Journal of the Ghana Institution of Engineering (2023) 23:3
https//doi.org/10.56049/jghie.v23i3.74

CASE STUDY

An evaluation of small-scale irrigation schemes infrastructure

Patrick A. Bowan[1,]*, Lee F. Anzagira[1], Zakaria Issahaku[2], Fidelis A. Bang-Era[3]

Received: 21st November, 2022 / **Accepted:** 26th July, 2023
Published online: 1st September, 2023

Abstract

The development and management of irrigation in many developing countries have been characterized by many challenges, which have led to irrigation capacity utilization on some existing schemes to be very low. This study assesses small-scale irrigation scheme infrastructure in the Upper West Region of Ghana using the Yeleyiri irrigation scheme in the Wa West District and the Pulima irrigation schemes in the Sissala West District as case studies. The focus of the assessment was on the status and an analysis of the rehabilitation requirements of the two schemes. In conducting the evaluation, transect walks, topographic surveys, field observation, field measurements, interviews, focused group discussions, and questionnaire surveys were the approaches and methodology adopted. The results showed that the head works, slopes, inlet and outlet structures, water distribution systems, and drainage in both schemes were in a deplorable state and, thus, required maintenance to ensure the optimization of the utilization of both schemes. The study, therefore, proposes some interventions for the rehabilitation and efficient optimization of the two small-scale irrigation schemes.

Keywords: Small-Scale Irrigation, Irrigation Infrastructure, Irrigation Management, Irrigation Assessment, Upper West Region, Ghana.

Introduction

The importance of irrigation in contributing to poverty reduction by enhancing the ecology and increasing productivity of land use in most developing countries cannot be over emphasized. Due to its potential, irrigation has been recognized by many development partners as the panacea to the food insecurity problem facing many developing countries, as rainfall patterns in many countries have become more unpredictable and inconsistent with traditional farming seasons. Irrigation projects are usually categorized into small, medium, or large primarily based on the size (Diaz-Elsayed *et al*, 2019). Sizes up to 200 ha are considered as small, sizes between 200 ha and 1000 ha are regarded as medium, and sizes above 1000 ha are classified as large (Albizua, Pascual and Corbera, 2019).

Large-scale irrigation, while providing enormous economic benefits, have created a lot of environmental and social problems (Panagopoulos and Dimitriou, 2020). For instance, large-scale irrigation projects are known to have increased the prevalence of water-borne diseases and have resulted in the flooding of lands (Caminade, McIntyre and Jones, 2019; Elagib *et al*, 2021). Because of these negative effects of large-scale irrigation projects and taking into consideration cost effectiveness, sustainability, and ease of management, many researchers and development partners have opted for small-scale irrigation engineering (Passarelli *et al*., 2018).

Small-scale irrigation schemes play a key role in the improvement of livelihood and economic welfare of many rural communities. Small-scale irrigation is usually on small plots, in which farmers have the controlling influence, using the level of technology that they can operate and maintain efficiently (Bryan and Garner, 2022). However, some researchers have observed that myopic project planning, inadequate engineering studies, unsound designs, too short a time for implementation, and lack of full farmer involvement at different levels of project planning and implementation have led to the failure of small-scale irrigation schemes in some developing countries (Parry *et al*, 2020; Pittock *et al*, 2020).

Consequently, Pittock *et al* (2020) observe that small-scale irrigation schemes in many developing countries, particularly countries in sub-Saharan Africa have performed poorly and failed to lift farmers out of poverty and enhance food security. Unsuitable irrigation technologies and agricultural practices, as well as poor assessment of the cost and the profitability of small -scale irrigation schemes are some of the reasons for the failure of many small-scale irrigation schemes in developing countries (Bjornlund *et al*, 2020; Higginbottom *et al*, 2021). In addition, McCarthy (2022) posits that ‘many new irrigation schemes in sub-Saharan Africa are neither fit nor fit for purpose and further observes that not only is irrigation infrastructure often poorly constructed, but their operation, maintenance and repairs are also often too costly and, therefore, not fit for purpose. Notwithstanding these challenges, small-scale irrigation provides the avenue for all year farming, due to unpredictable rain pattern in current times for rain-fed farming, as irrigable land and the numerous water resources in developing countries could be efficiently used to support sustainable development.

Irrigation development in Ghana began soon after independence in the 1960s. Though the history of irrigation development in the country is quite short, significant achievements have been made. According to Ghana Irrigation Development Authority (GIDA) (2022), approximately 19,000 ha of irrigable land has been developed so far in Ghana; of the developed irrigable land, about 9,000 ha has been developed by the government of Ghana, whiles the remaining hectares of irrigable land has been developed by the private sector, including development partners. GIDA further indicates that Ghana has 22 irrigation districts with 57 existing public irrigation schemes. Many of these irrigation schemes have been developed through financial and technological support from bilateral cooperation with foreign countries and development partners such as the World Bank.

However, according to Akuriba *et al.* (2020), the development and management of irrigation in Ghana have been charac-

*Corresponding email: p.a.bowan@dhltu.edu.gh

[1]Department of Civil Engineering, Dr. Hilla Limann Technical University, Wa, Ghana

[2]Market Oriented Agriculture Programme in North Western Ghana (MOAP-NW), Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Ghana

[3]Ghana Irrigation Development Authority, Wa, Ghana

terized by many challenges, including weak database, excessive cost, environmental problems, and extreme pessimism in some quarters because of the over reliance on rain fed agriculture. As a result, irrigation capacity utilization on some existing schemes in Ghana is very low. The Upper West Region of Ghana is endowed with many small-scale irrigation schemes, however most of these schemes are non-functional or performing below expectation due to poor infrastructure. A standard irrigation scheme usually consists of a (main) intake structure or (main) pumping station, a conveyance system, a distribution system, a field application system, and a drainage system (Cunha *et al.*, 2019), though most of these components of a standard irrigation system have been provided in some irrigation systems in the Upper West Region, many of them are not functioning effectively due to poor maintenance.

The objective of this study was to assess the infrastructure of small-scale irrigation schemes in the Upper West Region of Ghana, using Yeleyiri irrigation scheme in the Wa West District and Pulima irrigation scheme in the Sissala West District of the Upper West Region as case studies. The focus of the assessment is on the status of the two schemes as well as an analysis of the rehabilitation requirements of the two schemes. The scarcity of information on the status of these two irrigation schemes as well as their economic value to the communities that utilize them necessitated this assessment of the physical infrastructure of the two schemes for possible rehabilitation.

