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Analysis of Environmental and Socio-Economic Impacts of Dams Through Sustainable Management Strategies

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ABSTRACT

The study aims to enrich the information of planners, policymakers, and water resources managers for planning and operating dams. This research aims to address the following question: What are the environmental, economic, and social impacts of the construction and operation of dams on the environment and society? The study assumes that good management is the ideal solution to solve the problems of negative effects resulting from the construction and operation of dams. The research relied on the descriptive analytical approach in studying the positive and negative impacts of Haditha Dam and the government's role. A questionnaire was conducted for 30 specialists in urban and regional planning to find out the most important strategies for sustainable management. The questionnaire was validated and reliable to ensure the validity of the questions selected for the study. Cronbach's alpha value ($\alpha = 0.82$) was good and acceptable. The study concluded the importance of involving stakeholders in the planning and decision-making process, with a survey response rate of approximately 70%. Sixty percent of respondents believe that monitoring and decision support systems represent a challenge for decision-makers in the sustainable management process. The study recommends the importance of enhancing local community participation and improving focus on sustainability mechanisms to achieve maximum benefit from dams for society. The research recommends enhancing the contribution of the local community in the decision-making process and conducting a "follow-up" to assess the environmental impact, economic returns, and social impacts resulting from the operation and construction of the dam.

1. INTRODUCTION

Water is an essential natural element for human life in its economic and social prosperity, as well as environmental balance. In this context, water control becomes vital.

Dams contribute to protection from floods that used to lead to massive losses of life and property. They also contribute to the balanced growth of the country by enabling the creation of important economic development poles.

The lives of communities living close to dams may be affected and deteriorate. This requires that dams be treated differently than in the past, with greater attention paid to local needs. This is one of the most important goals of any large dam, as it provides development opportunities for all. Therefore, considering environmental and social factors in the planning and management of dams has become extremely important.

Planning and operating large dams are extremely difficult. The complexity results from the uncertainty of climate variability and hence river flow, the complexity of biophysical interactions within riverine ecosystems, and, perhaps most importantly, the number and type of stakeholders involved. This represents conflict and conflict of different values, interests, or rights in many cases: conflicting forms of knowledge, social norms, and attitudes of stakeholders.

The number of dams in the world increased significantly between the years 1930 and 1970, and their number became enormous, as Table 1 shows below:

Table 1. The number of dams and their distribution in the world [1]

Name of Continental	No. of Dams	%
Africa	1269	2.7
Asia	31340	65.8
America	8989	18.8
Europe	5480	11.5
Australia	577	1.2
Total	47655	100

In recent years, the issue of management, decision-making, and planning policies has contributed to decision-makers improving planning and controlling their results in many urban and regional issues. Planning, design, and operation of dams require the introduction of these tools. It can contribute to a wide range of management issues at all stages of the life of dams. Table 2 below shows only one aspect of the suffering, which is involuntary displacement (Figure 1).

Table 2. The number of dams, their location, the date of their construction, and the number of displaced people [2]

Dam's Name	Country	Construction Dates	Dislocated People
Aslantaş	Turkey	1975-1985	1,000
Aswan	Egypt	1950-1960	120,000
Grand Coulee	U.S.A	1934-1975	6,500
Kainji	Nigeria	1964-1980	44,000
Kariba	Zambia/Zimbabwe	1955-1959	57,000
Keban	Turkey	1965-1973	30,000
Norris	U.S.A	1933-1940	25,000
Pa Mong	Vietnam	1972-	450,000
Tarbela	Pakistani	1968-1976	96,000
Three Gorges	China	1950-1980	1,400,000
Tucurui	Brazil	1975-1985	35,000
Atatürk	Turkey	1983-1992	113,476
		Total:	2,377,976

