Performance evaluation of irrigation schemes: a case study of Akumadan and Kaniago schemes in the transition agro-ecological zone of Ghana

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Abstract: This work assessed the performance of the Akumadan and Kaniago irrigation schemes in the transition agro-ecological zone of Ghana using a set of comparative performance indicators. The performance of the schemes spanning the years 2018 – 2022 was evaluated using selected comparative indicators categorized into five (5) groups, namely: water delivery, physical structures, financial, environmental condition and agricultural production performance. The challenges of the schemes were also identified through the study. It was revealed that the main pipe at Akumadan had 100% maximum flow length whiles the canal system at Kaniago recorded a flow length of 64% due to low gravity-flow in the downstream of the canal. The developed irrigable areas in Akumadan and Kaniago were under-utilised with irrigation rates ranging from 15% – 36% and 18% – 57% respectively. The sustainability indices of the irrigated areas in Akumadan and Kaniago were low with recorded values of 31% and 28% respectively. Irrigation service charges recovery was poor in the Kaniago scheme with recovery efficiency ranging from 25% – 59% whereas that of the Akumadan scheme was good with efficiency ranging from 80% – 88%. A low degree of financial autonomy (25%) was recorded in Akumadan whereas a high degree of financial autonomy (100%) was recorded in Kaniago. Some irrigation structures in the Akumadan and Kaniago schemes were in poor working condition having recorded poor structure indices of 27% and 14% respectively. The road network in the Akumadan scheme was in good working condition as roads pass ability efficiency of 100% was achieved whereas Kaniago had no major road construction in the scheme. The schemes recorded statistically significant *p*-values of 0.0036, 0.00641 and 0.010697 for soil salinity, sodicity and pH measurements in the irrigable areas respectively. Production in the schemes was gradually declining due to the constant reduction in size of the cultivable area of the schemes. Poor agronomic practices, inadequate surface materials and low gravity-flow were major causes of the low production performance in the schemes.

Keywords: transition, agro-ecological, comparative, gravity-flow, statistically, agronomic

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1 Introduction

Water is essential for all kinds of life, every facet of socioeconomic growth, and the correct functioning of ecosystems. While sufficient freshwater resources exist on a worldwide scale to ensure continuing agricultural and industrial expansion, the long-term sustainability of water resources is a developing problem (FAO, 2015). Agriculture accounts for 70%

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of all water withdrawals globally according to Rosa et al. (2019). Irrigation systems are installed on roughly 330 million hectares worldwide, accounting for 20% of all cultivated land. This represents 40% of all food produced globally (Raza et al., 2022).

The demand for food, and consequently agricultural water for irrigation, is growing in tandem with population increase and rising food demand. By 2025, the global population is expected to increase by roughly 30% to 8.45 billion people (Shyam et al., 2014). Living standards are predicted to rise as indicated by Eriksen (2020) due to enhanced communications, globalization, and increased urbanization. This means that rivalry for water resources will rise to new heights among agricultural, industrial, household, and other users. As a result, irrigated agriculture water management is critical in addressing the growing global population's food needs (Mancosu et al., 2015). Although water resources are renewable, they are finite in quantity. It is vital to make the most efficient use of available resources in order to achieve maximum efficiency (Cosgrove and Loucks, 2015). Waterlogging, sodicity, salinity, and an increase in the level of subsurface water will all be reduced as a result of efficient use of limited water resources, particularly for irrigation. Rouzaneh et al. (2021) reported that, in developing countries, frustration with the performance of irrigation projects is frequent. Irrigation projects, despite their potential as agricultural growth engines, typically perform much below their potential. According to Akuriba et al. (2020), a substantial percentage of low performance could be attributed to overall poor facility management and insufficient water management at the system and field levels. Improving food supply and reducing the impact of high food prices necessitates significant expenditures in changing existing farming systems or building new ones if appropriate (Beddington et al., 2012).

Namara et al. (2011) indicated that despite significant development potential and focus on irrigation development in numerous ways, less than 2% of Ghana's total cultivable area is irrigated. Extensification (placing more land under cultivation) and intensification (raising the productivity of existing land) are two methods for achieving agricultural growth (Baudron et al., 2012).

Despite irrigation's huge potential and emphasis put on it in contemporary plans, the size of the potential irrigable land that is actually irrigated is negligible; a situation perceived of irrigable areas within the transition agro-ecological zone of Ghana. Ngenoh et al. (2015) reported that existing irrigation schemes, particularly those that are publicly developed, have generally poor performance and productivity. Evaluating and improving the performance of existing irrigation schemes is a viable option for long-term growth, and it can serve as a benchmark or entrance point for future irrigation development. Elshaikh et al. (2018) stated that performance evaluation of irrigation systems is critical in order to i) improve system operations; ii) assess progress against strategic goals; iii) be part of performance-oriented management; iv) measure a system's overall health; v) evaluate the impact of interventions; vi) diagnose constraints; vii) better understand determinants of performance; and viii) compare the performance of a system with others or with the same system over time. Good performance is not only a matter of high output, but also one of efficient use of available resources.

This research seeks to evaluate the performance of the Akumadan and Kaniago irrigation schemes located in the transition agro-ecological zone of Ghana in terms of production levels, water delivery, environmental conditions, physical and financial structures, and identify the challenges of the irrigation schemes that inhibit efficient performance.

2 Materials and methods

2.1 Description of the study area

The study was carried out in the Akumadan irrigation scheme of the Offinso north district and in the Kaniago irrigation scheme of the Techiman municipality. The Akumadan scheme lies on Latitude

7°24’46 N and Longitude 1°56’7 W. Kaniago area lies on Latitude 7°34’6 N and Longitude 1°52’31 W as shown in Figure 1. The Akumadan scheme is a sprinkler system whereas Kaniago scheme is a surface gravity-flow system. The location of both schemes falls within the transition agro-ecological zone of Ghana. The transition zone separates the Forest and the Savannah. It is called a transition zone because it shares its climate with the Savannah. It receives an annual rainfall of 1200 mm, which is quite fair as compared to the forest and the Savannah. It is characterized by semi-deciduous forest and guinea savannah vegetation, with a bimodal rainfall pattern peaking in June–July and again in September–October, and a dry period from December–March. The zone has a temperature of 23.9 ℃ averaging throughout the year and an average humidity of 75%. Three substantive soil groups are found within the transition ecological zone . These are: i) Forest Ochrosols which covering the south-western part. ii) Savanna Ochrosols which stretches as wide belt from the west and gradually narrows toward the east. iii) Ground water Laterite Ochrosols Inter which intergrades in the northern parts of the zone. Besides these soil groups, there are some small patches of Oxysols and Rubrisols.

