**ORIGINAL RESEARCH ARTICLE**

# Evaluating the technical, managerial, socio-economic and environmental performance of Kenya's Ahero irrigation scheme using the analytical hierarchy process (AHP) model

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**Abstract**

A majority of public irrigation schemes worldwide have continuously performed below their potential, and there is a need to investigate key components of irrigation scheme performance and provide study-based recommendations to enhance their optimal productivity. The Ahero Irrigation Scheme in Kenya is one such scheme, and this study is meant to evaluate the scheme's technical, management, environmental, and socio-economic performance, which are crucial to the overall performance of an irrigation scheme. The technical factor considers the system hydraulics; management considers the maintenance of infrastructure and the organizational set-ups in the scheme to ensure effective service delivery; the environmental factor evaluates scheme operations against adverse environmental impacts; and the socio-economic factor evaluates income by farmers from the sale of rice and credit access to enhance their farm operations. Models have been applied to evaluate the most significant parameters affecting the performance of schemes and to help plan out which factor is to be addressed first. This study aimed to evaluate the technical, managerial, socioeconomic, and environmental performance of the Ahero Irrigation Scheme in Kenya using the Analytical Hierarchy Process (AHP) model. The indicators used under the technical parameter include adequacy, equity, efficiency, and dependability. Questionnaires were used to obtain information on farmer satisfaction with irrigation water delivery amounts and timing and any extra feedback to improve the technical performance of the scheme. For the managerial parameter, the indicators include the effectiveness of infrastructure, land renovation ratio, and training. The number of functional structures was counted, and a ratio of functional to total structures was calculated to determine the effectiveness of infrastructure. The land renovation was calculated as a ratio of the area under irrigation to the total gazetted land of the irrigation scheme. Questionnaires were used to gather feedback on extension services, if any, advanced to farmers. Random sampling was used to select farmers distributed across the scheme, with a confidence level of 95%. For the environmental parameter, the indicators used include the drainage ratio, the river water ratio, and the groundwater ratio. On the technical parameter, the canal's conveyance efficiency was found to be 60% (fair); adequacy in the upper, mid, and lower streams of the scheme was 0.99 (very good), 0.82 (good), and 0.74 (poor), respectively; equity was 0.57 (poor); the coefficient of variance for dependability for the April-July season was 5.3 (good), while for the reference year 2020, it was 16.23 (poor). The findings for the scheme's hydraulic performance generally indicated that water distribution and utilization in the scheme were inefficient. Farmers also complained about inconsistencies in water delivery owing to the scheme's reliance on pumping irrigation water, which is affected whenever there


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are power outages. On the managerial parameter, the effectiveness of infrastructure was found to be 89%, while the irrigation ratio was established at 62%. It was also noted that training farmers was not done regularly. On the socio-economic parameter, it was noted that credit was given to farmers based on their capacity to pay it back. Notable also was the fact that the income of farmers was poor, which was the result of an unavailable market for harvested rice. On the environmental parameter, the river water ratio was found to be 1, since the irrigation scheme had no other source of water other than river water. Based on the overall AHP analysis, the technical parameter (51%) should be given more priority, followed by the socio-economic parameter (32%), the management parameter (11%), and the environmental parameter (6%).

**Key words**: Analytical hierarchical process model (AHP), environmental, hydraulic performance ratios, management, socio-economic and technical performance, optimization.

## 1.0 Introduction

Irrigated agriculture is vital in most countries worldwide. It is vital in terms of public development, food security, and settlement for people in rural areas. With the continued rise in world population, the need for more efficient and effective use of water and land resources is rising. Despite the massive potential of these resources in supporting agriculture, there has been a significant decrease in the performance of many irrigation projects, particularly large-scale irrigation projects (Bos et al., 2005; Dejen, 2015; Alcon et al., 2017). This is majorly attributed to the poor management of resources, the lack of planned benefits, and the devastating health and environmental effects. This scenario has led to an increased number of interventions meant to improve the performance of irrigation projects.

Many studies around the globe have been carried out to investigate the performance of irrigation projects. Cin (2017) evaluated performance in the Basoren irrigation area, Ankara, where the performance indicators of agricultural efficiency, water utilization efficiency, social efficiency, and economic efficiency were used. Cakmak (2009) assessed the performance of the Asartepe Irrigation Association in Turkey, where the main objective was to investigate the performance of the scheme's water user associations. Dejen (2016), on the other hand, analyzed the performance of water delivery in Ethiopia's smallholder irrigation schemes. Generally, the studies cover several irrigation projects worldwide, both in developing and developed countries (Gorantiwar et al., 2005). The goal of performance evaluation is to achieve efficient and effective resource utilization by providing critical feedback to management at all levels. Additionally, it helps in getting vital information so that corrective actions can be taken to maximize the benefits of an irrigation project. Performance assessment also helps with the verification of the important project lessons learned and in coming up with benchmarks that will improve the overall planning, execution, and management of similar projects (Bos et al., 2005).