Materials and Methods

The study was conducted through an on-site evaluation of the irrigation structures, interviews with key informants in relevant government departments and the beneficiaries of the schemes. In conducting the engineering (infrastructure) assessment, transect walks, field observation, and field measurement were the approaches and methodology adopted for the two irrigation schemes. In addition, detailed topographic survey was conducted on the schemes to generate the topographic maps, develop engineering drawings and designs for the execution of proposed works. Benchmarks and reference points were established during the topographic survey for easy referencing during the implementation of the rehabilitation. Key informants' interviews were conducted to ascertain the functionality and efficiency of the existing irrigation systems. Literature and existing designs and drawings were also reviewed during the assessment.

The topographic survey enabled the researchers to draw contour maps and the general layout for both irrigation schemes. The assessment took into consideration the existing infrastructure and the most cost effective approach in undertaking rehabilitation of the two schemes. The assessment process on the Yeleyiri irrigation schemes started at plot level with an assessment of the head required at the secondary canal offtakes to command the fields, and the necessary levels in the secondary canals. Thus, the levels needed at the heads of the secondary canals and in the main canal at each secondary canal offtake were determined. The re-design for the Pulima irrigation scheme for possible rehabilitation was based on the previous designs that was used in the construction of the scheme.

In addition, primary data was obtained through key informant interviews, semi-structured interviews, focus group discussions, direct observations and structured questionnaires for household surveys. Focus group discussions were held with five (5) and eight (8) participants in the focused group at Pulima and Yeleyiri respectively. Key informant interviews were conducted with staff of Department of Agriculture (DoA), GIDA, Plan Ghana and the Wa West and Sissala West District Assemblies. Furthermore, some farmers operating on the two schemes were interviewed. Interviews were conducted among the relevant stakeholders to gain insight into the institutional functions, water management within the schemes, resource use, conflict resolution mechanisms, and to gain insight in their perception on the importance of irrigation for local food security. Structured questionnaires were used for collecting data from 45 and 65 farmers and their households at Yeleyiri and Pulima respectively, who were the active farmers on the two irrigation schemes at the time the study was conducted. Simple random sampling technique was used to administer the questionnaire to all the active farmers in both irrigation schemes. The questionnaire survey was focused on the demographic characteristics of the respondents. The data was classified and analysed using the Statistical Package for the Social Sciences (SPSS) software package and the results were presented in percentages and charts.

Description of the irrigation schemes

Pulima irrigation scheme

The Pulima irrigation scheme is in the Sissala West District. The development and construction of the scheme was financed by Plan Ghana in 2007. It is a gravity and tank system for crop production. It has a developed irrigable area of 13.7 *ha*, with a reservoir area of 5 *ha*. The Pulima dam has a length of 410 m. The dam wall has an average crest width of 4*m*. The crest is undulating requiring maintenance with patch holes developed on the crest. The embankment has an average height of 1.4*m* above the spillway control structure. The upstream slope of the dam is stable. The downstream slope however needs reshaping. The embankment downstream is gradually eroding due to the absence of protection, such as vetiver grasses. The Pulima irrigation scheme has two inlet/outlet structures installed with 150 *mm* diameter sluice valves. The left valve chamber is silted. There is a leakage on the 150 *mm* diameter pipe connecting the right valve. The scheme has an estimated farmer population of 140, with 75 percent of the farmers being female. The major crops cultivated on the scheme are leafy vegetables; however, at the time of the assessment, only 65 farmers were on the scheme. The general layout for the Pulima irrigation scheme is shown in Figure 1.

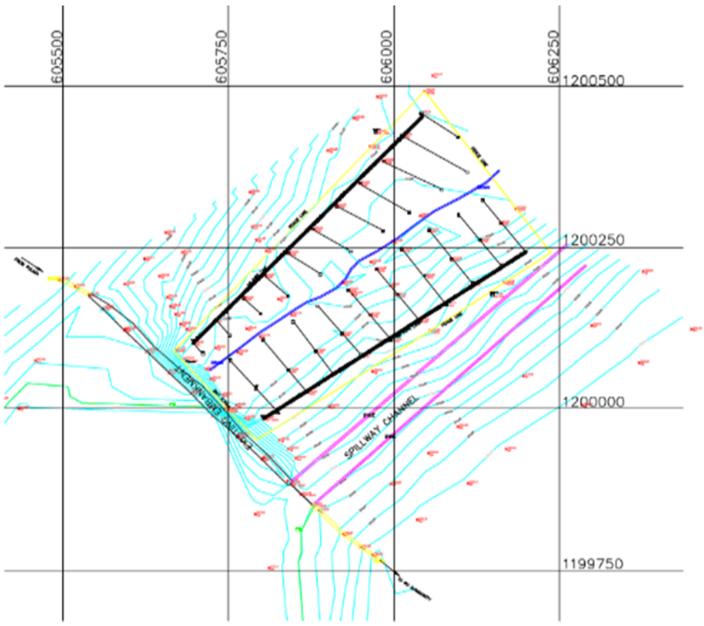

Figure 1 General layout of the Pulima irrigation dam

The Yeleyiri irrigation scheme

The Yeleyiri irrigation scheme is in the Wa West District of the Upper West Region. The scheme was constructed under the

https//doi.org/10.56049/jghie.v23i3.74

small-scale irrigation development project implemented by the GIDA between 2001 and 2003. The scheme is made of one main canal which is responsible for the distribution of water on the scheme. The scheme has no secondary and tertiary laterals. However, the scheme has a fenced irrigable area. According to GIDA, the reservoir's area of the dam is 157 000 m^2, and allows for an irrigable area of 18.50 *ha* . The general layout for the Yeleyire irrigation network is indicated in Figure 2.

at the time of the study, the active farmer population was 65, of which 56 of them were female representing 86.1 % of the farmer population as against 13.9 % male population on the scheme. Figure 3 illustrates the age and gender distributions of the farmers on the Pulima irrigation scheme. Most of the farmers on both schemes were below 40 years and, therefore, could cultivate on the schemes for many years if the schemes were properly maintained.