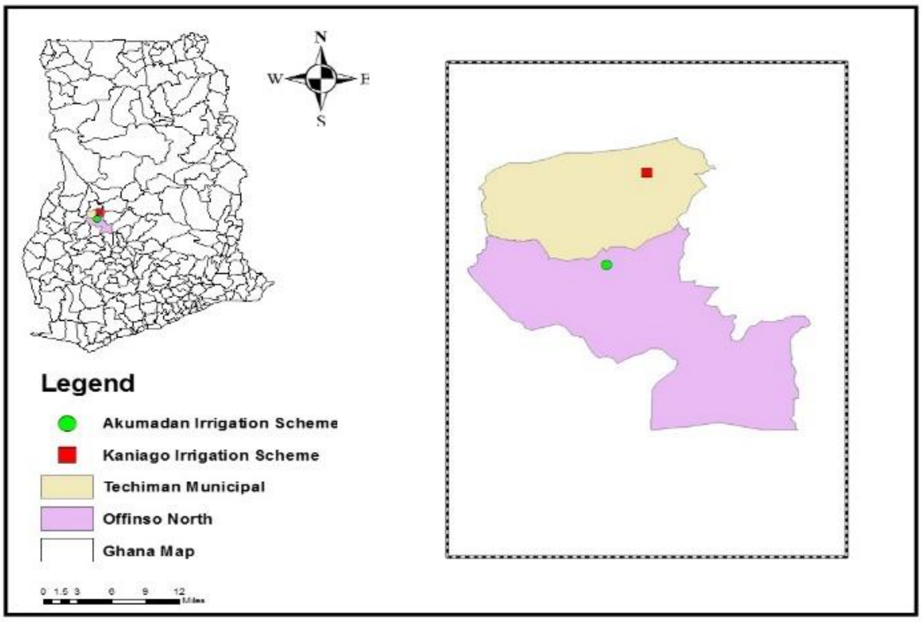

Figure 1 Location of the study

2.2 Measurement of canal flow velocity and area dimensions for discharge determination

The canal flow velocity in the Kaniago scheme was measured to determine discharge of water through the canal since there was no flow measurement device coupled with lack of concrete data from scheme management on flow discharge through the main canal in the scheme. The float method was used to measure the flow velocity. The measured parameters included the length of travel of float (*l*) and the time of travel of float (*t*). A reduction factor of 0.8 (JICA, 2004) was used to convert the surface velocity to mean velocity. The formula for estimating the mean canal flow velocity is expressed by Equation 1 as:

$$\text{Mean flow velocity (m s}^{-1}\text{)} = 0.8 \times \frac{Length\ of\ canal\ flow\ (m)}{Time\ taken\ (s)} \quad (1)$$

The depth (d) and width (w) of the canal were determined using measuring tape. Since the canal system was rectangular in shape, the flow area was determined as shown by Equation 2:

$$\text{Canal flow area (m}^2\text{) = width of flow (m)} \times \text{depth of flow (m)} \quad (2)$$

The discharge (Q) through the canal was calculated using the flow continuity equation as shown by Equation 3:

$$\text{Discharge, Q (m}^3\text{ s}^{-1}\text{) = velocity (m s}^{-1}\text{)} \times \text{area (m}^2\text{)} \quad (3)$$

2.3 Physical and chemical properties of soil in

irrigable areas of the schemes

The irrigable areas in the schemes were partitioned into three zones namely; up-stream, mid-stream and down-stream for soil sampling. Composite soils (0 – 30 cm depth) were sampled in each stream of the scheme. A total of six samples were obtained from the schemes with three samples each from a scheme. Illustrated in Table 1 are various soil sampling points within irrigable areas of the schemes. The samples were analysed in the laboratory for pH, salinity, sodicity and texture. pH was determined using 1:2.5 H_2O dilution method. The levels of salinity were determined by measuring the electrical conductivity (EC) of soil extract using the EC meter. The exchangeable sodium percentage (ESP) method was used to determine the sodicity level in the soils.

Table 1 Soil sampling coordinates in the irrigable areas

Scheme	Sampling Location	Latitude (º N)	Longitude (º W)
Akumadan	US	7.412728	-1.935346
	MS	7.413639	-1.935815
	DS	7.413362	-1.937482
Kaniago	US	7.571162	-1.877907
	MS	7.569272	-1.877418
	DS	7.567714	-1.874527

Note: US - Up stream; MS - Mid stream; DS - Down stream.

2.4 Comparative performance indicators

The set of comparative performance indicators as certified by the International Programme for Technology and Research in Irrigation and Drainage (IPTRID) were used in the performance evaluation of the irrigation schemes. These indicators are categorised into five groups namely: water delivery, physical structures, economic, environmental state and crop production performance (Cakmak et al., 2009).

2.4.1 Water delivery performance

Two sub-indicators were used in the evaluation of water delivery performance of the irrigation facilities.

(1)Total irrigation water supply per hectare per season

As indicated by Cakmak et al. (2009), total irrigation water supply per hectare per season was determined using the Equation 4:

$$TIWSHS=\frac{Tawd}{Ia} \quad (4)$$

where, *TIWSHS* is the total irrigation water supply per hectare per season (h m^3), *Tawd* is the total annual water delivery (m^3) and *Ia* is the irrigated area (ha).

(2) Extent of main canal/pipe flow length

According to Ijir (1994), the extent of main canal/pipe flow lengths (*EMCPFL*, %) is calculated as Equation 5:

$$EMCPFL = \frac{La}{Lt} \times 100\% \quad (5)$$

Where, *La* is the actual total length of main canal/pipe sections still flowing (km), and, *Lt* is the total length of main canal/pipe sections constructed (km).

2.4.2 Physical performance

Physical indicators relate to the changing and possible loss of irrigated land in the command area due to reasons such as dilapidated conveyance, regulatory, distribution and energy utilization structures in the scheme. Four sub-indicators were used to evaluate the physical performance of the schemes.

