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"From Soil to Society: How Environmental and Social Factors Shape Irrigation Scheme Outcomes: A case Study of Baringo County, Kenya"

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ABSTRACT :

Globally, irrigation schemes offer numerous benefits, which include improvement of livelihoods of rural farmers, enhancing food security and promoting agricultural productivity. However, irrigation schemes can also have negative environmental and social effects that need careful consideration and management regarding the use of Environmental Impact Assessment (EIA). This study aims to assess the extent to which environmental and social factors affect the management of selected irrigation schemes funded by Baringo County. To achieve this, a descriptive survey research design was used to collect both qualitative and quantitative data. The target population of the study was 387 drawn from 10 irrigation schemes funded by Baringo County government. The study found that water depletion and scarcity to downstream users and siltation of intakes are the most common environmental issues. Majority of the respondents indicated that the most common social effects of irrigation schemes were increased employment opportunities and improved income. In addition, results showed that there exists a positive significant relationship between environmental/social effects and management of irrigation schemes ($r = 0.402$, $p < 0.05$). The study concluded that both environmental and social factors significantly influence the management of irrigation schemes. While positive social outcomes such as increased employment and income were noted, environmental challenges including water depletion and siltation were prevalent. The study recommends that the County Government strengthen environmental management strategies such as watershed protection, erosion control, and continuous monitoring of water usage. Simultaneously, social impact mitigation plans should be developed and integrated into irrigation projects to ensure community interests are safeguarded and benefits equitably distributed. Community engagement should also prioritize dialogue and resolution mechanisms to address any emerging social tensions.

Keywords: Irrigation; Environment; Society; Climate change

Introduction

On 15 November 2022, the United Nations reported that the global population had reached an unprecedented eight billion, putting pressure on natural resources such as soil, water, and, energy supplies a challenge already threatened by the impacts of climate change.On the other hand, irrigation has been globally considered as a tool for ensuring food security and promoting agricultural production in areas with unpredictable rainfall patterns (Mhembwe, Chiunya, & Dube, 2019). For instance, irrigated agriculture accounts for 40% of global food production, and is practiced in arid and semi-arid lands (ASALs) ASALs areas (Rosa et al, 2020). ASALs areas are known for their extreme temperatures affecting plant growth and hence, irrigation can help to alleviate heat and water stress on crops, reducing climate variability and extremes.

Baringo County is in the former Rift Valley region of Kenya. Most of the areas within the County have a semi-arid type of climatic regime and for this reason, it is highly dependent on irrigation to increase crop production and improve food security. Baringo County has also been affected by banditry, cattle rustling and conflicts of natural resources. This has hindered the County government from delivering its services such as developing irrigation schemes and improving pasture fields in the affected areas Baringo County Integrated Development Plan (CIDP, 2012). The most common irrigation schemes in Baringo County are small-scale and medium-scale schemes primarily located along the County's rivers and lakes.

Baringo County government have invested a sum of 200 million in irrigation schemes within the County with an aim of increasing land under irrigation and improving food security (Baringo County Government, 2023; National Irrigation Authority, 2024). Despite these huge investments, the results of these irrigation schemes are generally far below expectations of the County's objectives. The factors responsible for poor irrigation performance in these irrigation schemes are organizational, water, environmental and production, soil and plant health issues which have caused the problems, condensed and summarized as water shortage, waterlogging, saline-sodic and fertility stress. These stresses account for the declining trends in agricultural production (Department of Water, Sanitation and Irrigation, 2023). Therefore, this project sought to establish the effects of environmental and social factors on the management of the selected irrigation schemes funded by Baringo County government. Understanding the interplay between environmental and social factors reinforces the importance of incorporating environmental impact assessment findings into irrigation project planning and implementation to ensure environmental protection and social cohesion. Irrigation plays a critical role in enhancing agricultural productivity and food security in Kenya's arid and semi-arid lands (ASALs). In Baringo County, where rainfall is increasingly unpredictable, irrigation schemes are vital for sustaining livelihoods and supporting rural economies. Despite significant investments in irrigation infrastructure, the sustainability and efficiency of irrigation schemes remain inconsistent. Environmental factors such as water scarcity and soil salinity, coupled with social issues like community participation and land tenure conflicts, often undermine effective management. While several studies have explored technical and economic aspects of irrigation, there is limited understanding of how environmental and social factors intersect to influence scheme performance at the county level. Explain why it's important to study this in Baringo County, and how your findings could inform policy, improve scheme management, or support sustainability. A better understanding of these contextual factors is essential for informing adaptive management strategies and ensuring long-term sustainability of irrigation systems in Baringo and similar ASAL regions. Clearly state your objective and research question. This study aims to assess the extent to which environmental and social factors affect the management of selected irrigation schemes funded by Baringo County.