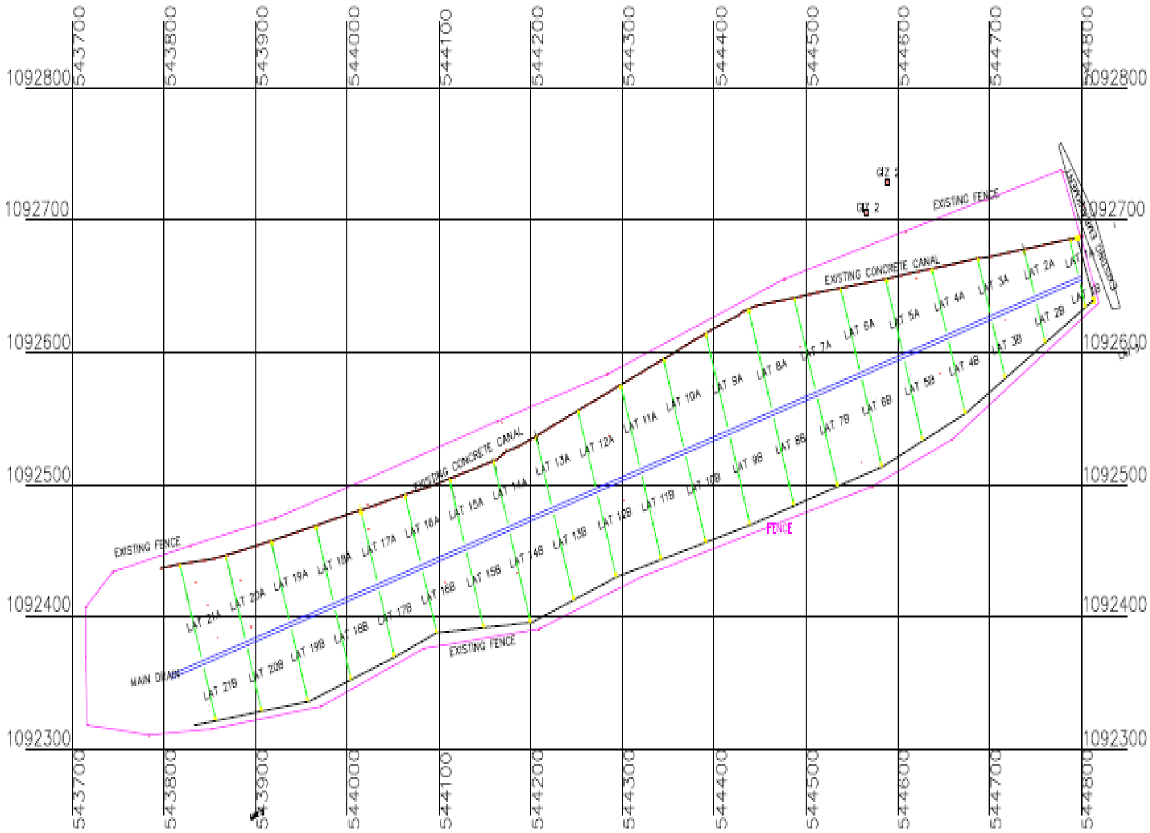

Figure 2 General layout of the Yeleyiri irrigation network

Results and Discussion

Population and demographic characteristics

Majority of the population in the study areas rely on farming for their livelihood. According to Ghana Statistical Service (2021), the population of the Yeleyiri community was 2,071, whereas the population of the Pulima community was 2,353. Yeleyiri irrigation scheme had a total registered farmer population of 125; however, at the time of this study only 45 farmers, all males were present and actively cultivating on the scheme. At Pulima the total registered farmer population was 145; however,

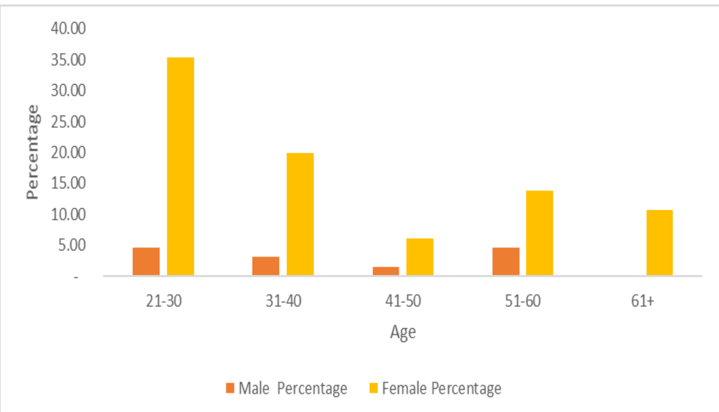

Figure 3 Age and gender distributions of famers on the Pulima irrigation scheme

Education and literacy levels in the study areas

The field survey indicated that farmers on the Yeleyiri and the Pulima irrigation schemes had very low level of education. More than half of the farmers on both irrigation schemes (58.46 %) had never been to school. This low literacy level of the farmers operating on the schemes, could make education on the irrigation infrastructure maintenance difficult, as some of the staff of GIDA, who usual develop and implement educational programmes on irrigation infrastructure operations and maintenance, do not understand the local languages spoken in the locations of the schemes. Figure 4 shows the educational level of the farmers at the Yeleyiri and Pulima irrigation schemes respectively.

Pulima irrigation scheme assessment

Head works: the dam wall and spillway

The Pulima dam has a length of 410 *m* . The dam wall has an average crest width of 4 *m* . The study found out that the crest was undulating and required maintenance. The embankment had an average height of 1.4 *m* above the spillway control structure. There was seepage at the toe of the embankment. This was visible between chainages 0+68 to 2+31 from the spillway, as indicated in Figure 5. In addition, the researchers observed that the dam wall was overgrown with shrubs and trees; therefore, required urgent attention for their removal. The spillway channel was 50 m wide and functioning properly. The spillway

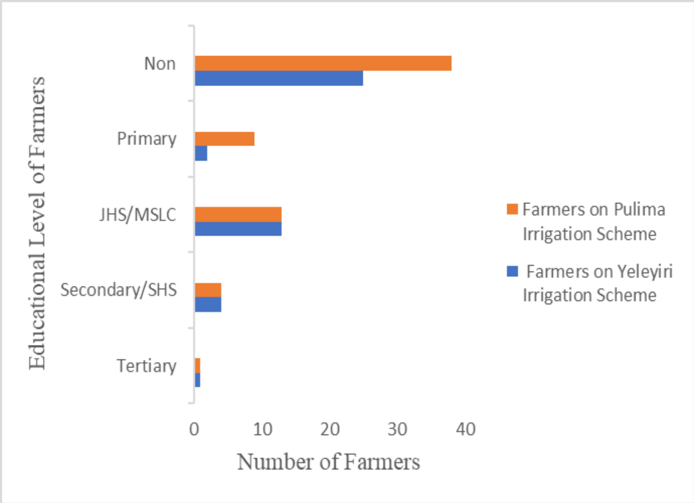

Figure 4 Educational level of farmers on the irrigation schemes

control beam was also in a good condition. Furthermore, vehicles drove on the dam wall to other adjoining communities. This led to the breaking of some portions of the spillway abutment protection. Portions at chainage 3+705 leading to the spillway channel was eroded due to the axial load imposed by the moving vehicles. Kouzehgar *et al*. (2021) indicate that embankment dams are usually earth-filled and that due to large footprint and lower stresses in the dam foundation, the foundation requirements for embankment dams are less stringent than those for concrete dams.