(1) Irrigation rate

According to Kuscu et al. (2009) and Cakmak et al. (2009), irrigation rate of an irrigation scheme is defined as the ratio of irrigated area to the total developed irrigable area of the scheme. Irrigation rate can be referred to as irrigable land utilization efficiency. Equation 6 expresses irrigation rate (*IR*, %) as:

$$IR = \frac{actual\ irrigated\ area\ (ha)}{total\ developed\ irrigable\ area\ (ha)} \times 100\% \quad (6)$$

(2) Sustainability of irrigated area index

Sustainability of irrigated area index (*SIAI*, %) is the ratio of the current irrigated area to the initial irrigated area when the scheme was fully completed (Sener et al., 2007). *SIAI* is expressed by Equation 7 as:

$$SIAI=\frac{current\ irrigated\ area\ (ha)}{initial\ irrigated\ area\ (ha)}\times 100\% \quad (7)$$

(3) Poor structure index of irrigation schemes

The poor structure index of irrigation schemes (*PSIIS*, %) of the schemes was calculated using a modified Sener et al. (2007) equation. For the modified equation, structures present on a scheme are assessed as a unit. Thus, for a particular set of structures; if the ratio of the number in good condition to the total number of existing structures is 0.9 or 1.0, it is assigned a score of 1. Similarly, if the ratio is less than 0.9, the assigned score is 0. The formula for calculating the PSIIS of a scheme is expressed by Equation 8.

$$PSIIS=\frac{Tnup}{Tnu}\times 100\% \quad (8)$$

Where, *Tnup* is the total number of unit structures in poor condition (defunct, not functioning adequately, at the verge of failure), and *Tnu* is the total number of unit structures present on the scheme.

(4) Efficiency of road network passability

The road network passability efficiency of a scheme was determined using Ijir (1994) formula, and is expressed by Equation 9 as:

$$Eff.\ of\ road\ network=\frac{Ra}{Rt}\times 100\% \quad (9)$$

where, *Ra* is the actual length of roads which has all year-round accessibility (km), and *Rt* is the total length of roads constructed within scheme (km).

2.4.3 Environmental performance using environmental stability index

The environmental performance of the schemes was evaluated using environmental stability index. According to Ijir (1994), the index considered the irrigated area not affected by negative environmental problems such as salinity, erosion or waterlogging and the total developed irrigable area. The Equation 10 defines the environmental stability index as:

$$Env.\ stability\ index=\frac{Tna}{Tdia}\times 100\% \quad (10)$$

Where, *Tna* is the total scheme area not affected by environmental problems of waterlogging, salinity or erosion (ha) and, *Tdia* is the total developed irrigable area (ha).

2.4.4 Economic performance

The economic performance of the schemes was evaluated using the following sub-indicators:

(1) Efficiency of irrigation service charges recovery

According to Sener et al. (2007), efficiency of irrigation service charges (ISC) recovery is calculated using Equation 11 as:

$$EISR=\frac{Ataisc}{Etaisc}\times 100\% \quad (11)$$

Where, *Ataisc* is the actual total annual ISC (GH¢) and *Etaisc* is the expected total annual ISC (GH¢).

(2) Scheme financial autonomy factor

As indicated by Ijir (1994), scheme financial autonomy factor is expressed by Equation 12 as:

$$SFAF=\frac{Fs}{Fg}\times 100\% \quad (12)$$

Where, *Fs* is the amount of scheme income retained by the irrigation scheme management (GH¢), and *Fg* is the amount passed to central government (GH¢).

(3) Financial self-sufficiency factor

Financial self-sufficiency factor of the schemes was computed using the Equation 13 as given by Kuscu et al. (2009):

$$FSF=\frac{Tai}{Taome}\times 100\% \quad (13)$$

where, *Tai* is the total annual scheme income from water charges and other revenue sources (GH¢), and *Taome* is the total annual management, operation and maintenance expenditure of the scheme (GH¢).

2.4.5 Production performance

Average yield (t ha^{-1}) per crop and average irrigated area (ha) per crop were used in evaluation of the production performance of schemes.

2.5 Data analysis

The collected field data were analysed using equations of performance evaluation and excel spreadsheet for *T* test analysis and drawing of tables and charts.

3 Discussion of results

3.1 Comparative performance evaluation

3.1.1 Water delivery performance

The water delivery performance of the irrigation schemes was evaluated using the following sub-indicators.

Extent of main canal/pipe flow lengths: The extent of main canal/pipe flow lengths of the schemes are presented in Table 2.

Table 2 Extent of main canal/pipe flow length of the schemes

Scheme	Total length of main canal/pipe constructed within the scheme (km) *	Actual total length of main canal/pipe sections still flowing (km) *	Extent of main canal/pipe flow length (%) **
Akumadan	1.6	1.6	100
Kaniago	2.2	1.4	64

Existing in the Akumadan scheme is a main pipe which conveys water from the reservoir by pumping unto the cropped field. The main pipe was a high quality and performance HDPE pipe (PE 100) that secured water flow in the scheme. Thus, the scheme recorded 100% maximum flow length. This means that water flowed through the entire length of the main pipeline in the scheme without any obstructions.

The main canal at Kaniago was in good condition with no damaged walls and leakages. However due to very low velocity flow at the downstream of the canal, the flow length was reduced by 36%, equating to 0.8 km of the total canal length (2.2 km). Ijir (1994) indicated a notional normal value of 100% for extent of main canal/pipe flow lengths.

Estimated total irrigation water supply per hectare per season: Akumadan irrigation scheme: Lacking in the scheme was a flow meter to monitor quantities of water supply per season in the irrigable area. The design discharges of the pumps were used to estimate the quantity of water supply per season on the irrigation scheme:

Pump discharge = 3 $m^3\ min^{-1}$

(Two pumps were operated simultaneously during irrigation)

Pump operating time per day = 9 *hours*

Thus, total pump discharge in a day = 3 m^3 × 60 *min* × 9 *hrs* = 1,620 $m^3\ day^{-1}$.

Irrigation frequency = 4 $days\ wk^{-1}$

Hence, total pump discharge per week = 1,620 × 4 = 6,480 $m^3\ wk^{-1}$

Per month = 6,480 m^3 × 4 = 25,920 $m^3\ month^{-1}$

Since active irrigation season begins from January to March (Thus; 3 months)

Therefore,

Pump discharge per season = 25,920 m^3 × 3 = 77,760 m^3

Since two pumps were operated, the total pump discharge per season = 77,760 m^3 + 77,760 m^3 = 155,520 m^3

Hence; volume of water supply per hectare per season = 155,520 m^3 ÷ 45 *ha* = 3,456 $m^3\ ha^{-1}\ season^{-1}$

According to Etissa et al. (2014), total irrigation in an intensive vegetable enterprise requires about 8000 m^3 of water per annum for each hectare worked. However, this quantity will be lower in cool, moist areas, especially under sprinkler and drip irrigation, and appreciably higher in hot, dry areas where less efficient flood irrigation is practiced. Thus, water supply quantity of 3,456 $m^3\ ha^{-1}$ under overhead irrigation was acceptable especially for a three (3) month irrigation period.

