*. Many activities contribute to reservoir degradation, such as uncontrolled tillage, grazing, unregulated pesticide application and fertilizer use. These have a direct impact on the health and ecosystem of the reservoirs. These practices should not be permitted upstream of the reservoirs. The creation of buffer zones around the reservoirs would reduce the inflow of pollutants. There is a need for an integrated and participatory management platform that will ensure that different components

of the watershed work in agreement with a focus on sustainability. An integrated watershed evaluation is key in this regard. Concerted efforts are required by the stakeholders—water user associations, management institutions, research agencies and other actors—to ensure a constant evaluation of activities around the reservoirs and to promote best management practices. Also, there is a need to strengthen data gathering on the state of the reservoirs, water abstraction, sedimentation rates and pollution levels to improve the health management of the system.

6. *Support for smallholder access to inputs, markets and gender inclusion*. Irrigators can make more profitable use of SRs if there is an adequate production environment. Access to production inputs (e.g., quality seed, fertilizer, tillage equipment), linking farmers with markets and off-takers, and support for increased access to equipment are some of the requirements to improve these production systems. Presently, men are the major actors in FLI while youth participation is on the increase. Access to land in the watershed is a major challenge. Nevertheless, the involvement of women in marketing farm produce seems more acceptable to the women than involvement in direct crop production. Poor market access due to the observed logistics gap often creates a pseudo glut in the local market whereas the products (vegetables, for instance) are in high demand in the cities.

The hundreds of small reservoirs in Nigeria represent investments already made but not yet producing at the full potential. This study has shown that in the Ogun watershed, and undoubtedly across other river basins as well, creation of appropriate institutions and governance structures around these reservoirs, modest investments in building farmers' capacities and provision of adequate support can improve the productivity of small reservoirs, promote sustainable livelihoods and have a positive impact on food security in the country.

References

Abric, S.; Sonou, M.; Augeard, B.; Onimus, F.; Durlin, D.; Soumaila, A.; Gadelle, F. 2011. *Lessons learned in the development of smallholder private irrigation for high-value crops in West Africa*. Joint Organizational Discussion Paper 4. Washington, DC, USA: World Bank. http://hdl.handle.net/10986/27375

Adelodun, B.; Choi, K.-S. 2018. A review of the evaluation of irrigation practice in Nigeria: Past, present and future prospects. *African Journal of Agricultural Research* 13(40):2087–2097. https://doi.org/10.5897/AJAR2018.13403

AgWater Solutions. 2011. *Small reservoirs in sub-Saharan Africa*. Agricultural Water Management Learning and Discussion Brief, September 2011. Available at http://awm-solutions.iwmi.org/Data/Sites/3/Documents/PDF/publication-outputs/learning-and-discussion-briefs/small-reservoirs-in-sub-saharan-africa.pdf (accessed on September 1, 2022).

Agyare, W.A.; Kyei-Baffour, N.; Ayariga, R.; Gyasi, K.O.; Barry, B.; Ofori, E. 2008. Irrigation options in the Upper East Region of Ghana. In: Humphreys, E.; Bayot, R.S. (eds.) *Increasing the productivity and sustainability of rainfed cropping systems of poor smallholder farmers: Proceedings of the CGIAR Challenge Program on Water and Food International Workshop on Rainfed Cropping Systems, Tamale, Ghana, 22-25 September 2008*. Colombo, Sri Lanka: The CGIAR Challenge Program on Water and Food. pp. 259–268. Available at https://assets.publishing.service.gov.uk/media/57a08b56e5274a27b2000ab5/CPWF_Proceedings_Rainfed_Workshop_1_.pdf (accessed on September 1, 2022).

Alam, M. 1991. Problems and potential of irrigated agriculture in sub-Saharan Africa. *Journal of Irrigation and Drainage Engineering* 117(2):155–172. https://doi.org/10.1061/(ASCE)0733-9437(1991)117:2(155)

Auta, S.J.; Dafwang, I.I. 2010. The agricultural development projects (ADPs) in Nigeria: Status and policy implications. *Research Journal of Agriculture and Biological Sciences* 6(2):138–143.