Materials and Methods

Research Design

A descriptive survey research method was used to collect both qualitative and quantitative data from community members and government officials. This research design was preferred because information about the opinions, attitudes, perceptions, and experiences of individuals were gathered by questionnaires and interviews on irrigation schemes as stated by (Kothari, 2004).

Study Area

The study was undertaken within Baringo County, which is located in former Rift Valley province, Kenya. The County boarders Elgeyo Marakwet County and West Pokot to the west, Nakuru County to the South, Samburu and Laikipia County to the East, Kericho to the west, and Turkana to the North. Baringo County is mostly agro-based growing cash crops such as pyrethrum, macadamia, cotton, and coffee. Other crops include - onion, tomatoes, finger millet, cassava, sorghum, sweet and Irish potatoes, beans, maize and pigeon peas. Livestock products include mutton, beef, honey, hides, and skin. The area was chosen for the study because of the underlying challenges faced by irrigation schemes funded by Baringo County Government. Further, the area has a history of conflicts raising from land tenure issues. The study was conducted on 10 irrigation schemes funded by Baringo County Government.

Target Population

According to the reports for the Department of Water and Irrigation schemes, (2023), there are 10 irrigation schemes funded by Baringo County government. These irrigation schemes were distributed across 5 electoral wards within Baringo County as shown in Table 1. The target population of the study was 387 drawn from 10 irrigation schemes funded by Baringo County government.

Table 1 The target population

Electoral Ward	Beneficiaries	Irrigation managers	Total (Target population)
Marigat	148	4	152
Mochongoi	83	2	85
Mukutani	92	2	94
Barwesa	37	1	38
Mogotio	9	1	10
Total	**369**	**10**	**379**

Source: Modified from the Department of Water and Irrigation schemes, (2023)

3.5 Sample and Sampling Procedures

The study adopted stratified and purposive sampling techniques. All the 10 irrigation schemes funded by the County Government of Baringo and the 10 managers were selected purposively. The total number of beneficiaries within the 10 selected irrigation schemes were 369 farmers (Department of Water & Irrigation, 2023). The study utilized Yamane formula Chaokromthong, K., & Sintao 2021) to obtain the sample size as follows;

Where:

n = Sample size of household farmers
N = Population size of farmers
e =the level of significance
1=Unite (constant value)

Total number of beneficiaries = 369 farmers

Sample size = $369/ (1+369(0.05)^2)$

n=192 farmers

The sample of 192 respondents was proportionately distributed among the 10 selected irrigation schemes based on the total number of beneficiaries.

Table 2 Sample size

Name of irrigation scheme	*Number of Beneficiaries*	*Sample size*	*Irrigation managers to be interviewed*
Ngenyin	46	24	1
Ketipterkek	37	19	1
Salabani	37	19	1
Endao	28	15	1
Sandai	46	24	1
Loboi	37	19	1
Cheratike	46	24	1
Mosuro	46	24	1
Barwesa	37	19	1
Rosoga	9	5	1
Total	**369**	**192**	**10**

Source: Modified from the Department of Water and Irrigation schemes, (2023)

Data Collection Instruments

The study utilized both primary and secondary data sources that were collected using a structured questionnaire and an interview guide.