The process of performance assessment is normally complex since several regular tasks must be done both sequentially and concurrently, and the tasks are to be coordinated within the available limited resources. To enhance this process, several efforts have been made to assess


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the influence of such interventions or to promote performance understanding so that improvement can be furthered. The factors that affect the performance of irrigation schemes are used together with their indicators during performance assessments (Sun, 2017). For instance, in the case of our study site, Ahero Irrigation Scheme, the critical non-technical factors significantly influencing performance are managerial, environmental, and socio-economic factors. The indicators used under the managerial parameter include: efficiency of structures, measurement equipment, credit ratio, and river water ratio; those under the socio-economic parameter are: income ratio, satisfaction ratio, equipping, and renovation of land ratio. Under the environmental parameter, the sub-parameters include the drainage ratio and the groundwater ratio (Montazar, 2012).

According to Miruri & Wanjohi (2017), the daily management of irrigation schemes significantly affects the performance of Kenya's public irrigation projects. The management of water use and hydraulic structures was critical, based on the studies by Miruri and Wanjohi (2017) on the determinants of performance of the Nthawa irrigation project. Waterlogging caused by poor drainage is an environmental concern in the Ahero Irrigation Scheme. Also, the Ahero Irrigation Scheme has been operating with little farmer returns and a generally low satisfaction level for farmers concerning the scheme's operation (Elshaikh, A.E., Jiao, X., & Yang, S., 2018).

The improvement planning of an irrigation project is influenced by the way irrigation professionals assess the status quo at the initial stage. Assessors must consider several aspects of irrigation projects, including engineering, economics, the environment, and the local community, and then recommend measures that are feasible to help achieve the goals linked to the improvement (Gitonga et al., 2019). At present, however, there is limited documented and verifiable baseline data on the status of irrigation schemes, especially in terms of their technical, managerial, socio-economic, and environmental performance. This makes it difficult to study and recommend production optimization measures, which are desperately needed in most irrigation schemes in Kenya, AIS included.

The purpose of this paper is to provide an evaluation of the technical, managerial, socio-economic, and environmental performance of AIS that can be used to enhance productivity. The paper also seeks to rank these parameters in order of their significance to guide prioritization. By addressing the identified inefficiencies in either of the listed parameters and as guided by their level of importance, if recommendations are implemented, then the general performance of AIS in terms of productivity will be enhanced. Farmers will in turn be able to realize the full potential of their operations under the scheme, which will minimize unnecessary costs and boost their incomes.

## 2.0 Materials and methods

### 2.1. Description of the study area

Ahero Irrigation Scheme (AIS) is located in Kisumu County, Kenya, between the Nyabondo plateau and the Nandi Escarpment in the Kano plains. The scheme's construction started in 1966, while operations commenced in 1969. The main crop grown in the scheme under surface


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irrigation by flooding water is rice. Other crops grown at the scheme include watermelon, soybeans, tomatoes, sorghum, and cowpeas. For rice, 90% is the Sindano variety, 5% is basmati, and the remaining 5% is the hybrid type. The gazetteer area for the scheme is 4,176 acres, and the area under irrigation is 2,586.5 acres. The River Nyando is the source of irrigation water for the scheme, which is pumped about 20 metres from the river into a partially lined earth canal. The scheme has 2,000 farmers, 570 farm holders, and 20,000 dependents (National Irrigation Board, 2018). Figure 1 presents the location of AIS and the farm layout, respectively.