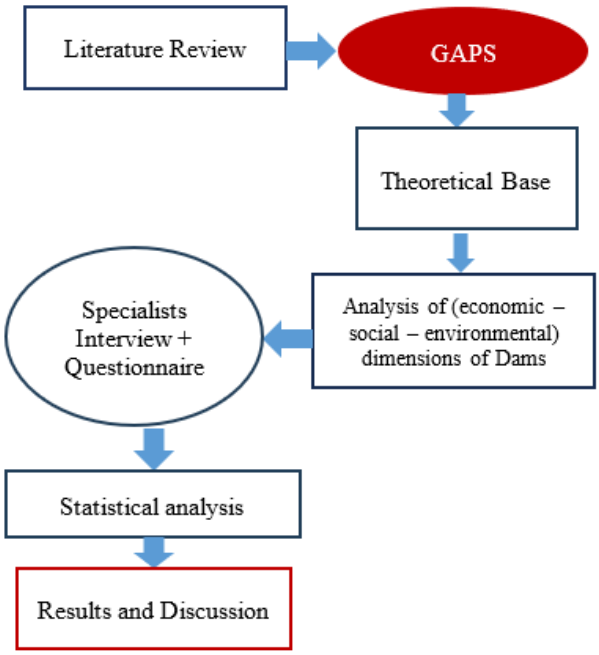

Figure 1. Flow chart of research methodology

2. LITERATURE REVIEW

To develop an economic life evaluation indicator system for reservoir dams, the study by Ge et al. [3] examined the variables affecting the economic life of reservoir dams. An economic life evaluation model for reservoir dams was built based on the costs and benefits of the dams, taking into account the social effects of the reservoirs on the lives and productivity of locals, as well as the possible consequences of dam breaches. Additionally, an analysis of the economics of various reservoir dam management strategies and their effects on the dams' economic life was conducted using economic theory.

The Luhun Reservoir in Henan Province, China, was subjected to the suggested model to estimate its predicted economic life, assess the trend of the "cost-benefit" relationship, and quantify the overall costs and benefits of its operation for each year following the 1990s. The findings indicated that the Luhun Reservoir's estimated economic life was 74 years while taking into account its risks and social repercussions. It is anticipated that the Luhun Reservoir will run until 2039, or the end of its non-economic life. Lastly, recommendations for extending the dams' economic life were made. Reservoir dams' economic life can be drastically shortened by potential dam breach losses. Additionally, everyday operations and administration of reservoir dams should prioritize the strengthening of risk management systems [3].

This study by Baurzhan et al. [4] evaluates the financial gains from 57 hydroelectric dam plant investments supported by the World Bank Group. One of the primary means of generating electricity and the world's greatest renewable power source is hydropower dams. In the Clean Energy Transition, hydropower dams are frequently a less expensive choice for power generation to combat global warming. Hydropower dam construction has generated controversy despite its obvious benefits. This study examines the World Bank's success in assisting with hydropower dam construction, given its lengthy history as the major lender of hydropower development.

The larger community involved in hydropower development can benefit from the study's findings. Seventy percent of the projects in this study had cost overruns, and over eighty percent had time overruns, which could have resulted in additional expenses. This hydroelectric portfolio of dams delivered a present value of net economic benefits by 2016 of over half a trillion USD, despite the high cost and delays. Our research indicates that the assessed hydropower portfolio prevented more than a billion tons of CO_2, resulting in an estimated USD 350 billion in environmental benefits worldwide. The extra environmental advantages of the initiatives increase the real rate of return from 15.4% to 17.3%. It follows that hydropower developers should take time and cost overruns into account when evaluating their projects and incorporate them into contingency plans for project planning. When hydropower resources are developed by industry standards and international norms, developing nations stand to gain a great deal from using them. When one considers hydropower's benefits for the climate, the case for its development might be stronger. If more is done to control cost and schedule overruns, hydropower may have even greater net economic advantages [4].

The study, which looks at the effects of Ghana's Bui Dam on 13 surrounding communities, was prompted by discussions over the advantages and disadvantages of hydroelectric dam construction. The capital assets framework, which encompasses seven different categories of capital assets—social, natural, human, physical, financial, cultural, and political—was used to evaluate the impacts. A quantitative questionnaire was distributed to 339 families to gather data, while 22 key informants participated in qualitative interviews. The results showed that, although they varied slightly, dam impacts on each capital item were typically negative. Age, ethnicity, education level, and gender were less significant explanatory variables than livelihood type and relocation [5].

The objective of the study by Kirchherr and Charles [6] is to analyze and aggregate the several frameworks that are now in use in the scholarly literature to bring together the scholarly understanding of the social repercussions of dams. To achieve this, we have methodically examined and compiled 27 frameworks used by scholars to assess the social effects of dams (found in a collection of 217 publications). The analysis's main conclusion is that the frameworks currently in

use frequently do not specifically address dams, thereby overlooking important effects related to them.

The analysis and aggregation produced a new framework (which is referred to as the "matrix framework") for scholarly investigation, focusing on the social repercussions of dams. Its core dimensions are space, time, and value, and its key components are infrastructure, community, and livelihood. By advancing our knowledge of this subject, we can better grasp the intricate and multifaceted problems surrounding the societal effects of dams. If this approach were widely used in academia (and maybe in practice), it would allow for more transparent project comparison and appraisal [6].