Kaniago irrigation scheme: The flow rate and cross-sectional area of the main canal were employed to estimate the total water delivery per hectare per season in the scheme.

Thus;

Canal mean flow velocity = $0.8 \times \left(\frac{10\ m}{29\ s}\right) =$ 0.276 $m\ s^{-1}$

Canal flow area (rectangular canal system) = *flow width* × *depth of flow*) = 1.0 *m* × 0.16 *m* = 0.16 m^2

Canal discharge = 0.276 $m\ s^{-1}$ × 0.16 m^2 = 0.044 $m^3\ s^{-1}$ = 2.64 $m^3\ min^{-1}$

Total irrigation time per day = 10 *hours*

Thus, discharge through main canal per day = 2.64 $m^3\ min^{-1}$ × 60 *min* × 10 *hrs* = 1,584 m^3/day.

Irrigation frequency = 4 $days\ wk^{-1}$

Hence, total discharge per week = 1,584 m^3 × 4 = 6,336 $m^3\ wk^{-1}$

Discharge per month = 6,336 m^3 × 4 = 25,344 $m^3\ month^{-1}$

Therefore;

Irrigation discharge from reservoir through main canal per season;

= 25,344 m^3 × 3 = 76,032 $m^3\ season^{-1}$

Hence; volume of water supply per hectare per season = 76,032 m^3 ÷ 24*ha* = 3,168 m^3 *ha season*

The discharge of 3,168 m^3 per season was considerable for vegetable crops raised on a hectare of land. However, it was realised that gravity flow in the main canal was very low at the tail end of the canal. This phenomenon could be attributed to the uneven canal slope in the scheme hence encumbered water supply to the downstream portions of the scheme.

3.1.2 Physical structures performance

Indicators such as irrigation rate, sustainability of irrigated area, poor structure index and efficiency of road network passability were considered for evaluation of the physical performance of the schemes.

Irrigation rate: Presented in Table 3 are figures of irrigation rate for the various schemes.

Table 3 Irrigation rates

Indicator	Actual Irrigated Area (ha) *					DIA (ha)	Irrigation Rate (%)**				
Year	2018	2019	2020	2021	2022		2018	2019	2020	2021	2022
Akumadan	60	55	41	-	25	166	36	33	25	-	15
Kaniago	32	34	26	19	11	60	53	57	43	32	18

Note: DIA - Developed irrigable area

Akumadan irrigation scheme: The irrigation rates for the scheme averaged as low as 27.25% from the year period of 2018 – 2022. This suggests that only 27.25% of the total developed irrigable area was put to cultivation in the scheme. The low rates recorded were attributed to inadequate surface materials (laterals, hydrants and sprinklers) making it difficult to efficiently utilize the developed irrigable area of the scheme. Ijir (1994) indicates a notional acceptable value range of 90%– 100% for irrigation rates.

Kaniago irrigation scheme: The irrigation rates for the scheme from 2018 – 2022 ranged from 18% – 57% with the lowest rate recorded in the year 2022. The low rate recordings in recent years on the scheme was ascribed to the gradual subsidence of farmers interest in irrigated agriculture due to:

Low market prices for the farm produce especially for the years 2018 and 2019.

Yield losses due to agronomic challenges on the scheme.

Low gravity flow in the main canal which impeded water conveyance to the downstream of the irrigable area.

Sustainability of irrigated area index (SIAI): Table 4 presents the sustainability indices of the irrigated areas in the schemes.

Table 4 Sustainability of irrigated area index

Scheme	Irrigated Area (ha) in 2022 *	Initial Irrigated Area (ha) After Scheme Completion *	SIAI (%)**
Akumadan	25	80	31
Kaniago	11	40	28

Akumadan recorded SIAI of 31% which outlies the sustainability range of 90% – 100% as indicated by Sener et al. (2007). The reduction in the irrigable area of the scheme over the years was as a result of the following factors:

Inadequate laterals and sprinklers caused by faults, and materials having outlived their usefulness on the scheme

Inadequate labour on the scheme to ensure efficient and effective operation.

Market losses, leading to a decline in farmers interest in irrigated agriculture.

Lack of credit facilities to boost production on the scheme.

Similarly, a low SIAI of 28% was recorded for the Kaniago scheme. This was as a result of the subsidence of farmers interest in irrigated agriculture due to yield and market losses observed over the years in the scheme. Moreover, the low gravity flow observed especially at the tail end of the canal impeded cultivation in the downstream of the irrigable area of the scheme.

Poor structure index (PSI): The poor structure indices of the schemes are presented in Table 5.

Table 5 Poor structure indices of the irrigation schemes

Scheme	No. of unit structures				Total No. of unit structures*	Unit No. in good condition*	Unit No. in poor condition*	Poor structure index (%)**
	C	R	Fm	Eu				
Akumadan	3	4	0	4	11	8	3	27
Kaniago	1	5	1	0	7	6	1	14

Note: C - Conveyance, R – Regulatory, Fm - Flow measurement, Eu – Energy utilization

Table 6 Roads passability in the irrigation schemes

Scheme	Actual length of roads which has all year round accessibilty (km) *	Total length of roads within the scheme (km) *	Efficiency of road passability (%)**
Akumadan	5.6	5.6	100
Kaniago	0	0	0

Table 7 Efficiency of ISC recovery (%)

Indicator	Expected total annual ISC (GH¢) – a *				
Year	2018	2019	2020	2021	2022
Akumadan	228,000	209,000	170,150	-	103,750
Kaniago	12,800	13,600	10,400	9,500	5,500
	Actual total annual ISC (GH¢) – b *				
Year	2018	2019	2020	2021	2022
Akumadan	193,100	184,324	136,595	-	85,450
Kaniago	7,550	6,820	3,500	3,050	1,350
	Efficiency of ISC recovery (%) – $(\boldsymbol{b/a}) \times \mathbf{100}\%$ **				
Year	2018	2019	2020	2021	2022
Akumadan	85	88	80	-	82
Kaniago	59	50	34	32	25

Akumadan irrigation scheme: The Table 5 shows PSI of 27% recorded on the scheme. This means that 73% of the conveyance, regulatory, flow measurement and energy utilization structures were in good working condition. A survey on the scheme revealed the poor physical condition of many sprinklers and hydrants. Moreover, laterals with unfit couplings made connections difficult on the scheme.