Slopes

The study showed that the upstream and down streams protection of the Pulima irrigation scheme at the time of the assessment was stable and solid however the downstream slope had eroded with time due to the absence of the downstream protection, such as vetiver grass. Consequently, Oshunsanya and Aliku (2017) observe that vetiver grass plays a vital role in watershed protection by slowing down and spreading runoff harmlessly on farmlands, recharging ground water, reducing siltation of drainage systems and water bodies, reducing agro-chemical loading in water bodies, and for rehabilitation of degraded soils. Thus, the use of vetiver grass has been regarded as a low-cost technology for the protection of dams' embankments. In addition, boulders at the upstream slopes of the dam shifted and required replacement at the upstream.

Inlet and outlet structures

There are two inlet and outlet structures distributing water to the irrigable area. Both outlets structures were fitted with two 150 *mm* diameter with one on the left of the embankment leaking and required replacement. Inlet and outlet structures are necessary to regulate flow, evenly distribute and abstract the water, and to control the water level in filters (Xu *et al*., 2021). Therefore, a flow rate control allowing accurate flow adjustment should always be installed at the inlet of roughing filters (Liu *et al*., 2021).

Water distribution system and the irrigable area

The Pulima irrigation scheme is made up of a pipe network, which carries water to various tanks then allowing farmers to fetch from the tanks to irrigate using watering cans and water hose. The irrigable area was fenced by a chained link. However, the fence was broken and weak at some sections allowing animals to have access to the crops cultivated on the scheme. Taps placed at sections of the irrigable area also facilitated the access

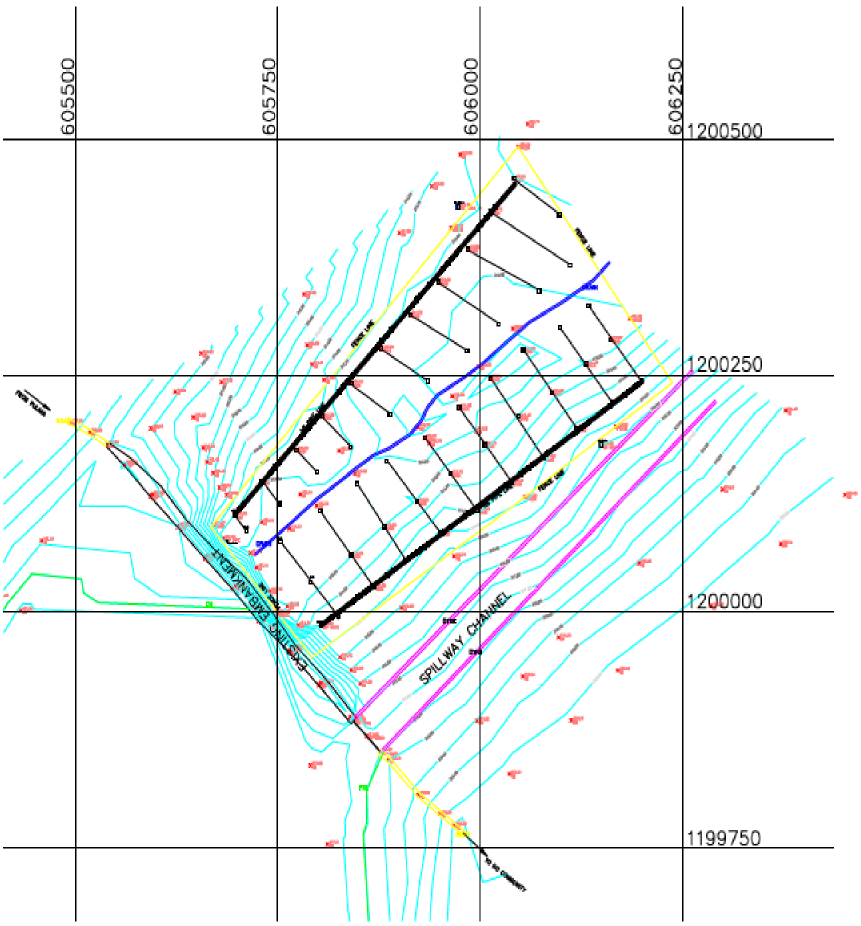

Figure 5 The embankment and spillway control structure of the Pulima irrigation scheme

to water for irrigation. There were seventy-six (76) tanks to irrigate the fields. The tank had a dimension of $2m$ x $2m$ x $2.5m$, thus the volume of each tank is 8 m^3. However, some of the tanks did not receive water as result of broken down pipe network. Figure 6 below shows a typical tank at the Pulima irrigation scheme that do not receive water.

Figure 6 A concrete tank not receiving water due to broken pipe network at the Pulima irrigation scheme

In addition, there were eight (8) standpipes across at various sections of the area, which were used to support irrigation. Some of the pipes connecting into the tanks were also completely broken making it difficult for some sections of the irrigable area to have access to water for irrigation (Figure 7 illustrates a pipe that was broken and leaking). Also, 15 number of the ¾ valves were leaking at various sections with most of the pipes blocked and thereby preventing water from reaching the tanks.

Figure 7 Assessment of broken down pipes to tanks at the Pulima irrigation scheme

Furthermore, the researchers observed that the irrigable area was fenced but in a deplorable state. The main fence gate was broken together with some of the poles and the wire mesh. 25 number of the fence posts were broken, allowing animals access to the farm (Figure 8 shows portions of the broken wire mesh fencing). Consequently, Breetzke *et al.* (2022) observe that fence must be placed around the irrigable area to avoid livestock from entering and, also, to protect against theft.

Figure 8 Portions of broken wire mesh fencing

Drainage

The field trip showed that the drain network to the Pulima irrigation scheme was silted. The main drain, which lies in the middle of the irrigable area, was silted limiting the available land for cropping. The silted drain, apart from reducing the available irrigable land, was also responsible for the poor soil fertility and the prevalence of pests and disease on the scheme. In addition, the drain was responsible for the occurrence of perennial flooding within the irrigable area. Thus, an effective drainage system is necessary to remove excess water from the irrigated land; excess water may be wastewater from irrigation or surface runoff from rainfall (Ding *et al*., 2021; Minhas *et al*., 2022).

Farmhouse structures

The Pulima scheme had no farmhouse and storage facility. This is a very key infrastructure for the effective management of the irrigation scheme. The absence of this infrastructure makes the effective management of the scheme a major challenge. Place for famers to keep their working tools, store harvested crops, and hold meetings was not available. Consequently, a farmer operating on the scheme in an interview claimed that:

"*It is very difficult for me to carry my farming tools and inputs to and from the house. I do not have a motor bike to always carry them to the irrigation scheme and after work, send them back home. If we had a storeroom at the irrigation scheme, we could always store our farm implements and inputs*".