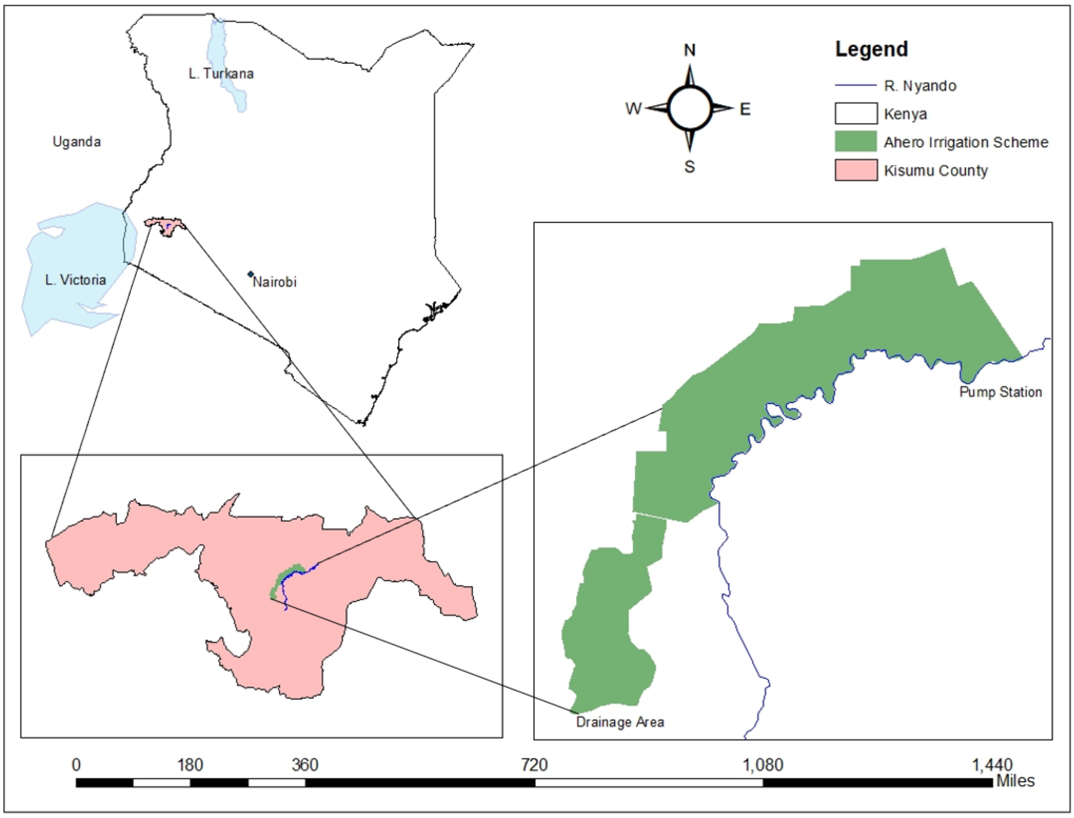


*Figure 1: Location of Ahero Irrigation Scheme, Kisumu County, Kenya*

### 2.2 Sources of data and methods of collecting the data

Data on the technical, managerial, socio-economic, and environmental parameters were collected through direct measurements in the field and the administration of questionnaires. Discharge measurements were done in the main and branch canals using the velocity area method, while the hydraulic structures were physically counted, taking note of their functionalities, to help in the determination of the effectiveness of the infrastructure. Information on production, income, training, equipment repairs, and maintenance was obtained through questionnaires administered to both the farmers and the scheme's board.

### 2.3 Managerial, socio-economic and environmental performance of AIS

#### 2.3.1 Managerial performance

The indicators used under the managerial parameter include the effectiveness of


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infrastructure, land renovation ratio, and credit ratio. The effectiveness of infrastructure is measured by the ratio of functional infrastructure to the total number of infrastructures. The land renovation ratio, on the other hand, is the ratio of land area under modernization to total land area in the scheme, whereas the credit ratio is the fraction of the credit amount requested by farmers to the credit amount provided by the financing organization. The number of functional structures was therefore counted, and a ratio of functional to total structures was calculated to determine the effectiveness of infrastructure (Henok, 2014). The land renovation was calculated as a ratio of the area under irrigation to the total gazetted land of the irrigation scheme. Questionnaires that were administered randomly to 95% of the total farmers were used to seek information on their satisfaction levels concerning the existing credit facilities. The credit policy of the lenders was sought from their website to check for consistency with the feedback received from farmers. The ratio of credit required to actual available credit was calculated from the questionnaire feedback to determine the credit ratio (Cin, 2017).

### 2.3.2 Socio-economic performance

Questionnaires were used to obtain information on farmer satisfaction with irrigation water delivery, yields, incomes, and the general operation of the scheme (Moreira, 2009). The respondents were randomly selected among the active farmers across the entire scheme, with a sample size representing a confidence level of 95%. The sampling ensured views from farmers in the upper, mid, and lower reaches of the scheme. The total number of satisfied and unsatisfied farmers was counted and recorded. The ratio of satisfied to unsatisfied farmers was calculated to obtain the satisfaction ratio. To determine the equipping and renovation ratio of land, the total land area under modernization was determined using Google Earth Pro (Kloezen, 2014). The scheme was then surveyed while collecting GPS boundary locations for the areas under modernization. Modernization includes land that has optimally functional equipment and processes. The process of area determination was repeated for the total land with and without modernization equipment in AIS. The ratio of land area under modernization to the total land area in AIS was computed to determine the status of equipping and renovating land in the scheme (Dejen, 2016).

### 2.3.3 Environmental performance

The indicators used to monitor environmental performance include the drainage ratio, the river water ratio, and the groundwater ratio (Montazar, 2012). An Otto C2 current meter was placed at the outlet of each of the main drainage lines to measure the velocity of the water drained. Thereafter, the current meter measured the velocity of irrigation water entering the farm. The cross-section area for each section was determined and multiplied by the respective velocities to obtain a discharge. The volumes were summed up accordingly to obtain the total amount of irrigation water entering the farms. (Darghouth, 2005). The ratio of irrigation water leaving the farm through drainage (Qo) to irrigation water entering the farm (Qi) was calculated to obtain the drainage ratio. This parameter is important as it indicates the possibility of water logging and salinization processes. If the ratio of $Qo$ to $Qi$ is approximately 1, then waterlogging was not a problem in the scheme (El-Shaikh, 2018). The river water ratio, defined as the fraction of irrigation water abstracted from the River Nyando compared to irrigation water abstracted from other sources such as boreholes, was also calculated. This ratio is an


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indicator of the pressure put on particular water resources in an irrigation project. The Water Surface Elevation mapper was used to determine average groundwater levels in the scheme (Moreira, 2009). Six random points in the scheme were selected, and their groundwater levels were established. Two points were selected on the upstream section, two at the midstream, and two at the downstream section of the scheme. An average of the groundwater level was computed to determine the general level of the scheme's groundwater. The critical groundwater level in AIS was sought from existing literature. The ratio of the established groundwater level to the critical groundwater level was calculated to determine the groundwater ratio (FAO, 2007). The parameter was used to develop recommendations to guide the abstraction of groundwater.