Kaniago irrigation scheme: The scheme recorded a low PSI of 14%. Consequently, 86% of structures on the scheme were in good working condition. The canal, canal valves, gate structures, weir and flume remained in good operating condition except for the faulty and nearing fault hydrants on the scheme. In all, the condition of structures on the scheme was commendable.

Efficiency of roads passability: There were no constructed roads in the Kaniago scheme hence no recorded figure on efficiency of road passability. This means farmers accessibility on the scheme was restricted rendering the transport of farm produce and inputs difficult on the scheme. Inspection and maintenance works were impeded to some extent.

At Akumadan, the scheme recorded a road network passability efficiency of 100%. This implies that accessibility by farmers and management was enhanced ensuring easy transport of farm input and produce and improvement of inspection and maintenace works on the scheme. Ijir (1994) reports the ideal efficiency value of roads passability as 100%. Table 6 shows the road passability efficiencies of the schemes.

3.1.3 Economic performance

The economic performance of the irigation schemes was evaluated using indicators of efficiency of ISC recovery, scheme financial autonomy factor and financial self-sufficiency rate.

Efficiency of ISC recovery: This indicator assesses the willingness of water users in paying for water usage in the schemes. High efficiency of ISC recovery reflects management's ability to properly manage the irrigation facilities. Presented in Table 7 are results of the efficiency of ISC recovery (EISCR) for the schemes.

ISC: The ISC for the past five (5) years had ranged from GH¢ 3,800 - GH¢ 4,150 at Akumadan and GH¢ 400 - GH¢ 500 at Kaniago for a hectare of land cultivated per season. The ISC for the Akumadan scheme was high since the scheme utilised energy during operations.

The EISCR for the Akumadan scheme spanning the years 2018 – 2022 was 84% on average. The seemingly high recovery rate obtained on the scheme was attributed to management's effectiveness in collection of irrigation service fees since operation and management of pumped schemes comes with enormous energy usage cost. Hence, electricity is pre-requisite for the operation of pumped irrigation schemes. According to Sener et al. (2007), the notional value for ISC recovery is between 90% – 100% of the expected total ISC for the season or year. Therefore recorded at the Akumadan scheme was an unsatisfactory EISCR value. Recorded on the Kaniago scheme was an average EISCR value of 40%. The reason for this low figure was because majority of the farm plots in the scheme were family lands and were mostly cultivated by members of those families. Therefore plot holders did not realise the obligatory sense in paying their irrigation service fees.

Scheme financial autonomy factor (SFAF): According to Adongo (2015), the amount of revenue retained by irrigation scheme management shows the degree of the scheme's financial control of internally generated funds rather than over-reliance on Central Government for financial assistance.

At Akumadan, 6% of the total generated revenue in the scheme was retained for management and overheads whiles 24% of the revenue was passed to the Central Governement (GoG). This clearly indicates the meagre portion of the total generated revenue retained by management. Kaniago being farmer managed scheme recorded a high degree of SFAF since all collected irrigation service fees were retained by the scheme. Ijir (1994) indicated that for an irrigation scheme to be described as financially autonomous, at least 50% of the collected irrigation service fees should be retained by the managing agency.

Financial self-sufficiency rate (FSSR): This indicator measures the ability of the irrigation scheme to independently sustain its finances with regards to regular management, operation and maintenance disbursements. MOM costs do not include major maintenance and rehabilitation works in the schemes.

Management, Operation and Maintenance Costs: The MOM costs incurred on the Akumadan scheme constituted 76% of the total revenue generated by the scheme. Thus 70% of the total revenue was expended on electricity annually whilst the remainder 6% was disbursed on management activities and overheads.

The total annual income from water charges and diverse revenue sources recorded on the Akumadan scheme between the years of 2018 – 2022 ranged from GH¢ 85,450 - GH¢ 193,100 against an annual MOM cost range of GH¢ 64,942 - GH¢ 146,756 within the same period. It was realised that majority of the MOM costs were energy cost that emanated from daily operation of the scheme. An average FSSR of 132% was recorded in the scheme. The FSSR was high and acceptable compared to the ideal FSSR value of 100% or more (> or = 100%) as reported by Kuscu et al. (2009). At Kaniago, none of the generated revenue was expended on MOM activities in the scheme. The scheme had no other revenue sources apart from the water-user fees. Albeit no other revenue sources apart from the water-user fees, the scheme was independently capable of sustaining its finances since it did not incur any management, operation and maintenance cost for the past five years. Thus, farmers assumed roles to help manage, operate and maintain the scheme.

3.1.4 Environmental performance using environmental stability index

The index assessed the stability of the developed irrigable areas of the schemes with regards to environmental conditions of salinity, sodicity, erosion and waterlogging as a result of the adverse impact of irrigation. Measurable soil salinity and sodicity levels helped in determining the environmental stability index. Table 8 displays the environmental stability indices of the schemes.

Table 8 Environmental stability indices of irrigation schemes (%)

Scheme	Total Developed Area (ha)*	Total Developed Area Affected (ha)*	Type of Environmental Problem in the Scheme*	Total Developed Area Unaffected (ha)*	Environmental Stability Index (%) **
Akumadan	166	0	-	166	100
Kaniago	60	0	-	60	100

The Table 8 shows 100% environmental stability indices recorded for both Akumadan and Kaniago. This means that both schemes were environmentally stable and free from problems of salinity, sodicity, erosion and waterlogging.