The literature has discovered the following Gaps:

1- Understanding positive and negative savings is crucial to sustainable development, as it allows the introduction of policies to maximize the future benefit of dams within the economic, social, and environmental dimensions.

2- All the studies that were presented focus on one aspect of sustainability, but in this article, we try to address the positive and negative aspects of constructing dams by discussing the dimensions of sustainability comprehensively.

3- No comparable research has been done that looks at the problem at the level of Iraqi cities.

3. THE EFFECTS OF THE SUSTAINABILITY DIMENSIONS (ENVIRONMENTAL, SOCIAL, AND ECONOMIC) OF DAMS

3.1 Environmental impacts of dams

Dams have far-reaching environmental impacts on river ecosystems, biodiversity, and the broader ecological balance. The construction and operation of dams disrupt natural water flow, sediment transport, and the migration patterns of aquatic species. This leads to numerous adverse ecological impacts that are critical to comprehend and mitigate [7].

3.1.1 Disruption of natural processes

Dams alter the normal hydrology of waterways, affecting the timing, size, and recurrence of water streams. This disturbance leads to a hydrologic administration that essentially contrasts with the pre-dam characteristic stream designs, causing environmental imbalances [8]. These changes affect sediment transport, supplement conveyance, and territory accessibility for different aquatic species, leading to a decline in biodiversity [9].

3.1.2 Impact on water quality

The impoundment of water in supplies results in noteworthy changes in water quality. Stratification inside supplies can lead to hypoxic conditions and the discharge of destructive substances like hydrogen sulfide and overwhelming metals from dregs, corrupting water quality downstream. The modified water chemistry influences oceanic biological systems, possibly coming about in algal blooms and other natural disarrangements [10].

3.1.3 Effects on sediment transport

Dams trap sediments that would naturally supplement downstream ecosystems. This sediment retention leads to increased erosion downstream, loss of fertile floodplains, and degradation of delta regions [11]. In the case of the Aswan High Dam on the Nile, sediment trapping has significantly reduced the nutrient-rich silt deposits in the Nile Delta, impacting agriculture and fisheries [12].

3.1.4 Biodiversity loss

The fragmentation of river habitats by dams hinders the migration of fish and other aquatic organisms, resulting in population declines and a loss of genetic diversity [13]. Floodplain habitats, crucial for breeding and feeding, are also reduced, which impacts species that rely on these areas for part of their life cycle [14].

3.2 Socio-economic and health impacts of dams

Building large dams often results in whole communities being displaced, as well as the destruction of local economies. Additionally, a change in the quality and flow of water can escalate the risk of waterborne diseases, impacting public health in surrounding communities [15]. For example, as reservoirs form, they may store water, which can be used as a vector for the breeding of diseases, thus worsening the health problems related to malaria and schistosomiasis [7].

The construction of dams disrupts river ecosystems, causing numerous environmental issues and affecting socio-economic factors. To protect the environment and support sustainable management of the dams, negative impacts and risks should be properly dealt with, which requires sufficient mitigation measures and thorough impact assessments [16].

3.2.1 Social impacts of dams

While dams offer considerable advantages like water storage, generating electricity, and controlling floods, they also entail considerable social expenses that need to be mitigated. Alongside the benefits they offer, the social impacts of dams include the displacement of entire communities, the modification of local economies, and even some health effects. This necessitates the careful weighing of the benefits against the social difficulties they create [17, 18].

3.2.2 Displacement and resettlement

Building large dams tends to require relocating communities situated within the boundaries earmarked for the reservoirs [19]. This dislocation results in considerable sociological disruption as communities are dismantled to be reconstructed in regions far away from where land, housing, and resources that they were used to were available, or resources they had relied on. As an estimate, around 60 million people around the world have been displaced due to the construction of dams [20]. The displaced communities are likely to face decreased standards of living, increased financial burdens, decreased employment, hunger, and a lack of basic healthcare, showing the necessity for proper financial assistance and welfare infrastructures.

3.2.3 Health impacts

Human health can be affected by the development of dams, in both positive and negative ways. Water (and irrigation) supply can have benefits on food security and poverty alleviation, which indirectly benefit human health. Conversely, changes in water flow and quality may favor the spread of other waterborne diseases, including malaria and schistosomiasis. These health effects are particularly noticeable in communities around large reservoirs, where still open water creates ideal environments for disease vectors.

3.2.4 Economic and livelihood changes

Dams can significantly alter local economies by changing access to natural resources and transforming land use patterns. While they can provide economic opportunities through hydroelectric power and improved irrigation, these benefits are not always evenly distributed. Often, the most vulnerable populations, such as rural communities and Indigenous peoples, suffer the greatest losses as their traditional livelihoods are disrupted without adequate compensation or alternative employment opportunities.