**2.3.4 Weighting by pairwise comparison**

The Analytic Hierarchical Process (AHP) model was used to run pairwise comparisons for the managerial, socioeconomic, and environmental factors to establish the most significant parameter that affects the scheme's performance (Moreira, Gomes, & Rangel, 2009). Two criteria were assessed at a time, based on their relative importance. Index values ranging between 1 and 9 were used, as shown in Table 1. If the managerial parameter was exactly as important as the socio-economic parameter, the pair was given an index of 1. If the managerial parameter was much more important than the socio-economic parameter, the index assigned was 9. All gradations in between were possible. For a relationship that involved less importance, the fractions 1/1 to 1/9 were given. If, for instance, the managerial parameter was less important than the socio-economic parameter, the assigned rating was 1/9. The values were entered into a cross matrix, row by row. The diagonal in the matrix contained values of 1. The filling was started from the right upper half of the matrix and continued until each criterion was compared with all the rest. If the rating of managerial to socio-economic was "*n*", then socio-economic to managerial was rated as "*1/n*".

*Table 1: Scale of Relative Importance of Parameters used in an Evaluation*

| Value | Level of Importance |
|---|---|
| 1 | Equal importance |
| 3 | Moderate importance |
| 5 | Strong importance |
| 7 | Very strong importance |
| 9 | Extreme importance |
| 2,4,6,8 | Intermediate values |
| 1/3, 1/5, 1/7, 1/9 | Values for inverse comparison |

The pairwise comparison is illustrated in Table 2. The most significant factor established informed the recommendations provided for mitigations.


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*Table 2: Pairwise Comparisons*

| | | |
|---|---|---|
| Managerial | - | Socio-economic |
| Managerial | - | Environmental |
| Managerial | - | Technical |
| Socio-economic | - | Environmental |
| Socio-economic | - | Technical |
| Environmental | - | Technical |

## 3. Results and discussion

### 3.1 Technical performance of the scheme

The canal's conveyance efficiency was found to be 60% (fair); adequacy in the upper, mid, and lower streams of the scheme was 0.99 (very good), 0.82 (good), and 0.74 (poor), respectively; equity was 0.57 (poor); the coefficient of variance for dependability for the April-July season was 5.3 (good), while for the reference year 2020 it was 16.23 (poor). The findings for the scheme's hydraulic performance generally indicated that water distribution and utilization in the scheme were inefficient. Also, there was no water scheduling on farms, a factor that greatly contributed to the inefficiencies in water utilization. It was also noted that about 40% of the water was lost through underground seepage since the main canal was unlined throughout its entire stretch. A 0.74 adequacy value at the tail reach of the farm was contributed by the inefficiencies of the main canal. Poor land levelling restricted uniformed flow and distribution of irrigation water on individual farms, a factor that made some parts of the farm have more water than others, and hence the 0.57 equity. Farmers also complained of inconsistencies in water delivery owing to the scheme's reliance on pumping irrigation water by electricity, which is often affected by power outages. The preference was to have the irrigation water flow by gravity from the river to the very outlet of the scheme. Solar water pumping would be appropriate to raise water from the river by 10m before flowing by gravity through the canals. The Ahero region has an average daily solar duration of about 8 hours, which makes solar energy suitable and a more economical fit. The hydraulic findings of this study conform to those of Bwambale (2019), who established the efficiency, adequacy, dependability, and equity of the Doho Irrigation Scheme in Uganda as 68% (fair), 0.84 (good), 0.07 (good), and 0.26 (poor). The author recommended structural changes in management so as to improve the hydraulic performance, especially at the tail end of the scheme. The author also highlighted the need to modernize the Doho irrigation scheme to improve its efficiency, provide better services for water delivery to all users, and improve the cost-effectiveness of its operation and management. In both the Ahero irrigation scheme and the Doho irrigation scheme, it is notable that hydraulic performance is poor on the tail reaches of the schemes compared to the mid- and upper-reaches of the schemes.

### 3.2 Managerial performance of the scheme

#### 3.2.1 Effectiveness of infrastructure

The total count of infrastructure in each block is provided in Table 3. The fraction represents the ratio of functional to total infrastructure in the given block. The 'Nil' description is used where the listed equipment is not found in the given block. The summary of the count and calculated *EoI* is given in Table 4. The evaluation was conducted in November 2020.


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*Table 3: EoI in the Different Blocks of the Scheme*

| Block/Canal | Gates | Weirs | Division boxes | Culverts | Pumps | Flume | Basin |
|---|---|---|---|---|---|---|---|
| A | 6/10 | Nil | 4 | 16/18 | Nil | Nil | Nil |
| B | 8/11 | Nil | 5 | 10/12 | Nil | Nil | Nil |
| C | 2 | Nil | 1 | 4/5 | Nil | Nil | Nil |
| D | 4/5 | Nil | 2 | 8/12 | Nil | Nil | Nil |
| Research Station | 8/12 | Nil | 14 | 20 | Nil | Nil | Nil |
| F | 3/4 | Nil | 2 | 11 | Nil | Nil | Nil |
| G | 8 | Nil | 3/4 | 18/20 | Nil | Nil | Nil |
| K | 2 | Nil | 1 | 2 | Nil | Nil | Nil |
| L | 3/6 | Nil | 3 | 7 | Nil | Nil | Nil |
| M | 2/3 | Nil | 1 | 3 | Nil | Nil | Nil |
| N | 9/12 | Nil | 5 | 8 | Nil | Nil | Nil |
| O | 3/6 | Nil | 3 | 10 | Nil | Nil | Nil |
| P | 4/8 | Nil | 3 | 9 | Nil | Nil | Nil |
| Main canal | 24 | 6/7 | 4 | 26 | 2/4 | 1 | 4 |
| Main drain | Nil | Nil | Nil | 8 | Nil | Nil | Nil |