(1) Soil pH in the irrigable area of the irrigation schemes

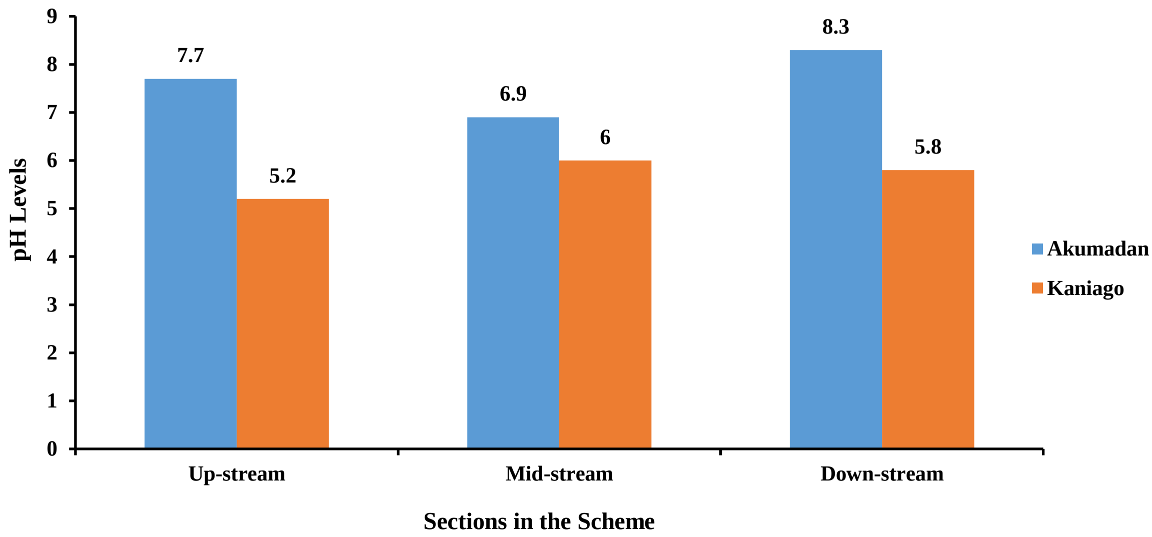

Figure 2 Soil pH levels of irrigable areas

As shown in Figure 2, the Kaniago scheme recorded average soil pH of 5.7 depicting moderately acidic soils. Soils from Akumadan scheme recorded average pH value of 7.6 indicating slightly alkaline soils in the irrigable area of the scheme. The T-test analysis performed on soil pH values obtained for the upstream, midstream and downstream of the irrigable areas in the schemes gave p-value of 0.010697 (< 0.05). This indicates that the differences in soil pH at the various sections of the irrigable areas of the schemes was statistically significant. The slightly alkaline nature of the Akumadan scheme soils could be attributed to naturally occuring sodium carbonate (Na_2CO_3) and sodium bicarbonate ($NaHCO_3$) released upon weathering. The presence of moderately acidic soils at Kaniago could be due to: i) rainwater leaching away basic ions of calcium (Ca^{2+}), magnessium (Mg^{2+}), potassium (K^+) and sodium (Na^+); ii) carbon dioxide (CO_2) from decomposing organic matter and root respiration dissolving in soil water to form a weak organic acid.

(2) Soil salinity in the irrigable area of the schemes

The measured values of EC describes the salinity levels in soils collected from the upstream, midstream and downstream of the irrigable area of the schemes. The Figure 3 shows measured values of EC recorded on the schemes.

The EC values as shown in Figure 4 shows permissible levels of EC measurement in the irrigable areas of the schemes. . The *T*-test analysis performed on salinity levels in soils across various streams of the irrigable areas gave *p*-value of 0.0036 (< 0.05), meaning soil salinity differences among the various sections in the irrigable area of the schemes was statistically highly significant. According to Hanson and May (2004), the allowable EC level in soil of an irrigable area should be equal to or less than 2.5 dS m^{-1} (= or < 2.5 dS m^{-1}). High soil salinity levels could inhibit plant growth and development by restricting nitrogen uptake from the soil. Mohanavelu et al. (2021) indicated that salinity in soil can originate from soil parent material; from irrigation water and from fertilizers or other soil amendments.

(3) Soil sodicity levels in the irrigable areas of the schemes

The ESP indicator was used to determine the sodicity levels in soils found in the irrigable areas of the schemes. The measured ESP values are presented in Figure 4.