Ayantunde, A.A.; Karambiri, M.; Yameogo, V.; Cofie, O.O. 2016. *Multiple uses of small reservoirs in crop-livestock agro-ecosystems of the Volta River Basin with an emphasis on livestock management*. Colombo, Sri Lanka: International Water Management Institute (IWMI). 29p. (IWMI Working Paper 171). https://doi.org/10.5337/2016.215

Burney, J.A.; Naylor, R.L. 2012. Smallholder irrigation as a poverty alleviation tool in sub-Saharan Africa. *World Development* 40(1):110–123. https://doi.org/10.1016/j.worlddev.2011.05.007

Chukwuemeka, E.; Nzewi, H.N. 2011. An empirical study of World Bank agricultural development programme in Nigeria. *American Journal of Social and Management Sciences* 2(1):176–187. Available at http://www.scihub.org/AJSMS/PDF/2011/1/AJSMS-2-1-176-187.pdf (accessed on September 5, 2022).

Daneji, M.I. 2011. Agricultural development intervention programmes in Nigeria (1960 to date): A review. *Savannah Journal of Agriculture* 6(1):101–107. Available at https://nairametrics.com/wp-content/uploads/2013/03/SJA_101_1071.pdf (accessed on September 5, 2022).

DWFI (Daugherty Water for Food Global Institute). 2018. *Pathways to increasing farmer-led investments in sustainable agricultural water management in sub-Saharan Africa*. Working Paper. Lincoln, Nevada, USA: Robert B. Daugherty Water for Food Global Institute at the University of Nebraska. Available at https://waterforfood.nebraska.edu/-/media/projects/dwfi/resource-documents/reports-and-working-papers/pathways-to-increasing-farmerled-investments-in-sustainable-agricultural-water-management-in-subsaha.pdf (accessed on September 5, 2022).

de Fraiture, C.; Giordano, M. 2014. Small private irrigation: A thriving but overlooked sector. *Agricultural Water Management* 131:167–174. https://doi.org/10.1016/j.agwat.2013.07.005

de Fraiture, C.; Kouali, G.N.; Sally, H.; Kabre, P. 2014. Pirates or pioneers? Unplanned irrigation around small reservoirs in Burkina Faso. *Agricultural Water Management* 131:212–220. https://doi.org/10.1016/j.agwat.2013.07.001

Dessalegn, M.; Merrey, D.J. 2015. Motor pump revolution in Ethiopia: Promises at a crossroads. *Water Alternatives* 8(2):237–257. Available at https://www.water-alternatives.org/index.php/alldoc/articles/vol8/v8issue2/289-a8-2-12/file (accessed on September 5, 2022).

Drechsel, P.; Keraita, B. (Eds.) 2014. *Irrigated urban vegetable production in Ghana: Characteristics, benefits and risk mitigation*. 2nd edition. Colombo, Sri Lanka: International Water Management Institute (IWMI). 247p. https://doi.org/10.5337/2014.219

Enplan Group. 2004. *Review of the public irrigation sector in Nigeria*. Report No. 0009/TF/NIR/CPA/27277-2002/TCOT. Abuja, Nigeria: Federal Ministry of Water Resources/Food and Agriculture Organization of the United Nations (FAO).

FAO (Food and Agriculture Organization of the United Nations). 2021. *Nigeria at a glance*. Available at http://www.fao.org/nigeria/fao-in-nigeria/nigeria-at-a-glance/en (accessed October 2, 2021).

Frenken, K. (Ed.) 2005. *Irrigation in Africa in figures: AQUASTAT survey - 2005*. FAO Water Reports 29. Rome, Italy: Food and Agriculture Organization of the United Nations (FAO). Available at https://www.fao.org/publications/card/en/c/A0232E/ (accessed on September 5, 2022).