This was collaborated by an Agricultural Officer who said that: "*in our monitoring and support for farmers at this irrigation scheme, the farmers have complained about the lack of a farmhouse to store their farm produce, implements, and inputs. Our department agrees with them that there is the need for a farmhouse, but we do not have the resources to provide the farmhouse at the moment*". The study, therefore, proposes the construction of a farmhouse as indicated in Figure 9.

Proposed interventions for the Pulima irrigation scheme

From the fieldwork and re-engineering of the Pulima irrigation scheme, the researchers proposed some interventions that were required for the rehabilitation and efficient optimization of the scheme as illustrated in Table 1 below. It is interesting to note that the Pulima scheme has a potential for expanding the irrigable area by an additional 10 *ha* if the proposed interventions are undertaken. This will increase the irrigable land holding per farmer on the scheme.

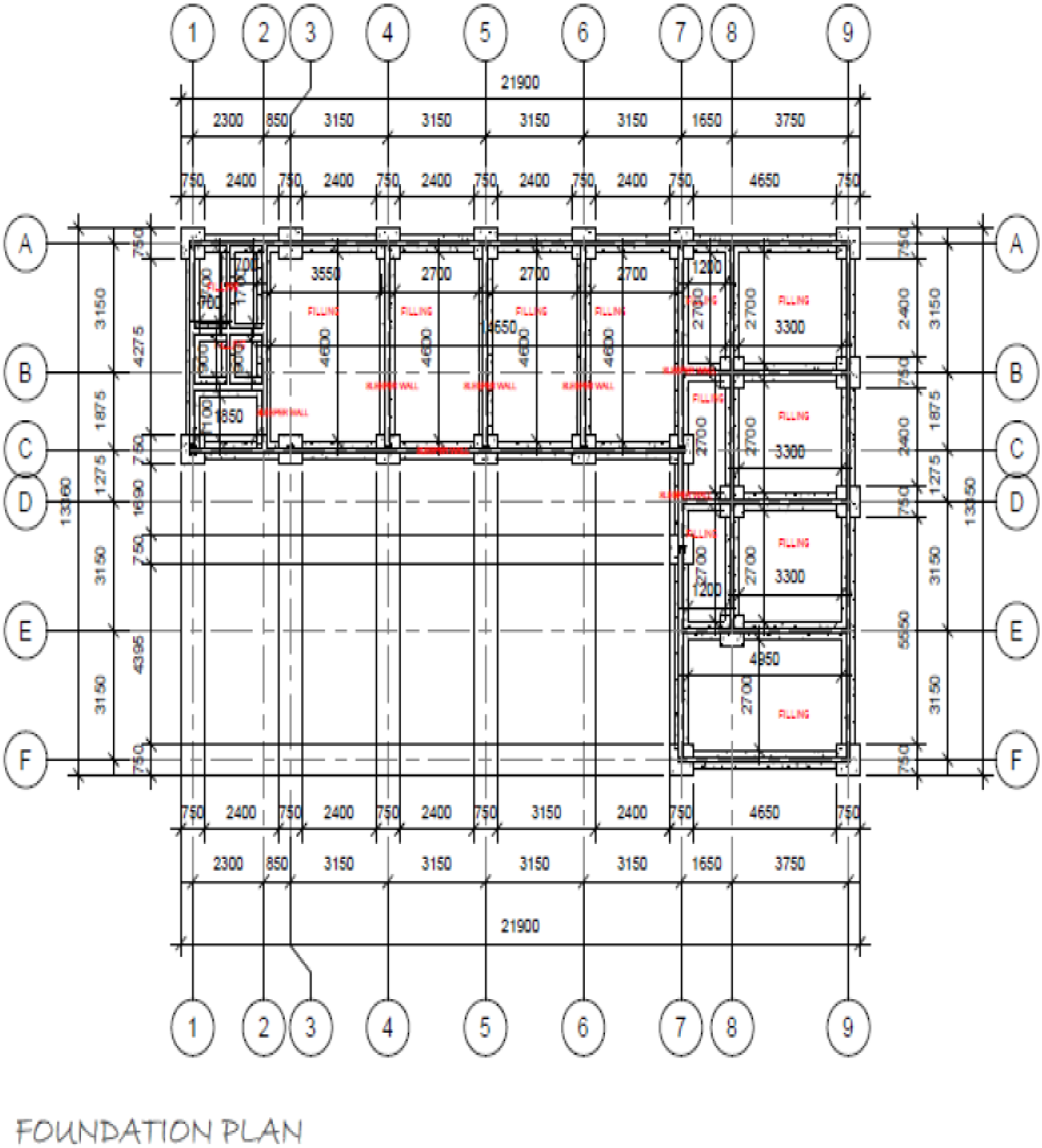

Figure 9 Proposed farmhouse floor plan

Yeleyiri irrigation scheme assessment

The head works: dam wall, slopes and the inlet and outlet structure

The assessment revealed that the Yeleyiri irrigation dam wall was in a solid and good condition, with an average crest width of 4 *m*. Both upstream and downstream slopes of the dam were stable. The embankment to the dam was however overgrown with trees on the slopes. The dam wall had no seepage. The spillway control structure is an Irish crossing linking Yeleyiri to the other adjoining communities. The spillway concrete structure was in a good state. However, the downstream of the spillway structure was however eroded, leaving the structure hanging. The eroding of the downstream of the spillway may impede or prevent operation of low level outlets during floods events when the proper performance of the spillway will be critical (Koskinas *et al*., 2019; Adamo *et al*., 2020). The spillway details is shown in Figure 10.