Table 3 shows the effect of dams.

3.2.5 Downstream impacts

Residents near rivers downstream from dams often observe significant variations in water availability and quality. This can impact farming, fishing, and their drinking water. These alterations may lead to disputes over water usage and exacerbate social inequalities. Changes to natural water flow can reduce the health of ecosystems downstream, affecting the people who rely on these areas for their living [21].

Table 3. The effects of dams

Affected Items		Effect Form	Type		Term			Nature		Effect Disappears	
			Direct	Indirect	Long	Medium	Short	Material	Immaterial	Possible	Impossible
Environmental impacts	water	loss	*		*			*			*
		quality	*		*				*		*
	soil	loss	*			*			*	*	
		drought		*	*				*		*
	aquatic epidemics	increase		*	*				*	*	
Economic and Social impacts	agriculture	declining		*	*			*			*
	commerce	declining		*	*			*			*
	population	migration		*	*				*		*
Effects on biodiversity	vegetarianism	desertification		*	*				*		*
	animalism	vanishing		*	*				*		*

4. ASSESSING THE DOWNSTREAM IMPACTS OF DAM CONSTRUCTION: CHALLENGES AND SOLUTIONS

The impacts of constructing dams frequently go unnoticed or are perceived as insignificant by people. Such circumstances can create major challenges for wildlife, surrounding neighborhoods, and economic stability. To plan well and reduce risks, it's important to collect enough information, involve everyone affected, and be flexible in how we manage things [22].

4.1 Conceptual framework: Best practices for impact assessment

4.1.1 Comprehensive data collection and analysis

Gaining insight into how dams impact downstream areas necessitates extensive data regarding the environment, society, and economy collected over an extended period. Lacking this information hinders precise evaluation of the effects. Comprehensive research on water patterns is essential to comprehend potential fluctuations in floods and groundwater levels. At the same time, surveys about people's lives will help us see how these changes affect their jobs and everyday life. Concurrently, surveys focused on individuals' lives will provide insight into how these changes impact their employment and daily routines. Simultaneously, surveys examining people's lifestyles will allow us to understand the effects of these changes on their occupations and day-to-day activities. At the same time, studies concerning people's lives will enable us to gauge the influence of these changes on their work and everyday experiences.

4.1.2 Involving local knowledge and stakeholders

Utilizing local and indigenous insights is crucial for grasping and mitigating adverse impacts downstream. Local people have important knowledge about nature and what their community needs that outside experts often overlook [23]. Productive engagement entails maintaining frequent dialogues and including people in joint decision-making efforts.

4.1.3 Environmental and social impact assessments

Impact assessments should not only focus on technical details but also include a thorough look at environmental and social factors. These should include possible changes in how sediment moves, the quality of water, and the health of ecosystems in areas downstream [24]. Assessments should be repeated and adjusted based on new information and changing situations.

4.1.4 Adaptive management and monitoring

Adaptive management strategies are essential for mitigating unforeseen impacts and ensuring the sustainability of dam projects. Continuous monitoring allows for adjustments to management practices, addressing negative social impacts and maximizing the positive contributions of dams to society.

While dams play a crucial role in modern infrastructure, their social impacts are profound and multifaceted. Addressing these impacts through comprehensive planning, fair compensation, and sustainable management practices is essential to mitigate negative outcomes and enhance the positive contributions of dams to society positive contributions of dams to society.

Dam operations to balance ecological health with human needs [25]. Monitoring programs should be designed to track

key indicators such as water quality, sediment levels, and biodiversity.

Addressing the downstream impacts of dams requires a holistic and integrated approach that combines robust data collection, stakeholder engagement, comprehensive impact assessments, and adaptive management. By adopting these strategies, it is possible to mitigate negative impacts and enhance the sustainability of dam projects.

4.2 Application to the Haditha Dam case: Research methodology

4.2.1 Overall research approach

This research adopts a straightforward and transparent method to examine the environmental and economic impacts of the Haditha Dam in Iraq. The method includes gathering basic information, speaking with residents, and watching how the dam affects the area.

4.2.2 Data collection

The authors gather important information from various places.

- Water Data: The authors collect information on river flow and sediment from local water agencies to observe changes before and after the dam was built.
- Environmental Reports: The writers look at reports from local governments and groups about how the dam affects the environment.
- Community Surveys: The authors do easy surveys in local communities to see how the dam has changed their lives and jobs [26].