Hanjra, M.A.; Ferede, T.; Gutta, D.G. 2009. Reducing poverty in sub-Saharan Africa through investments in water and other priorities. *Agricultural Water Management* 96(7):1062–1070. https://doi.org/10.1016/j.agwat.2009.03.001

Inocencio, A.; Kikuchi, M.; Tonosaki, M.; Maruyama, A.; Merrey, D.; Sally, H.; de Jong, I. 2007. *Costs and performance of irrigation projects: A comparison of sub-Saharan Africa and other developing regions*. Colombo, Sri Lanka: International Water Management Institute (IWMI). 81p. (IWMI Research Report 109). https://doi.org/10.3910/2009.109

Irrigation and Drainage Department. 2021. *Irrigation in Nigeria: Towards national food security*. Irrigation and Drainage Department, Federal Ministry of Water Resources. Abuja, Nigeria:

Keller, A.; Sakthivadivel, R.; Seckler, D. 2000. *Water scarcity and the role of storage in development*. Colombo, Sri Lanka: International Water Management Institute (IWMI). 21p. (IWMI Research Report 39). https://doi.org/10.3910/2009.046

Kortenhorst, L.F.; van Steekelenburg, P.N.G.; Sprey, L.H. 1989. Prospects and problems of irrigation development in Sahelian and sub-Saharan Africa. *Irrigation and Drainage Systems* 3:13–45. https://doi.org/10.1007/BF01102814

Kyei-Baffour, N.; Ofori, E. 2006. Irrigation development and management in Ghana: Prospects and challenges. *Journal of Science and Technology* (Ghana) 26(2):148–159. https://doi.org/10.4314/just.v26i2.32996

Ladan, S.I. 2014. An appraisal of climate change and agriculture in Nigeria. *Journal of Geography and Regional Planning* 7(9):176–184. https://doi.org/10.5897/JGRP2013.0405

Liebe, J.R.; Andreini, M.; van de Giesen, N.; Steenhuis, T.S. 2007. The small reservoirs project: Research to improve water availability and economic development in rural semi-arid areas. In: Kitissou, M.; Ndulo, M.; Nagel, M.; Grieco, M. (eds.) *The hydropolitics of Africa: A contemporary challenge*. Newcastle, UK: Cambridge Scholars. pp.325–332. https://hdl.handle.net/10568/37365

Lukman, S.; Otun, J.A.; Adie, D.B.; Ismail, A.; Oke, I.A. 2011. Brief assessment of a dam and its failure prevention. *Journal of Failure Analysis and Prevention* 11:97–109. https://doi.org/10.1007/s11668-010-9420-1

Merrey, D.J.; Lefore, N. 2018. *Improving the availability and effectiveness of rural and "micro" finance for small-scale irrigation in Sub-Saharan Africa: A review of lessons learned*. Colombo, Sri Lanka: International Water Management Institute (IWMI). 46p. (IWMI Working Paper 185). https://doi.org/doi: 10.5337/2018.225

Moro, M.O.; Onoja, S.B. 2006. Utilization of shallow aquifers for small scale irrigation: a case study of Agatu Local Government Area of Benue State, Nigeria. *Nigerian Journal of Technology* 25(2):59–65. Available at https://www.ajol.info/index.php/njt/issue/view/12834 (accessed on September 5, 2022).

NEPAD (New Partnership for Africa's Development). 2003. Comprehensive Africa Agriculture Development Programme (CAADP). Midrand, South Africa: NEPAD. Available at https://www.nepad.org/cop/comprehensive-africa-agriculture-development-programme-caadp (accessed on September 5, 2022).

Nkoka, F.; Veldwisch, G.J.A.; Bolding, J.A. 2014. Organisational modalities of farmer-led irrigation development in Tsangano District, Mozambique. *Water Alternatives* 7(2):414–433. Available at https://www.water-alternatives.org/index.php/alldoc/articles/vol7/v7issue2/254-a7-2-7/file (accessed on September 5, 2022).