The water distribution system

Water on the Yeleyiri Irrigation scheme was distributed by one main canal with a length of 1250 *m*. The researchers during the fieldwork observed that, portions of the main canal was cracked (as shown in Figure 11) and was therefore unable to convey water to all parts of the irrigable area due seepage from the canal bed. Also, there were no secondary or tertiary canals, thus, water from the dam was unable to reach the far ends of the irrigable area. The absence of the laterals made farmers to spend long hours waiting for water to reach their fields, which had led to majority of the farmers abandoning their plots at the far end of the irrigable area from the dam. Consequently, the

Table 1 Proposed intervention for the various sections of the Pulima irrigation scheme

S/N	Component	Section	Proposed Intervention
1	Head works	Dam wall	Fill and compact, levelling crest of the dam wall with gravel to about 0.5 *m*
		Slopes	Restore eroded slopes to prescribed standards. Provide slopes protections (upstream with boulders and downstream with vetiver grass.)
		Spill way	Provide stone pitching to the spillway abutment to control erosion.
		Inlet and outlet structures	Remove and replace 150 *mm* valve at the left main line to prevent the leakage from the valve.
		Tanks system	Clear tanks of bushes and shrubs growing around the reservoir. Carry out maintenance works on the tanks.
2	Water distribution and the irrigable area	Pipe layout	Replace broken down 3/4 pipes connected to tanks. Remove and replace blocked and broken down 3 inch pipes in the main line
		Taps	Remove and replace broken down 3/4 taps
		Fence	Replace broken sections of the fence and repair the 2 broken gates.
		Valves	Remove and replace 3/4 valves to prevent leakages.
		Drainage	Desilt main drain
		On - Farm Water Management Option	Introduce a drip system powered by solar. This will help ensure that water is productively and effectively used on the irrigation scheme. In areas where water is scarce, drip irrigation provides the most efficient way to conserve irrigation water (Wu *et al.*, 2021; Morianou, Kourgialas and Karatzas, 2023)
3	Construct farm structures	Shed, drying bed and office structure	Construct shed, drying bed, and office space for the management of the scheme. Water User Association should be formed

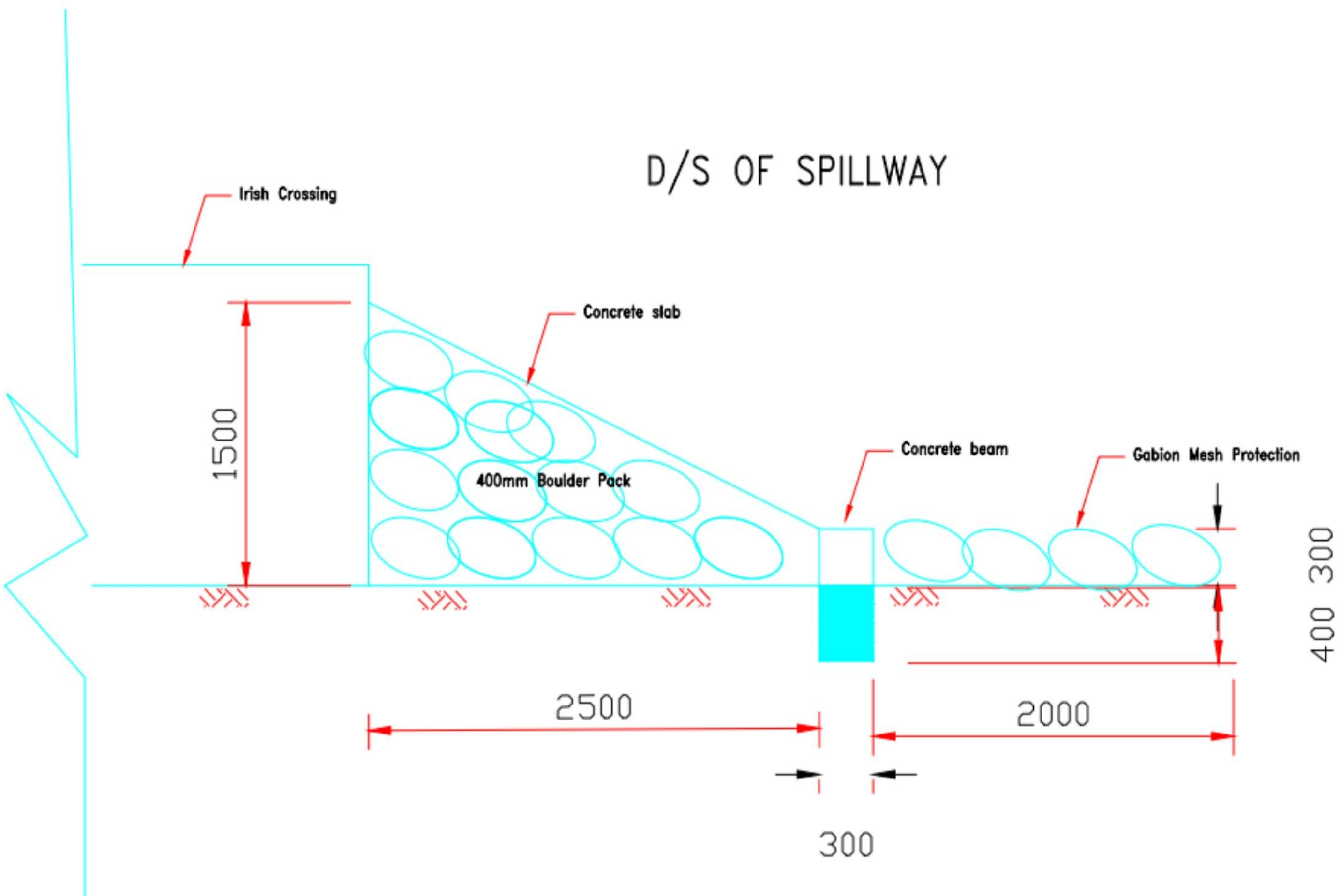

Figure 10 Yeleyiri irrigation dam spillway details

farmer population had decreased from 150 to 45 as at the time the study was conducted. In addition, the few farmers still operating on the scheme complained of poor yields due to the occurrence of pests and diseases and poor soil condition.

Figure 11 The main conveyance with the canal lining removed at the Yeleyiri irrigation scheme

Drainage
The assessment showed that there was no main drain on the Yeleyiri Irrigation scheme. The absence of the main drain had created a water-logged situation on the field, there by affecting soil fertility and crops productivity. Drainage was one of the major challenges confronting the Yeleyiri Irrigation Scheme. Figure 12 shows a pond of water within ridges in the irrigable area of the Yeleyiri irrigation scheme due to poor drainage.

Figure 12 Ponds within ridges in the irrigable area of the Yeleyiri irrigation scheme due to poor drainage

Farm structures
As was the case with the Pulima irrigation scheme, there was no storage facility and a farmhouse for farmers on the Yeleyiri irrigation scheme. Farmhouse are structures, usually 4 rooms with a shed, which serves as a facility where farmers sell their produce, keep their farm tools, and establish an office for the executives of WUA and hold meetings. Despite the importance of this facility, it was absent on the Yeleyiri irrigation scheme. It is proposed that a structure be constructed as part of rehabilitation measures to facilitate the optimization of the irrigation schemes. The proposed farm structure floor plan is shown in Figure 9.