*Table 4: General EoI of the Scheme*

| Description | Number |
|---|---|
| No. of functional structures | 317 |
| No. of dysfunctional structures | 39 |
| Total no. of structures | 356 |
| EoI (%) | 89 |

From Table 4, *EoI* has been established at 89%, which is more than the recommended 80% according to Elshaikh (2018). This is due to the regular repair and maintenance work on the structures at the scheme. Structures that are faulty and beyond repair are also usually replaced on a regular basis. However, it should be noted that an EoI of at least 80% does not necessarily mean that the system is functional. In an instance where a critical unit is dysfunctional and the rest are functional, the minimum *EoI* of 80% would be met, yet the system would not function because of the one critical component that was not functioning. This is because *EoI* does not look at the importance of individual structures in a system but considers every component as equal. EoI is therefore meant to provide a general indication of the condition of structures in the scheme. Thus, based on these findings, the structures in the Ahero Irrigation Scheme are generally in good condition; hence, the maintenance schedule of the structures in the scheme can be maintained with the objective of enhancing the *EoI* from 89%.

### 3.2.2 Land renovation ratio

The total irrigated area was 2,586.5 acres, and the gazetted area was 4,176 acres. Hence, the irrigation ratio was established at 62%. The probable reasons for not utilizing the full capacity of the scheme could be limited storage for harvested rice, a limited market, and a limited


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pumping capacity of irrigation water. Currently, even with the scheme, which allows farming on only 62% of its total gazetted land, the harvested rice still does not have a market. Farmers, for instance, explained how they still had their harvest in the stores for over a year, according to the farmers interviewed. On irrigation water pumping, there have been challenges with frequent electricity outages and pump breakdowns. In terms of resources, therefore, the scheme was not ready to manage irrigation on the entire 4,176 acres of land. Kartal et al. (2019), while ranking irrigation schemes based on principle component analysis in the arid regions of Turkey, reported an average irrigation ratio of 55.68% and recommended an improvement of the distribution systems of water and also the technology utilized on both farm and management levels.

### 3.2.3 Training

Farmers' capacity building was not a regular feature of the scheme. Farmers could spend over two years without getting any extension service aimed at making them better, which was mostly attributed to a lack of goodwill by the responsible institutions. Due to limited capacity development, farmers are therefore unable to cope with emerging farming trends and end up not farming optimally. According to Augier et al. (1995), to improve the performance of an irrigation scheme, it is vital to not only promote the execution of irrigation scheduling methods but to concurrently improve system performance and design and to better the skills of farmers in managing and controlling their irrigation system more efficiently during operation.

## 3.3 Socio-economic performance of the scheme

### 3.3.1 Credit ratio

Based on the questionnaire feedback, the credit ratio was 0.5–0.75 and was given to farmers based on their capacity to pay back. Capacity was evaluated in terms of their farm sizes and expected yield. Most farm owners had 4-acre parcels of land, while a few had 2-acre parcels of farmland. It was therefore expected that farmers with 4-acre lands would be given more credit than those who owned 2-acre farmlands. Farmers' loans were to be repaid through deductions from rice sales. Atera et al. (2018), while studying Kenya's rice production and marketing, recommended that to integrate and promote rice agribusinesses in the country, there was a need for the rice farmers to have easy access to financial services that would sustainably provide affordable revolving funds.

### 3.3.2 Income

The income to farmers was poor as a result of the poor markets for the harvested rice. At the time of conducting this study, farmers had not received payment for one year because their previous harvest had not yet been sold. The local Kenyan market was heavily endowed with cheap imported rice, a factor that made it difficult for the local rice to sell. Atera et al. (2018) cited competition from cheap imported rice as one of the reasons constraining the rice sub-sector in the country. It was noted, for instance, that farmers had spent over a year without getting proceeds from their previous harvest. The main source of income for most farmers was rice farming, and therefore most of their farming operations relied on revenues generated from the sale of rice. In scenarios where a previous payment is delayed, their subsequent farming operations will be negatively affected and exposed for exploitation by middlemen and


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brokers.

## 3.4 Environmental performance of the scheme

### 3.4.1 River water ratio

The river water ratio was found to be 1 since the irrigation scheme has no other source of water other than river water. The challenge of depending on one source of irrigation water supply is the possibility of over-abstraction that will eventually reduce water flows in the river. Reduced flows affect not only the river's ecology but also the community downstream that depends on it. Specifically, irrigation may result in reduced fishing opportunities. A similar case can be found on the Indus River in Pakistan, where water has been over-abstracted for agricultural purposes. This has threatened fish populations and subsequently caused an imbalance in the natural food chain. Water abstraction from the river has also affected human populations that rely on fishing both as an economic activity and as a source of dietary protein. Also, when river flows are significantly reduced, it can lead to the disappearance of flood-forested ecosystems and wetlands. Additionally, it results in insufficient industrial, drinking, and municipal water supplies (McDermid, 2021). Within River Nyando, however, the problem of water over-abstraction might become serious when the scheme expands under the new development plans. It is even more necessary, therefore, for the scheme to efficiently manage her water.