Nwankwoala, H.O. 2015. Hydrogeology and groundwater resources of Nigeria. *New York Science Journal* 8(1):89–100. Available at http://www.sciencepub.net/newyork/ny080115/014_27934ny080115_89_100.pdf (accessed on September 5, 2022).

Ogbalubi, L.N.; Wokocha, C.C. 2013. Agricultural development and employment generation: The Nigeria experience. *IOSR Journal of Agriculture and Veterinary Science* 2(2):60–69. https://doi.org/10.9790/2380-0226069

Ogunjimi, L.A.O.; Adekalu, K.O. 2002. Problems and constraints of small-scale irrigation (Fadama) in Nigeria. *Food Reviews International* 18(4):295–304. https://doi.org/10.1081/FRI-120016207

Ogunsola, O.E.; Yaya, O.S. 2019. Maximum and minimum temperatures in south-western Nigeria: Time trends, seasonality and persistence. *Journal of Physics: Conference Series* 1299:1–10. https://doi.org/10.1088/1742-6596/1299/1/012057

Oke, A.O.; Are, K.S.; Adelana, A.O. 2015. Hydrological potential of ephemeral rivers and streams for water harvesting using micro check-dam technology in Ogun Watershed, South-Western Nigeria. *Moor Journal of Agricultural Research* 15:80–93.

Oke, A.O.; Sangodoyin, A.Y.; Ogedengbe, K.; Omodele, T. 2013. Mapping of river water quality using inverse distance weighted interpolation in Ogun-Osun River Basin, Nigeria. *Landscape and Environment* 7(2):48–62. Available at https://ojs.lib.unideb.hu/landsenv/article/view/2301

Okeke, O.C.; Onyekuru, S.O.; Uduehi, G.; Israel, H.O. 2011. Geology land hydrogeology of Northern Ishan district, Edo State, Southwestern Nigeria. *International Research Journal of Geology and Mining* 1(1):1–11.

Okolo, D.A. 2006. *Agricultural development and food security in Sub-Saharan Africa: Building a case for more public support—the case of Nigeria*. Working Paper No. 05. Paper prepared for the Policy Assistance Unit of the FAO Subregional Office for East and Southern Africa. Rome, Italy: Food and Agriculture Organization of the United Nations (FAO). Available at http://www.fao.org/3/a0817e/a0817e.pdf (accessed on September 1, 2022).

Owusu, S.; Cofie, O.; Mul, M.; Barron, J. 2022. The significance of small reservoirs in sustaining agricultural landscapes in dry areas of West Africa: A review. *Water* 14(9):1440. https://doi.org/10.3390/w14091440

Palanisami, K.; Meinzen-Dick, R.; Giordano, M.; van Koppen, B.; Ranganathan, C.R. 2011. Tank performance and multiple uses in Tamil Nadu, South India–comparison of 2 time periods (1996–97 and 2009–10). *Irrigation and Drainage Systems* 25:121–134. https://doi.org/10.1007/s10795-011-9114-1

Poussin, J.-C.; Renaudin, L.; Adogoba, D.; Sanon, A.; Tazen, F.; Dogbe, W.; Fusillier, J.-L.; Barbier, B.; Cecchi, P. 2015. Performance of small reservoir irrigated schemes in the Upper Volta basin: Case studies in Burkina Faso and Ghana. *Water Resources and Rural Development* 6:50–65. http://dx.doi.org/10.1016/j.wrr.2015.05.001

Roost, N.; Cai, X.L.; Molden, D.; Cui, Y.L. 2008. Adapting to intersectoral transfers in the Zhanghe Irrigation System, China: Part I. In-system storage characteristics. *Agricultural Water Management* 95(6):698–706. https://doi.org/10.1016/j.agwat.2008.01.010

Saruchera, D.; Lautze, J. 2019. *Small reservoirs in Africa: A review and synthesis to strengthen future investment*. Colombo, Sri Lanka: International Water Management Institute (IWMI). 40p. (IWMI Working Paper 189). https://doi.org/10.5337/2019.209

Skinner, J.; Niasse, M.; Haas, L. (Eds.) 2009. *Sharing the benefits of large dams in West Africa*. Natural Resource Issues No. 19. London, UK: International Institute for Environment and Development (IIED).