Questionnaires

Data from the beneficiaries of the irrigation schemes was obtained through a close-ended questionnaires. The questionnaires were self-administered to the 192 respondents.

Key informant interview schedule

Key informant interview schedule used by the study is indicated by Appendix VI. The interview schedule was adopted in collecting data from 4 sub-counties irrigation engineers from the representatives' sub-counties (Baringo North, Baringo Central, Baringo South and Mogotio), 10 selected irrigation managers and 4 randomly selected environmental experts in Department of Environment, Water and irrigation.

Validity of the instruments

Validity of an instrument ensures accuracy in data collection. The three validities were achieved in the study namely: face, content, and criterion validities. Face validity was through interrogation of the instrument with the university supervisors. Content validity ensured the objective was well measured from the conceptual framework as presented in the questionnaire. The researcher gave the supervisors to go through the instrument and direct on various sections to enable changes to be made. Finally, criterion validity was achieved by examining the instrument where the supervisors ensured that all questions achieve recommended standards in measuring the variable. The study questionnaires were pre-tested to ensure validity of the instrument. The questionnaires were administered to 5 percent of the total number of the sample size were randomly selected. The questionnaires were administered to 10 respondents from Perkerra irrigation scheme, Marigat sub-County whereas 9 farmers and 1 irrigation manager were involved in the pre- test study. The population size that was used for the pre-testing did not participate in the actual study. This ensured that biasness was avoided during the main study. The pre-tested questionnaire was then edited to ensure that the final questionnaires was capable of obtaining the required information.

Reliability of the instruments

Reliability is a measure of the degree to which a research instrument yields consistent data after repeated trials (Elliott *et al.,* 2022). The three types of errors that arose during data collection included: errors due to the inaccuracy of the instrument, the inaccuracy of scoring by the researcher, and unexplained errors. These errors combine to produce consistency in the measurements, which will ultimately affect the reliability of the data collected. The data obtained was analyzed using the version SPSS 23.3 where test-retest method was used to achieve a Cronbach Alpha coefficient greater than 0.7, deeming reliable research instrument.

Data collection procedures

Permission to collect data was obtained from the University of Kabianga which facilitated the application of NACOSTI permit. The researcher obtained necessary permits from the County Commissioner of Baringo and the Department of Water and Irrigation of Baringo County. The individual managers for County funded irrigation schemes were approached for their consent and permission to allow respondents to respond to their study. Primary data commenced by issuing out the close-ended questionnaires to the sampled respondents who were given ample time to respond, and therefore the researcher gave a one-week period to collect the questionnaire.

Data analysis and Presentation

The data collected by the researcher was carefully reviewed and refined. Thereafter, the data was analyzed to assess the effects of environmental impact assessment on management of the selected irrigation schemes, a case of Baringo, County, Kenya. The analysis process included editing, coding, tabulation, and report formatting to ensure the data was reliable before analysis. Quantitative data was analyzed using descriptive statistics such as means, frequencies, and standard deviation. Qualitative data was categorized into themes and analyzed thematically. The findings were presented using tables in form of narration, pie charts and bar graphs.
purposes, and the respondents were allowed to withdraw from the study at any time without incurring any cost. The study was conducted with the highest degree of sincerity and openness to ensure transparency.

Results and discussion

Demographic Information of respondents

The study gathered detailed demographic and contextual information from respondents, focusing on gender, geographical location, the dominant crops cultivated, and the farm size within the designated study area. These variables were essential for understanding the socio-economic and agricultural characteristics that may influence perspectives on irrigation schemes and environmental assessments.