### 3.4.2 Drainage ratio

The other environmental parameter measured in the scheme was the drainage ratio, which was found to be 33%. According to El-Shaikh (2018), if the drainage ratio is close to 100%, then waterlogging is not a challenge. It should be noted, however, that the ratio here includes only the water measured at the inflow and outflow of the scheme. Water lost through deep drainage and evapotranspiration is not factored, and therefore the value of 33% does not necessarily imply that the scheme has a problem with waterlogging. The problem of flooding in the scheme has mostly been the result of excess rains during the wet season, but has been exacerbated by the poor drainage conditions at the scheme. Flooding usually results in tremendous damage to crops and infrastructure, and therefore flood control mechanisms should always be installed to alleviate this danger in flood-prone areas. In Ahero and West Kano irrigation schemes, for instance, rice worth USD 0.8 million was destroyed after the River Nyando's banks were broken by flood waters that swept through the farms. The floods also extensively damaged the infrastructure belonging to the National Irrigation Authority (NIA) in the two schemes. Large areas of land were flooded, and seedlings were washed into Lake Victoria. By addressing the management criteria, the environmental criteria will be taken care of. This will in turn guarantee the safety of crops and infrastructure under the scheme.

### 3.4.3 Groundwater ratio

The water tables in AIS were in the range of 1–2 metres, influenced by the continuous flooding of irrigation water in the scheme. The critical groundwater depth for rice is given as 1.2m. The groundwater ratio was established at 83%. Lower water tables affect farmers extremely since there will be no water to irrigate crops. On the other hand, a rise in the water table or waterlogging brings with it salts that are left on the cultivable part of the soil when the water


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evaporates. Low irrigation efficiencies in the range of 20–30% are another reason for the rise in the water table. Poor systems of water distribution, poor management of the main system, and archaic in-field irrigation practices are other reasons. The recommendation by ICID to improve field application efficiency to about 50% can greatly minimize the rise in groundwater. The environmental criteria, although significant in determining irrigation scheme performance, are comparatively of less importance in this study (FAO/ICID Joint Publication, 1997).

### 3.5 Farmer feedback on technical, environmental and socio-economic performance of the scheme

Farmers were asked to provide feedback about their satisfaction levels with the amount of water delivered on their farms, the timing of water delivery, yield, annual income, training, and inputs. Figure 2 presents the feedback obtained from farmers on the various parameters considered.

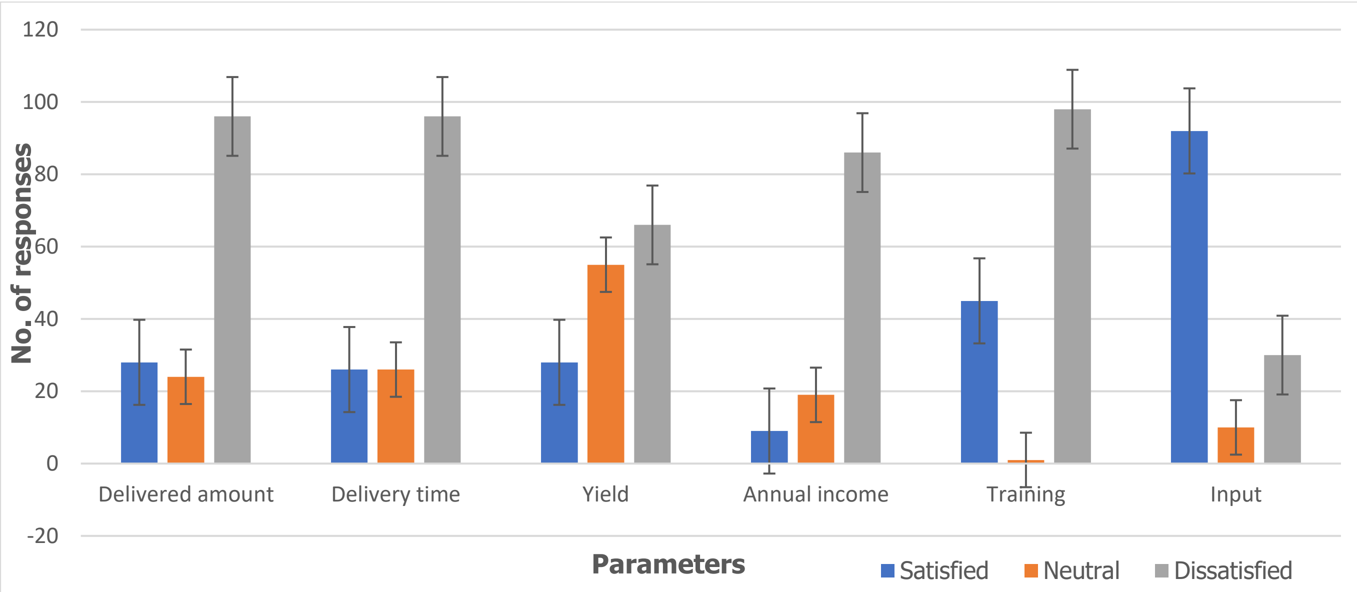


*Figure 2: Farmer Feedback on Satisfaction Levels with Irrigation Water Delivery, Yield, Income, Training and the Provision of Farm Inputs*

Most farmers were dissatisfied with the amount of water delivered on their farms, the time of water delivery, yield, income, and training. The amount of water delivered was below requirement and affected majorly by weather and power outages. The timing of water delivery was heavily affected with the existing water scheduling practice from block to block. This eventually affected yield and, hence, the income that farmers got from the harvests. Capacity development for farmers on efficient farming practices was also not regularly done and contributed to the suboptimal yields. The only arrangement that farmers were okay with was on inputs. With inputs, the quantity and timeliness of delivery were generally good.