4.2.3 Data analysis

The authors use simple methods to analyze the collected data:

- Mapping: The authors make simple maps to show how land use, plants, and water quality have changed around the dam.
- Data Comparison: We look at the information from before and after the dam to see if there are any clear differences.
- Getting Community Feedback. We talk to local people and officials in casual conversations to learn what they think.

4.2.4 Environmental and social impact assessment

We perform straightforward assessments:

- Baseline Conditions: We note the conditions before the dam was built to compare with current conditions.
- Impact Observation: We directly observe and record how the dam affects the environment and communities.
- Mitigation Suggestions: We suggest simple ways to reduce negative impacts based on our observations and discussions [17].

5. DESCRIPTION OF THE HADITHA DAM STUDY AREA

The authors focus on the Haditha Dam, located on the Euphrates River. We look at its basic effects on water storage, irrigation, and power generation, and how it impacts local communities.

Haditha Dam is an archaeological, historical, and tourist landmark on the upper Euphrates River in the influential city of Haditha Economic, cultural, and social landmark for the areas located on the banks of the upper Euphrates River, and the source of clean energy production.

The height of the dam is 57 meters, its length at the top is 8933 meters, the width of the base of the dam is 386 meters, and the width of its summit.

Twenty meters, and the water spillway has 6 radial doors and 6 openings, each opening 16 meters wide, it's a drainage capacity. 7900 cubic meters per second when the storage level is 147 meters above sea level. The highest discharge of the stream is 11,000 meters per second when the reservoir level is 4.150 meters above sea level. The design capacity of the station is 660 megawatts. After the construction of the dam was completed, the dam began operating in 1985 for the first time at a level of 122 meters above sea level.

In February 1986, the first unit of the hydroelectric station was operated using water. The turbine blades are turned to generate electricity by releasing water from the top of the lake to the bottom of the dam to enter the riverbed and then sending electricity to different areas via electrical wires.

Haditha Dam is the second largest dam in Iraq in terms of area in generating electrical power after the Mosul Dam. It has a maximum production capacity of 1050 megawatts and contains hydroelectric generating stations with a capacity of 660 megawatts. The dam was placed under the supervision of the Iraqi Ministry of Electricity and the Ministry of Water Resources. Its construction cost amounted to about 12 million dinars, and it was the goal of constructing the dam was to regulate the water of the Euphrates River in times of high or low water levels and to work on its continuity and balance in the dam lake to continue to generate energy.

5.1 Study area description

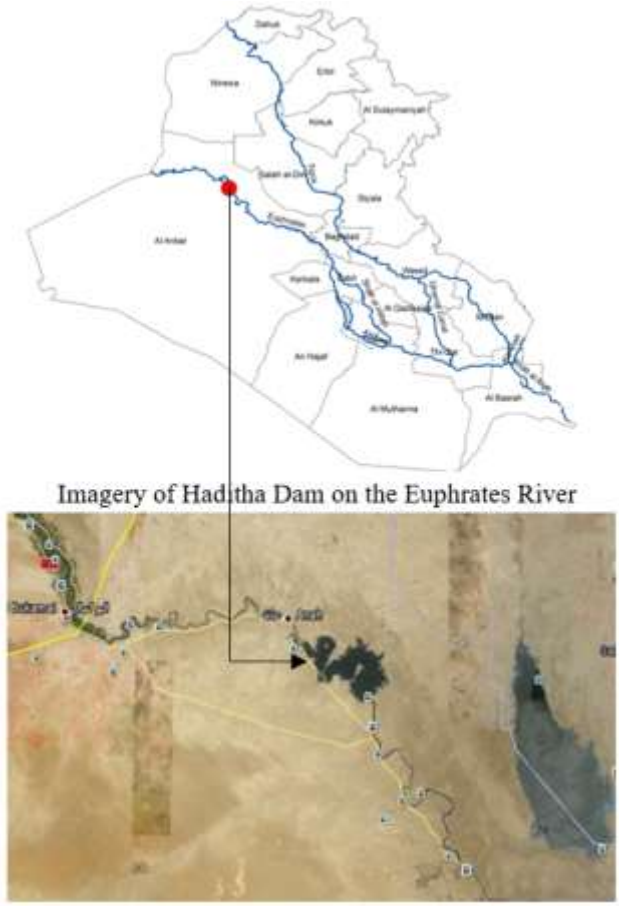

Figure 2. Location of Haditha Dam in Iraq

The Haditha Dam is located on the Euphrates River in the western part of Iraq. Figure 2 represents a significant piece of infrastructure with both beneficial and challenging impacts on the region's environment and socio-economic conditions. This section provides a detailed description of the study area, which is crucial for understanding the environmental and socio-economic impacts of the dam.