Proposed interventions for the Yeleyiri Irrigation Scheme
The interventions proposed are cost effective and may not take a long time to be implemented. Table 2 below indicates the

Table 2 Proposed intervention on components of the Yeleyiri Irrigation Scheme

S/N	Component	Section	Proposed Intervention
1	Head works	Dam wall	Fill and compact, levelling the crest of the dam wall with gravel
		Spill way	Provide boulders and straighten spillway channel, allowing excess water to move freely.
		Inlet and Outlet structures	Provide an additional valve to conduct water to the left of the irrigable area for easy distributing of water.
2	Water distribution and the irrigable area	Irrigable area	Provide a second main pipe or canal of 1250 *m* length and 15 number laterals of 60 *m* length laterals to effectively conduct water to parts of the irrigable area
		Valves	Provide valves along the laterals to control the distribution of water across the irrigable area.
		Fence	Replace broken sections of the fence and repair the main gate at the entrance of the scheme.
		Drainage	Construct a main drain to drain excess water of the irrigable area. Drainage should include sub-drains and main-drains
3	Farm market and storage structures	Shed and storage structure	Construct shed, drying bed and office space for the management of the scheme. WUA should be formed

recommended interventions needed for the rehabilitation of the Yeleyiri irrigation scheme.

Management of the two irrigation schemes

To ensure sustainable water availability in this era of climate change and the agro-climatic zone in which the irrigation schemes are situated, the researchers held interviews with some farmers operating on irrigation schemes and a staff of GIDA to solicit their opinions on water management practices. The farmers interviewed generally agreed that all the farmers operating on the irrigation schemes should guard against waste of water in the reservoirs, as one farmer acknowledged that "*the water in the reservoir is a finite commodity*". In addition, on the maintenance of irrigation infrastructure, a farmer operating at the Yeleyiri irrigation scheme observed that, "*to minimize conveyance loses through leakages, a periodic maintenance schedule to repair all conveyance structures including drains are supposed to be undertaken by the Water User Association (WUA). However, due to inadequate funds for maintenance works, the WUA was unable to undertake periodic maintenance works"*.

Consequently, an agronomist with GIDA in an interview buttressed the importance of WUA in irrigation water management by saying that, "*developing and strengthening the capacity of WUA in accordance with GIDA Regulations 2016 L.I. 2230 on both schemes was essential for the effective water management in the two irrigation schemes, as WUA plays a key role in the distribution of water at the farm level and equally plays a significant role in the management of the schemes*. Bonye *et al.* (2022) support the formation of WUA in the irrigation management by positing that WUA should always institute stringent but enforceable guidelines on violations of irrigation water scheduling, over irrigation and all forms of water wastage, and that WUA leaderships should form vigilante groups to monitor compliance with these guidelines.

Furthermore, agricultural practices and extension services as well as access to quality agro inputs are a precondition for the success of the irrigation schemes. Thus, an agricultural extension officer of MOFA at the Regional Office in Wa in an interview said that "*it is important for MOFA and development partners to provide technical advice to improve the quality of farming practices and access to inputs so that the farmers operating in the irrigation schemes can increase yields and have access to ready markets to increase their incomes*". The agricultural extension officer further revealed that, MOFA had approached some development partners for technical and financial support in order to accomplish this aim. On his part, the district planning officer for Sissala East District, where the Pulima irrigation scheme is located, suggested in an interview that, "*the training of farmers in water management, irrigated crop production, and marketing as well as general management, operation and maintenance of the schemes were of vital importance, and that the continuous monitoring and evaluation of irrigation schemes jointly with farmers should be carried out, to provide feedback to planners and to assist the farmers to improve their performance*". Therefore, the involvement of all stakeholders in the management of the irrigation schemes is vital to maintaining the schemes infrastructure and optimising the usage of the schemes.

Conclusions

Smallholder irrigators can grow high-value crops both for the local and export markets, and thus effectively participate in the mainstream economy. In areas of very low rainfall, particularly in northern Ghana, farmers practicing irrigation enjoy the human dignity of producing their own food. Smallholder irrigation development has made it possible for rural infrastructure to be developed in areas, which would otherwise have remained without roads, telephones, electricity, schools, or shops.

This study assessed small-scale irrigation schemes infrastructure in the Upper West Region of Ghana, using Yeleyiri irrigation scheme in the Wa West District and Pulima irrigation scheme in the Sissala West District of the Upper West Region as case studies. The assessment focused on the status and an analysis of the rehabilitation requirements of both schemes. The rehabilitation of the two irrigation schemes will create more successful irrigation farmers on the irrigation schemes, as climate change has spurred renewed interest in irrigation schemes to be built to be resilient, to improve the livelihood of farmers. Therefore, the study recommends the rehabilitation of the two irrigation schemes to optimise the utilization of the schemes, which could contribute to food security, create employment opportunity for the teeming unemployed youth in the locations of the irrigation schemes and be young, and eventually contribute to sustainable development.

Acknowledgement

The researchers are grateful to all the study participants, particularly the farmers in the study communities, the staff of the Department of Agriculture, staff of the Wa West and Sissala West District Assemblies, GIDA Staff in Wa, and Staff of GIZ in Wa, who supported the researchers during the field trips or provided the team with relevant data.

Conflict of Interest Declarations

The authors declare no competing financial interests.

Funding

This research received grant from GIZ Market Oriented Agriculture Programme in Northwestern Ghana (MOAP-NW) for the field trips and data collection.

References

Adamo, N., Al-Ansari, N., Sissakian, V., Laue, J. and Knutsson, S. (2020). Dam safety: sediments and debris problems. Journal of Earth Sciences and Geotechnical Engineering, 11(1), pp. 27–63. https://doi.org/10.47260/JESGE/1112.

Akuriba, M.A., Haagsma, R., Heerink, N. and Dittoh, S. (2020). Assessing governance of irrigation systems: a view from below. World Development Perspectives, 19, p. 100197. https://doi.org/10.1016/j.wdp.2020.100197.

Albizua, A., Pascual, U. and Corbera, E. (2019). Large-scale Irrigation Impacts Socio-cultural Values: An Example from Rural Navarre, Spain'. Ecological Economics. Elsevier, 159, pp. 354–361. https://doi.org/10.1016/j.ecolecon.2018.12.017.

Bjornlund, V., Bjornlund, H. and van Rooyen, A. F. (2020). Exploring the factors causing the poor performance of most irrigation schemes in post-independence sub-Saharan Africa. International Journal of Water Resources Development. Routledge, 36(sup1), pp. S54–S101. https://doi.org/10.1080/07900627.2020.1808448.

Bonye, S.Z., Yiridomoh, G.Y., and Bebelleh, F.D, (2022). Common-pool community resource use: Governance and management of community irrigation schemes in rural Ghana. Community Development, 53(1), pp. 39-56

Breetzke, G. D., Mosesi, N. and Bester, P. (2022). The "contestation of crime": Using a spatial theory of crime to examine livestock theft among small-scale farmers in

Swartruggens, Northwest province. South African Geographical Journal. Routledge, 105(2), pp. 262-275 https://doi.org/10.1080/03736245.2022.2102062.