Based on this farmer feedback, Table 5 illustrates the pairwise comparison between the different criteria used. The reasons that farmers gave for their disapproval with the scheme's


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performance in the given parameters were coherent with the observations and measurements taken for *EoI*, adequacy, and sales.

*Table 5: Pair-wise Comparison Matrix of the Technical, Managerial, Socio-economic and Environmental Factors*

| | Technical | Management | Socio-economic | Environmental |
|---|---|---|---|---|
| Technical | 1.0 | 5.0 | 3.0 | 5.0 |
| Management | 0.2 | 1.0 | 0.2 | 3.0 |
| Socio-economic | 0.3 | 5.0 | 1.0 | 7.0 |
| Environment | 0.2 | 0.3 | 0.1 | 1.0 |

*Table 6: Normalized Pair-wise Matrix of the Technical, Managerial, Socio-economic and Environmental Factors*

| | Technical | Management | Socio-economic | Environmental | Criteria Weights |
|---|---|---|---|---|---|
| Technical | 0.588 | 0.442 | 0.698 | 0.313 | 0.510 |
| Management | 0.118 | 0.088 | 0.047 | 0.188 | 0.110 |
| Socio-economic | 0.176 | 0.442 | 0.233 | 0.438 | 0.322 |
| Environment | 0.118 | 0.027 | 0.023 | 0.063 | 0.057 |

*Table 7: Consistency Calculations*

| | 0.510 | 0.110 | 0.322 | 0.057 | | | |
|---|---|---|---|---|---|---|---|
| | Technical | Management | Socio-economic | Environmental | Weighted sum | Criteria weights | |
| Technical | 0.510 | 0.550 | 0.967 | 0.287 | 2.315 | 0.510 | 4.536 |
| Management | 0.102 | 0.110 | 0.064 | 0.172 | 0.449 | 0.110 | 4.080 |
| Socio-economic | 0.170 | 0.550 | 0.322 | 0.402 | 1.445 | 0.322 | 4.484 |
| Environment | 0.102 | 0.037 | 0.032 | 0.057 | 0.228 | 0.057 | 3.974 |
| | | | | | | $\lambda_{max}$ | **4.269** |

Table 8 presents calculated random indices for the given "n" attributes.

*Table 8: Random Indices for 'n' Attributes*

| n | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| RI | 0.00 | 0.00 | 0.58 | 0.90 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.49 |

The random index of one pairwise comparison matrix is defined as $RI = (\lambda\text{-}n)/((n\text{-}1)$ where *lambda* is the maximum eigenvalue and *n* is the number of attributes. The consistency ratio is the ratio between the consistency index (CI) and the random index (RI) and is used to measure consistency and, hence, reliability of judgments.

CR = 0.0897/ 0.90 = 0.0997 < 0.10, hence OK. We can therefore proceed with the process of decision-making using Table 5, which summarizes the weights of the various non-technical criteria used.


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*Table 9: Criteria Weights for the Evaluated Parameters*

| Criteria | Weightage |
|---|---|
| Technical | 0.51 |
| Socio-economic | 0.32 |
| Management | 0.11 |
| Environment | 0.06 |

From Table 9, the technical parameter should be given more priority, followed by the socio-economic, management, and environmental parameters, respectively. From the data gathered, there's a 51% weight that water delivery challenges are to be addressed; a 32% weight that poor market conditions and low farmer returns are to be countered; an 11% weight that scheme management is to be fixed; and an almost insignificant weighting for the need to address environmental problems. The technical parameters to be improved are the efficiency, adequacy, equity, and timeliness of water supply in the scheme. On water delivery to farms, farmers preferred the introduction of a gravity-fed system to the existing pumped-gravity system. On various occasions, electricity outages occur, affecting pump operation and hence water deliveries on farms. However, with a gravity system, a continual flow of water will be guaranteed, enabling farms to receive an adequate flow.

Zadbagher and Montazar (2010) used the AHP model to assess the global productivity of water for the Saveh and Dez irrigation networks in Iran. An analysis of the AHP model indicated that the criteria for crop water demand and the cultivated area had great importance. Hasily et al. (2020) used AHP while evaluating networks for irrigation and drainage in Khuzestan Province. Findings indicated that the field and climate factors in the Hendijan and Shahid Rajae networks had the most weight in the Ramshir network. Economic factors had the least weight. The simplicity of this technique and the available literature guiding its use made it convenient for use in this study. This model is also preferred because it incorporates consistency checks for evaluation by the decision maker. This minimizes bias in the making of decisions.