5.2 Geographical and hydrological characteristics

The geographical coordinates of the dam place it in a region characterized by arid to semi-arid climate conditions, which significantly influence the hydrological dynamics of the Euphrates River. The exposed geological formations in the dam site and reservoir area are primarily the Euphrates Formation (Lower Miocene) and the Fatha Formation (Middle Miocene), both of which are known for their karstified nature. This karstification poses substantial challenges for dam engineering, including the formation of numerous sinkholes on the right bank of the river [27].

Despite the benefits that dams bring, they are not without drawbacks, and the Haditha Dam is one of the dams that served the areas along both banks of the Euphrates River in Iraqi territory, but it caused damage that some considered negative, while others considered it positive. These damages include:

1- Flooding of the ancient city of Anah and Rawa, flooding of ancient roads and residences and 92 of the villages adjacent to the lake, flooding of agricultural lands, and economic damage to several farmers, homes, and many historical monuments in the ancient city of Anah, known as the Ziggurat of Anah, which was recovered from its old place after the loss of its lower parts.

2- Forced displacement of indigenous people and their separation from their civilizational and cultural heritage to areas far from their original homeland.

3- The migration of several farmers and the abandonment of their lands that were flooded with water. High soil salinity.

4- Causing a major shortage in the livestock that farmers used to raise. One of the negative effects of the dam is the increased accumulation of dead stock of silt in the dam lake, which leads to exposure of its enormous surface to sunlight and high temperatures, or loss as a result of high production rates due to the spread of some plants and their environmental adaptation to the new conditions, as well as Moreover, evaporation during the hot season of the year that occurs in water dams may lead to the possibility of Iraq losing a huge amount of water as a result of evaporation. Climate studies and research have estimated that evaporation in Haditha Dam amounts to about 1.5 billion cubic meters, and in Mosul Dam, it may reach 0.6 billion cubic meters, and in the Hamrin Dam, it was estimated at 0.25 billion cubic meters [28].

6. STRATEGIES USED TO COMPENSATE THOSE AFFECTED BY THE HADITHA DAM

The most important strategies that have been taken to overcome the negative effects of the dam

1- Preparing studies, designs, and land reclamation in agricultural development, and establishing pioneering projects in a location that includes preparing model villages and a training center for mechanization and modern agricultural methods.

2- Establishing modern villages for rural residents to house those displaced from the cities of Anah and Rawa.

3- Securing agricultural lands for residents of villages on both sides of the Euphrates River and adjacent to the edge of the reservoir, and providing irrigation water for them.

4- Estimating the damage to the facility, sites, and orchards submerged in the reservoir basin, and what is required for compensation in this regard.

5- Develop coordinated plans to settle the basin's population in new places and gradually, as work on constructing the dam progresses.

6.1 Environmental context

Building and using the Haditha Dam has greatly changed how water flows in the Euphrates River. The dam stops dirt and sand from flowing downstream, which harms the ecosystems there. This causes more erosion and damages areas like floodplains and deltas. Keeping sediment in one place has greatly affected the environment. It has led to fewer homes for fish and other water animals, and farming has become less productive downstream because of the loss of rich soil. Also, storing water in the reservoir has changed its quality. Layering in the reservoir can lead to low oxygen levels and release dangerous substances like hydrogen sulfide and heavy metals from the bottom. This can harm the water quality further down the stream. These changes can lead to more algae growth and other problems that harm the variety of life and the health of water ecosystems (Figure 3) [29].

Figure 3. A photo of a modern dam taken in 2022
Source: Google images

6.2 Socio-economic context

The Haditha Dam plays a crucial role in the local economy and community wellbeing. It provides water for farming, drinking, and making electricity, which are very important for nearby people and businesses. Building the dam required

moving many communities, which caused a lot of disruption in people's lives. Displaced populations often face reduced quality of life, increased debt, unemployment, and food insecurity, highlighting the need for comprehensive compensation and support systems [17, 30].

In addition to displacement, changes in water flow and quality due to the dam have exacerbated public health issues by increasing the prevalence of waterborne diseases. Reservoirs can become breeding grounds for disease vectors, thus impacting the health of nearby communities. Furthermore, the alteration of natural flow regimes has affected downstream agricultural and fishing activities, leading to economic disruptions and conflicts over water use [29].