Gender and location of the respondents

Understanding the gender distribution of respondents is essential in assessing the extent to which both male and female perspectives is represented in the study. Gender dynamics often influence access to resources, decision-making processes, and participation in agricultural activities, particularly in rural settings. As such, analyzing the gender composition of the respondents provides important context for interpreting responses related to the management and utilization of irrigation schemes. The distribution is presented in figure 1

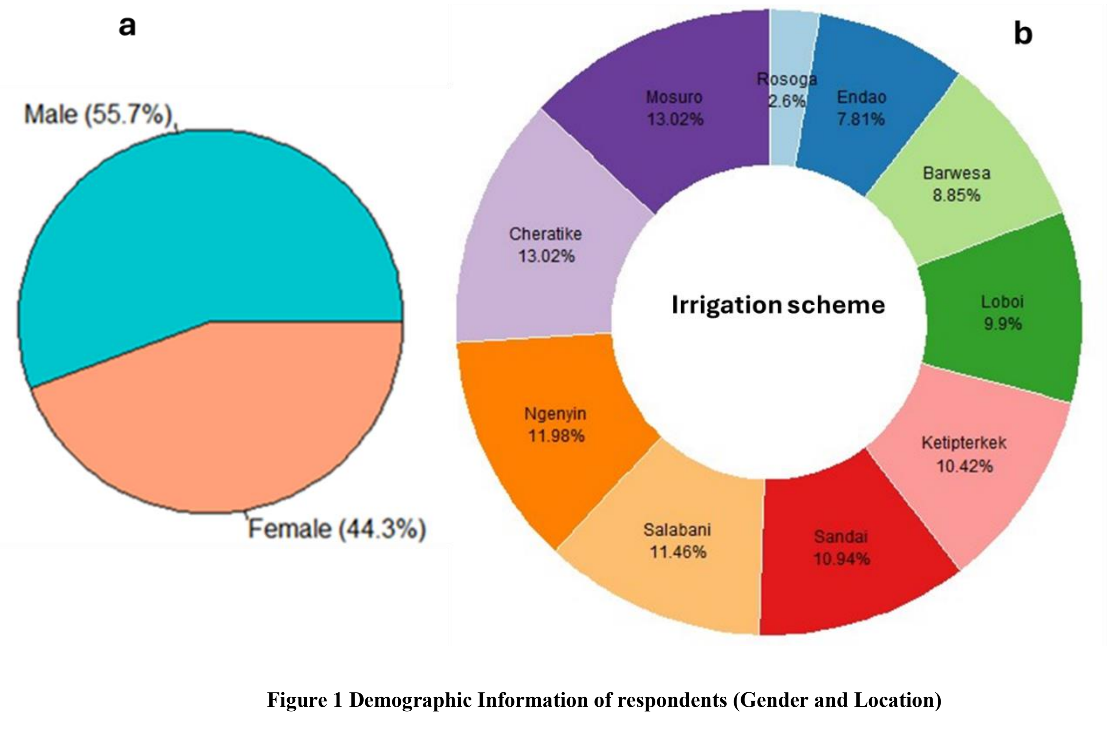

Figure 1 Demographic Information of respondents (Gender and Location)

Source: Field Data, 2024

Figure 1a indicate that a majority of the respondents were male, comprising 107 individuals (55.7%), while 85 respondents (44.3%) were female. This distribution highlights a slight gender imbalance, with male respondents being more prevalent. Nonetheless, both genders were represented, thereby providing a balanced perspective across gender lines in relation to the study's focus on irrigation schemes and environmental impact assessments. The inclusion of both male and female voices enriches the analysis and strengthens the generalizability of the findings, particularly in rural agricultural settings where gender roles may influence land use and resource management.

The study further determined the administrative location of the respondents in Fig.1b. The geographical distribution of respondents across the ten selected irrigation schemes within the study area. The highest representation was from Cheratike and Mosuro, each contributing 25 respondents (13.02%), followed by Ngenyin (11.98%), Salabani (11.46%), and Sandai (10.94%). The least number of respondents came from Rosoga, accounting for only 5 individuals (2.60%). These findings indicate that participants were drawn from a diverse range of irrigation schemes, ensuring a broad and inclusive representation of the study area. Such geographical diversity enhances the robustness and generalizability of the research findings, particularly in evaluating the varied experiences and challenges across different schemes.