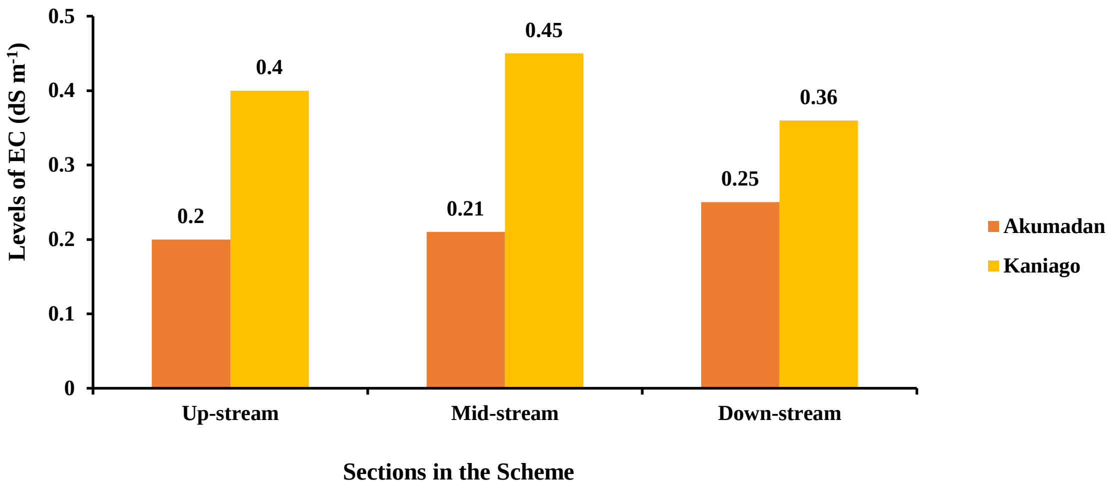

Figure 3 Salinity levels in soils of the irrigable areas

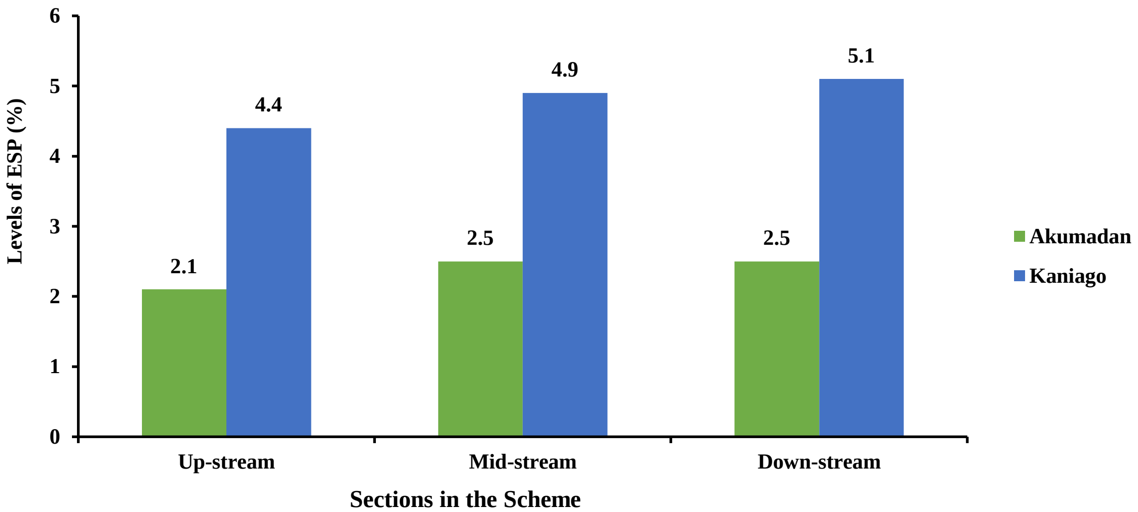

Figure 4 Levels of sodicity in the soils of the irrigation schemes

The average ESP values recorded at Akumadan (2.4%) and Kaniago (4.8%) showed differences in proportions of sodium in soils of the irrigable areas of the schemes. The *p*-value of 0.00641 (< 0.05) from T-test analysis shows a significant difference in sodium levels across the streams of both schemes. It was realised that the ESP of soils within the irrigable areas of the schemes were at acceptable levels that do not interfere with vegetable crop growth and development.

(4) Soil texture in the irrigable area of the schemes

The textural classes of soils present in the various irrigation schemes are shown in Table 9.

3.1.5 Production performance

A survey across the irrigation schemes revealed variations in the type of crops cultivated on the schemes. Due to lack of proper production records, evaluations were limited to the 2020/2021 irrigation seasons while referencing past production records as discussed in other published and unpublished researched materials about the schemes.

Akumadan irrigation scheme: According to management, cultivation on the scheme had for the past three years been limited to three crop types; tomato (*Solanum lycopersicum*), bell pepper (*Capsicum annuum*)and okra (*Abelmoschus esculentus*). According to Odamtten et al. (2016), Akumadan recorded yield values of 10 t/ha and 9.5 t/ha for tomato and pepper respectively in the 2013 production year. Shown in Table 10 are yield comparisons of the Akumadan scheme for years 2013 and 2020.

Table 9 Textural classes of soils in the irrigable areas of the schemes

Scheme	Location in field	Textural classes	Average textural class
	US	Sandy Clay Loam	
Akumadan	MS	Sandy Clay Loam	Sandy Clay Loam
	DS	Sandy Loam	
	US	Sandy Loam	
Kaniago	MS	Silt Loam	Silt Loam
	DS	Silt Loam	

Note: US - Up stream; MS - Mid stream; DS - Down stream.

Table 10 Yield value recordings of the Akumadan scheme for years 2013 & 2020

Crop	Average yield (t ha^{-1}) 2013	Average yield (t ha^{-1}) 2020	MoFA achievable yield (t ha^{-1})
Tomato	10.4	12	15
Pepper	9.5	9	32
Okra	-	10.5	15

From Table 10,tomato production was high in the year 2020 compared to the baseline data of the year 2013. However, pepper production rate had decreased in the year 2020. Comparing values to MoFA's achievable yield shows a decline in production performance in the Akumadan scheme. The regular decrease in the cultivable area size in the scheme affected the production performance of the scheme.

Kaniago irrigation scheme: The plot-holders in the scheme cultivated mainly cabbage (*Brassica oleracea var*. *capitata*), garden eggs (*Solanum melongena*) and maize (*Zea mays*). In the year 2021, yield values of 27.6 t ha^{-1}, 11.3 t ha^{-1} and 0.95 t ha^{-1} for cabbage, garden eggs and maize respectively. However, MoFA (2020, 2011) reported achievable yields of 15 t ha^{-1} for garden eggs and 3.5 t ha^{-1} for maize. Thus, MoFA had no yield records on cabbage production. Nevertheless, the Farmdreams Guide (2021) reports an achievable yield value of 70 t ha^{-1} on cabbage production. Conclusively, yield values recorded in Kaniago were low as a result of poor agronomic practices coupled with poor water conveyance and distribution especially at the downstream of the scheme.

3.2 Challenges encountered in the irrigation schemes

According to management of both schemes, some farmers were reluctant in the payment of ISC which affected maintenance and repair works on the schemes. Allocation and utilization of irrigation services income was problematic especially on the Kaniago scheme since there was no clear-cut plan by the WUA executives on usage of irrigation services income.

Regarding the condition of infrastructure, the Akumadan scheme was confronted with challenges of many faulty sprinkler heads, inadequate laterals with un-fit coupling and hydrants having broken valves.

These challenges affected conveyance and uniform distribution of water on the scheme. At Kaniago, the infrastructure challenges were that of faulty hydrants and poorly designed canal slope that resulted in low gravity flow in the main canal hence affecting water conveyance to the downstream of the scheme. Shown in Figures 5 and 6 are photographs of poorly functioning infrastructure in the Akumadan and Kaniago schemes.

(a) Leaking pipe lateral with unfit coupling (b) Hydrant with broken valve

(c) Faulty hydrant abandoned in the scheme (d) Faulty and abandoned sprinkler

Figure 5 The deplorable state of structures in the Akumadan scheme

(a) A faulty hydrant (b) Evidence of low gravity flow in the downstream of the scheme

Figure 6 The challenges in the Kaniago scheme

4 Conclusion

The study revealed that:

The developed irrigable areas at Akumadan and Kaniago were under-utilised; thus, with recorded average irrigation rates of 27.25% and 41% respectively.

The sustainability of irrigated area indices of Akumadan (31%) and Kaniago (28%) were low indicating a substantial decline in irrigated agriculture.

Akumadan recorded 100% maximum pipe flow length whiles Kaniago recorded a low canal flow length of 64%.

Considering the efficiency of road network passability, the road network at Akumadan was accessible all year round. However, Kaniago had no major road network in the scheme.

Irrigation structures were in deplorable condition due to worn-out parts, broken parts or outlived lifespan. Thus, the structures lacked maintenance and rehabilitation.