The dam has affected the social lifestyle of the population by enhancing integration into society, especially work , In the development projects that were opened to residents and immigrants, the abundance of job opportunities that have a great economic return, and the improvement of the economic, health, and educational situation that became active and increased after the settlement of the population, the abundance and diversity of markets, the integration of people among themselves, the exchange of opinions, social communication, and mingling, especially after the settlement of residents in modern, modern villages established by the state to ease The suffering of those affected and their compensation for their lost lands, orchards, and their old homes that were flooded, providing integrated job opportunities, services, health centers, schools, and paved roads, increasing livestock, managing water resources, and improving fish wealth, which affected the social situation of the tribes, as follows:

1- Saving time after people wasted a lot of time fetching water before building the dam.

2- The number of livestock increased as a result of a decrease in their sale, which represented an economic strategy that enabled the tribes to purchase food in times of severe drought and food shortages and to recover their income.

3- The level of education has increased in areas with dams due to the availability of time and the recovery of the economic situation, which has provided families with higher income levels and school attendance for both sexes, as well as a decrease in the rate of diseases.

7. CHALLENGES AND OPPORTUNITIES FOR SUSTAINABLE MANAGEMENT STRATEGIES FOR HADITHA DAM

An interview and questionnaire were conducted for a random sample of 30 people, including specialists in the field of urban and regional planning, to study the issue of sustainable management of Haditha Dam and the strategies that must be followed to achieve sustainable management of the case under study (Table 4).

Table 4. Analysis of questionnaire results with arithmetic mean and standard deviation

Questions	St. Agree	Agree	Neutral	Disagree	St. Disagree	Mean	STD. DV
Planning and operating challenges	21	3	4	1	1	4.3	1.4
Monitoring and decision support systems	15	7	5	2	1	4.1	1
Opportunities for improvement	7	18	3	2	0	4	0.63
Integration of stakeholder input	9	9	7	2	3	3.52	0.5

The validity of the questionnaire was confirmed by analyzing the validity and reliability of the questionnaire as follows:

7.1 Validity and reliability of the study tool

Content honesty or apparent truthfulness (validity): The study instrument was submitted to a panel of arbitrators with experience in sustainability to verify that its content is legitimate and meets the goals of the research. After reviewing the tool, they were asked to comment on whether it was appropriate for the indicator, given the content, how many paragraphs it had, how comprehensive it was, how diverse the content was, and how it produced results. They were also asked to provide any relevant feedback regarding any amendments, changes, or deletions that should be made by the arbitrator's judgment when the (Stability) [31].

Analyses were made of Cronbach's alpha coefficient, also known as the stability coefficient Alpha Cronbach's, which is used to determine internal consistency. A value falls between 0 and 1 and is considered statistically acceptable when it is 60% or higher. This indicates that utilizing the tool again under the same circumstances will provide the same outcomes, which are shown in Table 5.

Table 5. The results of alpha Cronbach's analysis

Sustainable Management Strategies	**Validity α**	**Reliability, $\sqrt{\propto}$**
	0.8292	0.874

Table 5 makes it evident that the Cronbach's alpha coefficient for the questionnaire items was 0.82. This suggests that the items have a high level of internal consistency, which is statistically acceptable and validates the measurement tool's stability and applicability.

7.2 Improving the management of dams and river basins

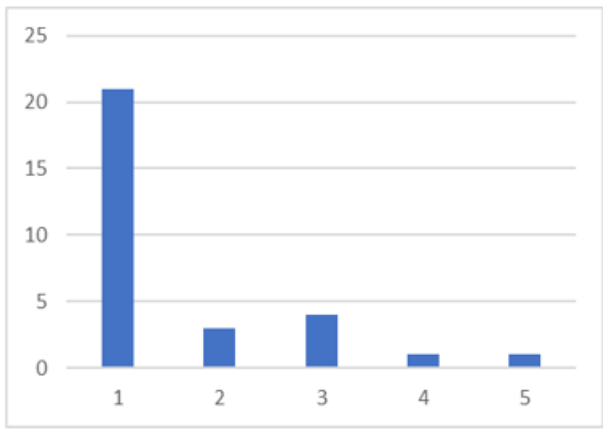

Figure 4. Questionnaire results for the first indicator

What are the most important challenges that support the sustainable management of Haditha Dam?

The experts' answers revolved around several issues that were classified into four indicators to achieve sustainable

management of the dam:

1- Integration of stakeholder input
2- Monitoring and decision support systems
3- Opportunities for improvement
4- Planning and operating challenges

The results of the survey were according to a five-point Likert scale for each strategy, where the number 1 indicates very agree, the number 2 indicates agree, the number 3 is neutral, No. 4 disagree, and No. 5 strongly disagree. Figure 4 indicates the questionnaire results for the first indicator.