Stephens, T. 2010. *Manual on small earth dams: A guide to siting, design and construction*. FAO Irrigation and Drainage Paper 64. Rome, Italy: Food and Agriculture Organization of the United Nations (FAO). 124p. Available at https://www.fao.org/publications/card/en/c/8c4e96a6-1c34-5cc5-879d-10320bb9d7e1/ (accessed on September 5, 2022).

Sugunan, V.V. 1995. *Reservoir fisheries of India*. FAO Fisheries Technical Paper No. 345. Rome, Italy: Food and Agriculture Organization of the United Nations (FAO). Available at https://www.fao.org/fishery/en/publications/21383 (accessed on September 5, 2022).

Suleiman, A. 2017. Water resources roadmap 2016-2030. In: *Immediate and long-term strategies for the water sector (2016-2030)*. Abuja, Nigeria: Federal Ministry of Water Resources.

USBR (United States Bureau of Reclamation). 2000. *Safety evaluation of existing dams: A manual for the safety evaluation of embankment and concrete dams*. Denver, Colorado, USA: USBR, United States Department of the Interior. Available at https://www.usbr.gov/tsc/techreferences/mands/mands-pdfs/SEED.pdf (accessed on March 10, 2018).

van de Giesen, N.; Liebe, J.; Andreini, M.; Steenhuis, T. 2004 Use of small reservoirs in West Africa as remotely-sensed cumulative runoff gauges. In: Teuling, A.J.; Leijnse, H.; Troch, P.A.; Sheffield, J.; Wood, E.F. (eds.) *The terrestrial water cycle: Modelling and data assimilation across catchment scales. Proceedings of the 2nd International CAHMDA workshop, October 25–27, 2004, Princeton, NJ, USA*. pp. 28–31. https://hdl.handle.net/10568/38706

van de Giesen, N.; Liebe, J.; Andah, W.; Andreini, M. 2008. Assessing the hydrological impact of ensembles of small reservoirs. In: Humphreys, E.; Bayot, R.S.; van Brakel, M.; Gichuki, F.; Svendsen, M.; Wester, P.; Huber-Lee, A.; Cook, S.; Douthwaite, B.; Hoanh, C.T.; Johnson, N.; Nguyen-Khoa, S.; Vidal, A.; MacIntyre, I.; MacIntyre, R. (eds.) *Fighting poverty through sustainable water use: Proceedings of the CGIAR Challenge Program on Water and Food, 2nd International Forum on Water and Food, November 10-14, 2008, Addis Ababa, Ethiopia (Vol. 3. Water benefits sharing for poverty alleviation and conflict resolution; drivers and processes of change)*. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food (CPWF). pp.27–31. Available at https://cgspace.cgiar.org/bitstream/handle/10568/3708/IFWF2_proceedings_Volume%20III.pdf (accessed on September 5, 2022).

Venot, J.-P.; de Fraiture, C.; Nti Acheampong, E. 2012. *Revisiting dominant notions: A review of costs, performance and institutions of small reservoirs in sub-Saharan Africa*. Colombo, Sri Lanka: International Water Management Institute (IWMI). 39p. (IWMI Research Report 144). https://doi.org/10.5337/2012.202

Wisser, D.; Frolking, S.; Douglas, E.M.; Fekete, B.M.; Schumann, A.H.; Vörösmarty, C.J. 2010. The significance of local water resources captured in small reservoirs for crop production – a global-scale analysis. *Journal of Hydrology* 384(3–4):264–275. https://doi.org/10.1016/j.jhydrol.2009.07.032

Woodhouse, P.; Veldwisch, G.J.; Venot, J.-P.; Brockington, D.B.; Komakech, H.K.; Manjichi, Â. 2017. African farmer-led irrigation development: re-framing agricultural policy and investment? *The Journal of Peasant Studies* 44 (1):213–233. https://doi.org/10.1080/03066150.2016.1219719

World Bank Group. 2023. Nigeria: Current climate. Climate Change Knowledge Portal. Available at https://climateknowledgeportal.worldbank.org/country/nigeria/climate-data-historical#:~:text=Nigeria%20is%20characterized%20by%20three,amounts%20from%20south%20to%20north (accessed on January 24, 2023).