Environmental and social effects of irrigation schemes

The study aimed at establishing the effect of environmental and social factors on the management of the selected irrigation schemes funded by Baringo County.

Environmental effects of the irrigation schemes.

The study sought to assess the extent of environmental effects resulting from the implementation of irrigation schemes within the study area. Table 4.6 presents the summarized responses of participants across several key environmental indicators.

Table 3 Levels of environmental effects of irrigation schemes

Effect	Very Low	Low	Neutral	High	Very High	M	SD
Water depletion and scarcity to downstream users	0.0%	25(13.0%)	63(32.8%)	21(10.9%)	83(43.2%)	3.84	1.12
Soil erosion	12(6.3%)	32(32%)	27(14.1%)	58(30.2%)	63(32.8%)	3.67	1.26
Soil salinization	54(28.1%)	17(8.9%)	31(16.1%)	41(21.4%)	49(25.5%)	3.07	1.57
Siltation of intakes	5(2.6%)	17(8.9%)	45(23.4%)	42(21.9%)	83(43.2%)	3.94	1.12
Biodiversity loss and habitat destruction	28(14.6%)	40(20.8%)	63(32.8%)	36(18.8%)	25(13.0%)	2.94	1.23
Water pollution from farm chemicals and herbicides	69(35.9%)	51(26.6%)	25(13.0%)	26(13.5%)	21(10.9%)	2.37	1.37

The findings reveal notable environmental concerns within the study area. Water depletion and scarcity to downstream users (M = 3.84, SD = 1.12) was the most pronounced issue, with 43.2% of respondents reporting it as having a very high impact. Additionally, 32.8% of respondents felt that water scarcity had a neutral impact, indicating significant concern regarding the availability and equitable distribution of water resources. This high mean value reflects the critical nature of water management within irrigation schemes, particularly in regions prone to water scarcity. These results align with the findings of Kantamaturapoj et al. (2023), who observed that overuse and mismanagement of water resources in irrigation schemes often exacerbate water scarcity, especially for downstream users.

Similarly, siltation of intakes (M = 3.94, SD = 1.12) was seen as a severe environmental issue. 43.2% of respondents rated the impact as very high, and 21.9% rated it as high. The relatively high mean and standard deviation suggest a diverse range of perceptions regarding the severity of sedimentation, likely due to variations in local conditions such as soil types, water flow, and the maintenance of irrigation infrastructure. These findings echo the concerns raised by Enríquez-de-Salamanca (2021), who highlighted that poor land management practices, coupled with ineffective sediment control measures, often lead to siltation, affecting water quality and the efficiency of irrigation systems.

Soil erosion (M = 3.67, SD = 1.26) was another significant concern, with 32.8% of respondents perceiving it as a very high impact. This is consistent with the understanding that irrigation schemes, when improperly managed, can increase the susceptibility of soils to erosion. Bjornlund et al. (2020) note that erosion exacerbates the degradation of agricultural land, leading to lower soil fertility and reduced agricultural productivity over time.

On the other hand, soil salinization (M = 3.07, SD = 1.57) was perceived as moderately problematic, with 28.1% of respondents reporting a very low effect. Although salinization is a significant concern for irrigation systems, particularly in semi-arid regions, its lower mean score suggests that it may not be as pervasive in the study area as other issues such as water depletion or siltation. However, this still indicates a need for monitoring soil health and the implementation of appropriate drainage and irrigation practices to mitigate salt buildup (Shammi et al., 2022).