Bryan, E. and Garner, E. (2022). Understanding the pathways to women's empowerment in northern Ghana and the relationship with small-scale irrigation. Agriculture and Human Values, 39(3), pp. 905–920. https://doi.org/10.1007/s10460-021-10291-1.

Caminade, C., McIntyre, K. M. and Jones, A. E. (2019). Impact of recent and future climate change on vector-borne diseases. Annals of the New York Academy of Sciences. John Wiley & Sons, Ltd, pp. 157–173. https://doi.org/10.1111/nyas.13950.

Cunha, H., Loureiro, D., Sousa, G., Covas, D. and Alegre, H. (2019). A comprehensive water balance methodology for collective irrigation systems. Agricultural Water Management, 223, pp. 105660. https://doi.org/10.1016/j.agwat.2019.05.044.

Diaz-Elsayed, N., Rezaei, N., Guo, T., Mohebbi, S. and Zhang, Q. (2019). Wastewater-based resource recovery technologies across scale: A review. Resources, Conservation and Recycling. Elsevier, pp. 94–112. https://doi.org/10.1016/j.resconrec.2018.12.035.

Ding, G., Mancl, K., Lee, J. and Tuovinen, O.H. (2021). Bacterial movement in subsurface soil during winter irrigation of reclaimed wastewater. Sustainability (Switzerland). Multidisciplinary Digital Publishing Institute, 13(17), pp. 9594. https://doi.org/10.3390/su13179594.

Elagib, N.A., Al Zayed, I.S., Saad, S.A.G., Mahmood, M.I., Basheer, M. and Fink, A.H. (2021). Debilitating floods in the Sahel are becoming frequent. Journal of Hydrology. Elsevier, 599, pp. 126362. https://doi.org/10.1016/j.jhydrol.2021.126362.

Ghana Irrigation Development Authority (2022). E-Agriculture Portal. Available at: http://www.e-agriculture.gov.gh/index.php/about-mofa/subvented-organisations/ghana-irrigation-development-authority (Accessed: 9 November 2022).

Ghana Statistical Service (2021). Ghana 2021 population and housing census general report. Available at: https://statsghana.gov.gh/gssmain/fileUpload/pressrelease/2021 PHC General Report Vol 3F_Difficulty in Performing Activities_final_161221.pdf (Accessed: 25 March 2022).

Higginbottom, T.P., Adhikari, R., Dimova, R., Redicker, S. and Foster, T. (2021). Performance of large-scale irrigation projects in sub-Saharan Africa. Nature Sustainability. Nature Publishing Group, 4(6), pp. 501–508. https://doi.org/10.1038/s41893-020-00670-7.

Koskinas, A., Tegos, A., Tsira, P., Dimitriadis, P., Iliopoulou, T., Papanicolaou, P., Koutsoyiannis, D. and Williamson, T. (2019). Insights into the Oroville dam 2017 spillway incident. Multidisciplinary Digital Publishing Institute, 9(1), p. 37. https://doi.org/10.3390/GEOSCIENCES9010037.

Kouzehgar, K., Hassanzadeh, Y., Eslamian, S., Yousefzadeh Fard, M. and Babaeian Amini, A. (2021). Physical modeling into outflow hydrographs and breach characteristics of homogeneous earthfill dams failure due to overtopping. Journal of Mountain Science, 18(2), pp. 462–481.

Liu, Z., Muhammad, T., Puig-Bargués, J., Han, S., Ma, Y. and Li, Y. (2021). Horizontal roughing filter for reducing emitter composite clogging in drip irrigation systems using high sediment water. Agricultural Water Management. Elsevier, 258, p. 107215. https://doi.org/10.1016/j.agwat.2021.107215.

McCarthy, N. (2022). Designed to fail: Many new irrigation schemes in sub-Saharan Africa are neither fit nor fit for purpose. The Water Dissensus – A Water Alternatives Forum. Available at: https://www.water-alternatives.org/index.php/blog/SSAirrig (Accessed: 15 November 2022).

Minhas, P.S., Saha, J.K., Dotaniya, M.L., Sarkar, A. and Saha, M. (2022). Wastewater irrigation in India: current status, impacts and response options, Science of the Total Environment. Elsevier, 808, p. 152001. https://doi.org/10.1016/j.scitotenv.2021.152001.

Morianou, G., Kourgialas, N. N. and Karatzas, G. P. (2023). A review of HYDRUS 2D/3D applications for simulations of water dynamics, root uptake and solute transport in tree crops under drip irrigation. Water (Switzerland). Multidisciplinary Digital Publishing Institute, p. 741. https://doi.org/10.3390/w15040741.

Oshunsanya, S. and Aliku, O. (2017). Vetiver grass: a tool for sustainable agriculture', in Grasses – Benefits. Diversities and Functional Roles, pp. 143–158. https://doi.org/10.5772/65845.

Panagopoulos, Y. and Dimitriou, E. (2020). A large-scale nature-based solution in agriculture for sustainable water management: The Lake Karla Case. Sustainability (Switzerland). Multidisciplinary Digital Publishing Institute, 12(17), p. 6761. https://doi.10.3390/SU12176761.

Parry, K., van Rooyen, A.F., Bjornlund, H., Kissoly, L., Moyo, M. and de Sousa, W. (2020). The importance of learning processes in transitioning small-scale irrigation schemes. International Journal of Water Resources Development. Routledge, (sup1), pp. 1–25. https://doi.org/10.1080/07900627.2020.1767542.

Passarelli, S., Mekonnen, D., Bryan, E. and Ringler, C. (2018). Evaluating the pathways from small-scale irrigation to dietary diversity: evidence from Ethiopia and Tanzania, Food Security. Springer Netherlands, 10(4), pp. 981–997. https://doi.org/10.1007/s12571-018-0812-5.

Pittock, J., Bjornlund, H. and van Rooyen, A. (2020). Transforming failing smallholder irrigation schemes in Africa: a theory of change, International Journal of Water Resources Development. Routledge, 36(sup1), pp. S1–S19. https://doi.org/10.1080/07900627.2020.1819776.

Xu, L., Hu, Z., Fang, C., Li, J., Hong, P., Jiang, H., Guo, D. and Ouyang, M. (2021). Anode state observation of polymer electrolyte membrane fuel cell based on unscented Kalman filter and relative humidity sensor before flooding. Renewable Energy, 168, pp. 1294–1307. https://doi.org/10.1016/j.renene.2020.12.085.