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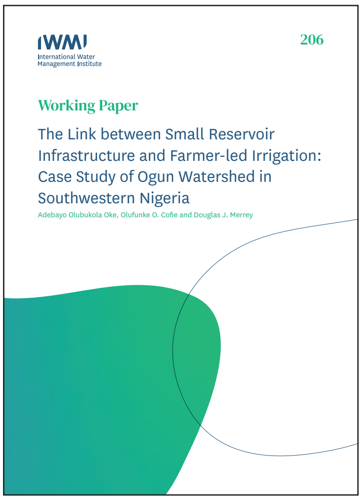

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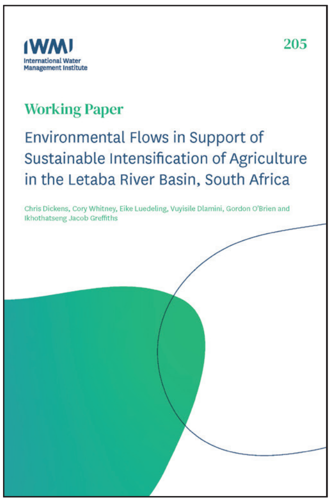

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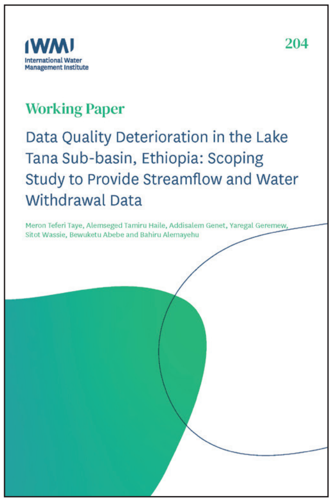

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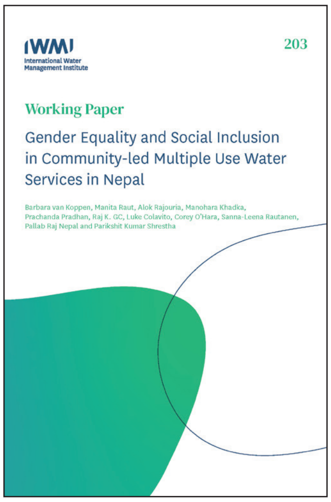

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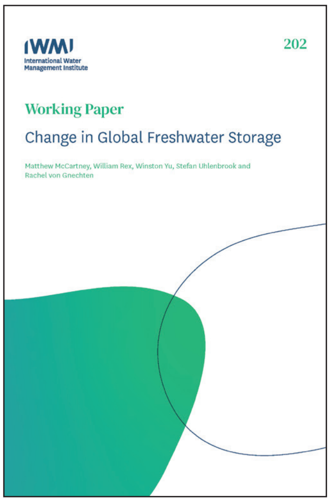

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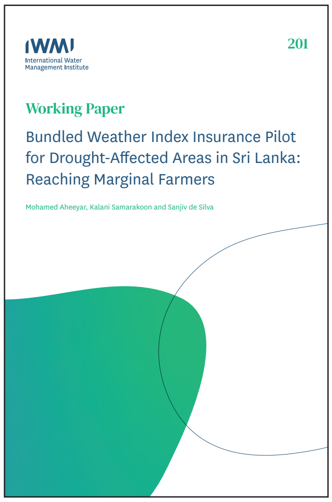

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