Regarding biodiversity loss and habitat destruction, respondents reported a neutral to low impact, with an overall mean of 2.94 (SD = 1.23). Although 13.0% of respondents rated it as very high, the majority of responses were clustered around neutral (32.8%) and low (20.8%) impacts. This suggests that, while there are concerns about the negative effects of irrigation on local ecosystems, these impacts were perceived as less immediate or severe compared to other environmental factors. Vanclay (2020) stresses the importance of integrating ecological conservation into irrigation planning to prevent irreversible damage to biodiversity and ecosystems.

Finally, water pollution from farm chemicals and herbicides (M = 2.37, SD = 1.37) received the lowest mean score, with 35.9% of respondents indicating a very low impact. This suggests that, while pesticide and herbicide used may have not been viewed as the most pressing environmental concern. However, Tschakert and Amede (2022) argue that even low levels of chemical pollution can accumulate over time, leading to adverse effects on both soil health and water quality.

The key informants, highlighted soil erosion and the resulting siltation of intakes as the most pressing environmental challenges affecting irrigation schemes in Baringo County. These issues were largely attributed to poor catchment management, inadequate soil conservation measures, and weak infrastructure within the schemes. The heavy siltation was reported to interfere significantly with the functionality of irrigation intakes, leading to inefficiencies in water supply. In addition, soil salinization was mentioned as a concern in some areas particularly those with poor drainage, and this has hindered crop productivity by reducing soil fertility. According to the key informants, water scarcity downstream was a key concern, especially during dry seasons when upstream irrigation activities deplete river flows, impacting other water users and ecosystems. The informants observed that many of these environmental impacts stem from the absence of proper Environmental Impact Assessments (EIA) prior to project implementation and weak follow-up on mitigation measures.

Social impacts of irrigation schemes

The study sought to assess the social effects resulting from the establishment and operation of irrigation schemes in the region. Respondents provided their perceptions on several social aspects, including security, conflicts, employment, income, and cultural impacts. The summarized results is presented in Table

Table 4 Social impacts of irrigation schemes

Statement	Very Low	Low	Neutral	High	Very High	M	SD
vandalism of the irrigation scheme	14(7.3%)	52(27.1%)	61(31.8%)	34(17.7%)	31(16.1%)	3.08	1.18
Water-related conflicts	37(19.3%)	48(25.0%)	47(24.5%)	33(17.2%)	27(14.1%)	2.82	1.32
Land tenure conflicts on irrigation area	68(35.4%)	33(17.2%)	36(18.8%)	28(14.6%)	27(14.1%)	2.55	1.45
Increased employment opportunities	10(5.2%)	6(3.1%)	20(10.4%)	84(43.8%)	72(37.5%)	4.05	1.04
Improved income	4(2.1%)	7(3.6%)	22(11.5%)	116(60.4%)	43(22.4%)	3.97	0.82
Traditional practices disruption	52(27.1%)	39(20.3%)	85(44.3%)	4(2.1%)	12(6.3%)	2.40	1.10

The findings from Table 4 reveal that the positive social impacts of irrigation schemes were more pronounced than the negative ones. Increased employment opportunities emerged as the most significant social benefit with a mean score of 4.05 (SD = 1.04). The majority, of respondents (43.8% and 37.5%) rated this impact as high and very high, respectively. This indicates that irrigation schemes have substantially contributed to job creation within the region, either directly through agricultural labor demand or indirectly through related services. These results are consistent with Bjornlund et al. (2020), who observed that well-managed irrigation schemes tend to stimulate local economies by creating employment across the agricultural value chain.

Similarly, improved income levels recorded a high mean of 3.97 (SD = 0.82). 60.4% of respondents acknowledged a high increase in income, while 22.4% rated it as very high. This suggests that irrigation has enhanced farm productivity and profitability, thus improving household livelihoods. Muli et al. (2023) confirm that irrigation schemes in rural Africa often lead to increased cropping intensity, market participation, and consequently better income levels.