Although an EoI of 0.89 (good) was found, the parameter is not an exhaustive indicator of the technical performance of the scheme, as it only expresses the ratio of functional structures to the total number of infrastructures in the scheme. This means that despite the good state of infrastructure, their number and distribution in the scheme are limited. The total number of flow-measuring devices should be increased to at least twelve, representing each of the twelve blocks. This will help track flows entering individual farm blocks, making it possible for farmers to schedule irrigation water applications.

Concerning returns, it was noted that the farmers were spending well over one year waiting to make sales from a previous harvest because of the constrained markets. The crop was facing competition in the market from imported rice. As a result, the scheme's management needed to look for new markets for the crop both locally and internationally. Also, farmers preferred the unsustainable incentive of fertilizer provision by the NIA to further enhance returns. Okada (2018) conducted research to quantify the effects of management and hardware improvements on the performance of an irrigation project using AHP. The research revealed


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that the quality of the water delivery service had a significant effect on crop production. This compares well with the findings from this study that show the significance of water delivery on farms.

Haoyang (2017) evaluated the management of agricultural water in northern China's irrigation districts using an improved Analytical Hierarchy Process method. The index system that was used in the evaluation included engineering, technology, management, economics, and environment. The agricultural water management grades for Shijin, Renmin, Shengliqu, and Fenhe irrigation districts in north China were established by the fuzzy comprehensive evaluation and the grey correlation method. The weights of engineering, management, technology, economics, and environment were found to be 0.2147, 0.2138, 0.2128, 0.1797, and 0.1791, respectively. Thus, the engineering index was the most important factor in influencing the management of agricultural water in irrigation districts, followed by management. (Haoyang, 2017). These findings conform to the findings of this research work since the technical parameter was found to be the most critical factor in influencing the performance of the Ahero Irrigation Scheme.

Okada (2007) applied the AHP model to evaluate the effects of the internal processes of an irrigation project on crop yield. The study quantified the impacts of hardware and management improvements on the performance of an irrigation project. The study started by developing the AHP model using the project's internal process indicators of the improvement process. The model was then applied in scoring 16 projects that have been dealt with in FAO Water Reports No. 19. The effects of the assessment factors on the performance of the irrigation project were then analyzed by varying the weights of the factors used for evaluation and making comparisons of the correlations between the scores of the AHP model and the crop yields. Findings revealed that crop production was significantly influenced by the quality of water delivery services. The correlation analyses did not indicate any serious relationship between water delivery services, hardware, and management. The study in AIS also revealed a serious relationship between the quality of water service delivery and crop yield. The low reaches of the scheme that had poor water deliveries had low yields, while the upper reaches that had better water service deliveries had better yields.

Mahbobeh et al. (2017) used AHP and the Topsis method to evaluate the performance of both the irrigation and drainage networks in Sefidrood. The attributes used include management, technical, environmental, social, and economic criteria. For each of the attributes, several sub-criteria were selected. The weights of the criteria and sub-criteria were measured using AHP and TOPSIS. Findings indicated that management had the highest significance with a weight of 0.384, while the environmental criterion had the least significance with a weight of 0.09. Findings for AIS also showed that the environmental criterion had the least impact on the performance of the scheme.


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## 4. Conclusions

The performance evaluation of AIS considered the management, technical, environmental, and socio-economic parameters of the scheme. Indicators for each of these parameters were used to assess them, as discussed. On the managerial parameter, *EoI* was found to be 89%, while the irrigation ratio was established at 62%. It was also noted that training farmers were not done regularly. On the technical parameter, the canal's conveyance efficiency was found to be 60% (fair); adequacy in the upper, mid, and lower streams of the scheme was 0.99 (very good), 0.82 (good), and 0.74 (poor), respectively; equity was 0.57 (poor); the coefficient of variance for dependability for the April-July season was 5.3 (good), while for the reference year 2020, it was 16.23 (poor). On the socio-economic parameter, it was noted that credit was given to farmers based on their capacity to pay it back. Notable also was the fact that the income of farmers was poor, which was the result of an unavailable market for harvested rice. On the environmental parameter, the river water ratio was found to be 1, since the irrigation scheme had no other source of water other than river water. Generally, the technical, managerial, socio-economic, and environmental performance of the scheme was found to be below optimal, which contributed to the sub-optimal rice production in the scheme. Based on the overall AHP analysis, the technical parameter (51%) should be given more priority, followed by the socio-economic parameter (32%), the management parameter (11%), and the environmental parameter (6%). To reduce water conveyance losses by 40%, this study recommends the lining of the entire main canal. A gravity system is also recommended to improve the reliability of the irrigation water supply. However, water from the river should be pumped using solar energy rather than electricity. The study also recommends the installation of flow-measuring equipment in each of the 13 blocks to help in scheduling and appropriating irrigation water to the farms. Management improvement options should include seasonal desiltation of canals, prompt servicing and/or replacement of damaged sluices and pumps, and the incorporation of water scheduling on farms. Recommendations to improve the socio-economic performance of the scheme should include the advancement of timely and adequate credit facilities, the introduction of an alternative credit option in the form of farmer savings schemes, and a market expansion for the harvested rice to boost farmer incomes.

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### 5.1 Funding

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### 5.2 Conflict of interest

None.

### 5.3 General acknowledgment

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### 5.4 Ethical consideration and clearance

None

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