Both irrigation schemes were environmentally stable and resilient with regards to problems of salinity and sodicity.

Akumadan experienced low degree of financial autonomy since only 6% of the irrigation services income was retained by management whiles 24% was passed to the central government. Kaniago on the otherhand recorded high degree of financial autonomy.

Crop production on the schemes was generally low due to the constant decrease in size of the cultivable areas.

To improve upon the performance of the irrigation schemes, the following are recommended:

Management should ensure regular and periodic repairs, maintenance and replacement of infrastructure in the schemes.

Management of the pumped scheme (Akumadan) should make available enough surface materials to enhance efficiency in operations.

Payment of ISC before cropping should be adopted by management of the schemes to ensure high recovery rates.

Management should adopt the culture of proper record keeping so as to keep track of operations and activities on the schemes.

The Scheme Managers should fully involve farmers in the operation and management of the schemes, which would consequently improve performance.

The WUA managed schemes (Kaniago) should periodically seek professional advice on proper agronomic practices so as to enhance production.

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Appendices

Appendix A1a Comparison of performance indicators between actual and notional normal values for the irrigation schemes

Performance Indicator	Notional Normal Value (%)	Scheme	Actual Values for the Schemes (%)				
			2018	2019	2020	2021	2022
Irrigation rate (%)	90 - 100	Akumadan	36	33	25	-	15
		Kaniago	53	57	43	32	18
Efficiency of ISC recovery (%)	90 - 100	Akumadan	85	88	80	-	82
		Kaniago	59	50	34	32	25
Financial self sufficiency factor (%)	> or = 100	Akumadan			132		
		Kaniago			> 100		
Scheme financial autonomy factor (%)	> or = 50	Akumadan			25		
		Kaniago			100		
Extent of main canals/pipe flow lengths (%)	100	Akumadan			100		
		Kaniago			64		
Poor structure index (%)	0	Akumadan			27		
		Kaniago			14		

Appendix A1b: Comparison of performance indicators between actual and notional normal values for the irrigation schemes

Performance Indicator	Notional Normal Value (%)	Scheme	Actual Values for the Schemes (%)				
			2018	2019	2020	2021	2022
Sustainability of irrigated area index (%)	90 - 100	Akumadan			31		
		Kaniago			28		
Efficiency of roads passibility (%)	100	Akumadan			100		
		Kaniago			0		
Environmental stability index (%)	90 - 100	Akumadan			100		
		Kaniago			100		

Appendix A2a Qualitative checklist of performance indicator measurements on the irrigation schemes

Performance Indicator	Type of Performance Measure	Scheme	Performance Ranking				
			2018	2019	2020	2021	2022
Irrigation rate	Output	Akumadan	VP	VP	VP	-	VP
		Kaniago	P	P	VP	VP	VP
Efficiency of ISC recovery	Output	Akumadan	A	A	A	-	A
		Kaniago	P	P	VP	VP	VP
Financial self sufficiency factor	Process	Akumadan			Good		
		Kaniago			Good		
Scheme financial autonomy factor	Process	Akumadan			Very poor		
		Kaniago			Good		
Extent of main canal/pipe flow lengths	Input	Akumadan			Good		
		Kaniago			Poor		
Poor structure index	Input	Akumadan			Very poor		
		Kaniago			Very poor		

Note: VP - Very poor, P - Poor, A - Acceptable and G - Good

Appendix A2b Qualitative checklist of performance indicator measurements on the irrigation schemes

Performance Indicator	Type of Performance Measure	Scheme	Performance Ranking				
			2018	2019	2020	2021	2022
Sustainability of irrigated area index (%)	Output	Akumadan			Very poor		
		Kaniago			Very poor		
Efficiency of roads passibility (%)	Input, Output	Akumadan			Good		
		Kaniago			Very poor		
Environmental stability index (%)	Output	Akumadan			Good		
		Kaniago			Good		

Appendix A3 Indicator measurement ranges and their corresponding remark

Measurement Range (%)	Remark
< 50	Very poor
50 - 79	Poor
80 - 89	Acceptable
= > 90	Good

Appendix A4 Laboratory results for the physico-chemical characteristics of soils in the irrigable areas of the schemes

Akumadan Scheme					
Parameter	Up-stream	Mid-stream	Down-stream	Mean value	Acceptable Mean value
pH	7.7	6.9	8.3	7.6	6.0 – 7.0
EC (dS/m)	0.2	0.21	0.25	0.22	= or < 2.5
ESP (%)	2.1	2.5	2.5	2.4	< 15
Texture	Sandy clay loam	Sandy clay loam	Sandy loam	Sandy clay loam	Loamy sand
Kaniago Scheme					
Parameter	Up-stream	Mid-stream	Down-stream	Mean value	Acceptable Mean value
pH	5.2	6.0	5.8	5.7	6.0 – 7.0
EC (dS/m)	0.4	0.45	0.36	0.4	= or < 2.5
ESP (%)	4.4	4.9	5.1	4.8	< 15
Texture	Sandy loam	Silt loam	Silt loam	Silt loam	Loamy sand

Appendix B1 The ratio of good irrigation structures to the total number of structures in the schemes

Irrigation Structure	Total No. of Structures	No. of Structures in Good Condition	No. of Structures in Bad Condition	$\frac{\text{Good struc.}}{\text{Total No. of struc.}}$
Akumadan Scheme				
Pump(s)	4	4	0	1.0
Power distribution panel	1	1	0	1.0
Motor starting panel	4	4	0	1.0
Main pipe	1	1	0	1.0
Spillway	1	1	0	1.0
Sprinkler(s)	88	21	67	0.2
Pipe lateral(s)	72	34	38	0.5
Hydrant(s)	156	82	74	0.5
Valve(s)	2	2	0	1.0
Kaniago Scheme				
Main canal	1	1	0	1.0
Weir	1	1	0	1.0
Flume	3	3	0	1.0
Gate structure(s)	9	8	1	0.9
Valve(s)	2	2	0	1.0
Diversion boxes	8	8	0	1.0
Hydrant(s)	32	19	13	0.6

Appendix $B2_a$ Existing structures and facilities in the Akumadan scheme

Pumphouse

Pumps

Power distribution panel

Motor starting panel

Reservoir and its catchment

Spillway

Appendix B2b Existing structures and facilities in the kaniago scheme

Weir

Flume

Reservoir

Main valve

Diversion box

Canal