In contrast, the negative social impacts of irrigation schemes were perceived to be less significant. For instance, the issue of insecurity associated with irrigation schemes recorded a neutral mean score of 3.08 (SD = 1.18), with 31.8% of respondents indicating a neutral stance. This suggests that perceptions regarding the impact of irrigation on local security were mixed, possibly due to concerns such as conflicts over water usage, vandalism of infrastructure, or incidents of theft.

Water-related conflicts, a common concern in shared-resource environments, had a lower mean score of 2.82 (SD = 1.32). Although 25% of respondents acknowledged low levels of such conflicts, about 14.1% rated the impact as very high, indicating that while such conflicts may not be widespread, they are still present in some areas. This finding aligns with Raschke (2024) who notes that water access in community-based irrigation often leads to disputes, especially in seasons of scarcity.

Land tenure conflicts had a similarly low perception, with a mean of 2.55 (SD = 1.45). 35.4% of respondents rated these conflicts as very low, while only 14.1% perceived them as very high. These figures suggest that land disputes are not widespread in most irrigation areas, though pockets of tension may still exist where land rights and usage boundaries are unclear. Smith et al. (2022) support the view that clear land tenure systems are critical in minimizing conflicts in irrigation schemes.

Lastly, the disruption of traditional practices had the lowest mean score of 2.40 (SD = 1.10). With 44.3% of respondents opting for a neutral view and 27.1% rating the impact as very low, the data suggests that while irrigation development introduces new agricultural and water-use practices, it has not substantially eroded local traditions in most communities. However, Vanclay (2020) cautions that modernization through irrigation, if not culturally sensitive, can gradually lead to the loss of traditional knowledge and customs.

The findings from the key informants further revealed a significant negative livelihood changes resulting from the irrigation schemes. Some community members, particularly small-scale farmers, whom were marginalized, and struggled to access water for their farms, lead to reduced productivity. Additionally, the key informants indicated that shifting from traditional farming practices to more intensive irrigation-based agriculture altered local livelihoods, with some respondents mentioning a decline in pastoral activities as the land was converted to agricultural use.

The study also identified water and land related social conflicts as a by-product of the irrigation schemes. Respondents reported disputes over water allocation and land use between different community groups, especially between large-scale farmers and small-scale or pastoralist communities. These conflicts were exacerbated by the unequal distribution of resources and lack of effective conflict resolution mechanisms. Furthermore, some key informants pointed out that these conflicts often escalated during dry seasons when water flows in rivers were very low, leading to tensions that could affect the social fabric of the community.

Key informants, noted that while irrigation schemes have positively contributed to increased employment opportunities and improved household incomes, there are still underlying social concerns. Instances of vandalism, particularly of irrigation infrastructure, were reported, often linked to conflicts over water access, especially between upstream and downstream users

Discussion

The study found that water depletion and scarcity to downstream users and siltation of intakes are the most common environmental issues, since most respondents (43.2%) indicated that they were very high. A majority of the respondents (43.8% and 60.4%) indicated that the most common social effects of irrigation schemes were increased employment opportunities and improved income as stated that they were high respectively. The study also found that majority of the respondents (62.5%) believed that EIA process addresses potential environmental and social effects of the irrigation scheme in their area moderately well. These results showed that there exists a positive significant relationship between environmental/social effects and management of irrigation schemes ($r = 0.402$, $p < 0.05$).

The study concludes that environmental and social factors significantly influence the management of irrigation schemes. Environmental concerns such as water scarcity for downstream users and siltation of intake structures emerged as key issues requiring attention. On the social dimension, the study observed both positive outcomes including increased employment opportunities and improved livelihoods and adverse effects such as disruptions to traditional practices and emerging land-use conflicts. These dynamics reinforce the importance of incorporating EIA findings into irrigation project planning and implementation to ensure environmental protection and social cohesion. The established relationship between environmental/social effects and scheme management affirms that addressing these effects through EIA enhances the sustainability and acceptability of irrigation projects.

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