7.3 Integration of stakeholder input

Seventy percent strongly agree of the specialists interviewed strongly agree that one of the most important strategies needed is the integration of stakeholder input.

Incorporating stakeholder input into the planning and decision-making processes is crucial for achieving equitable and sustainable outcomes. Engaging local communities and ensuring their participation in decision-making can mitigate social impacts and enhance public acceptance of dam projects. Effective communication strategies and transparency are essential to address concerns and foster collaboration among stakeholders.

Effective management of dam and river basin projects requires addressing complex challenges through advanced decision support systems, stakeholder engagement, and sustainable planning practices. By leveraging technological advancements and fostering inclusive decision-making processes, it is possible to achieve balanced and sustainable outcomes that meet both human and environmental needs.

7.4 Monitoring and decision support systems

Fifty percent strongly agree, while 23% agree, of the specialists interviewed believe that one of the most important strategies needed by dams includes Monitoring and decision support systems (Figure 5).

Advanced monitoring systems integrated with decision support capabilities are essential for real-time analysis and diagnosis of dam behavior. These systems utilize engineering, mathematical, and artificial intelligence methods to provide comprehensive safety evaluations and operational diagnostics. Effective DSS can enhance the safety and functionality of dams by continuously evaluating data from multiple sensors and integrating it into actionable insights.

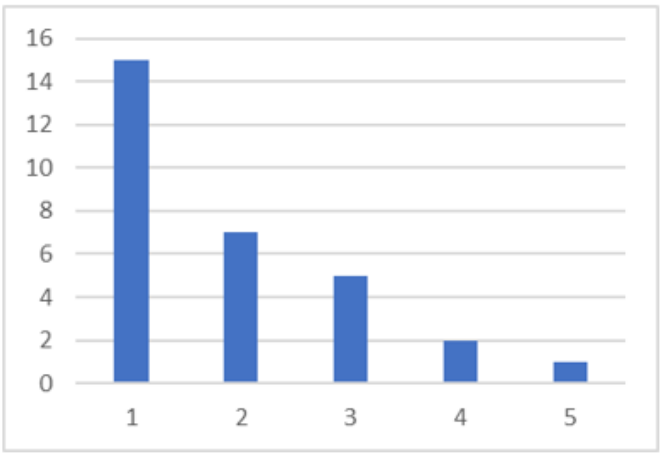

Figure 5. Questionnaire results for the second indicator

7.5 Opportunities for improvement

Sixty percent agree, 23% strongly agree, of the specialists interviewed believe that one of the most important strategies needed by dams includes planning and operation processes (Figure 6). Questionnaire results for the third indicator, including Opportunities for improvement. This can be explained by the Technological advancements that present significant opportunities for improving dam management. The use of multisensorial information fusion and intelligent inference engines can minimize human error and provide more accurate predictions of dam behavior. Additionally, the implementation of eco-engineering decision scaling frameworks helps balance engineering and ecological needs, promoting sustainability in water resource management.

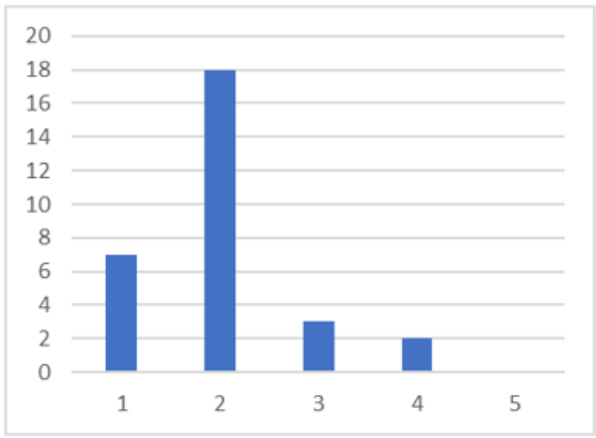

Figure 6. Questionnaire results for the third indicator

7.6 Planning and operating challenges

Thirty percent strongly agree, and 30% agree that the specialists interviewed believe that the planning and operating challenges are important strategies needed by dams (Figure 7).

The primary challenges in dam planning and operation include managing conflicting demands, ensuring safety, and adapting to changing environmental conditions. Optimal reservoir operations must consider multisectoral human pressures and climate extremes, making decision-making complex. Additionally, the unpredictability of hydrological events necessitates robust planning to mitigate risks associated with dam failure and to maintain the ecological balance.

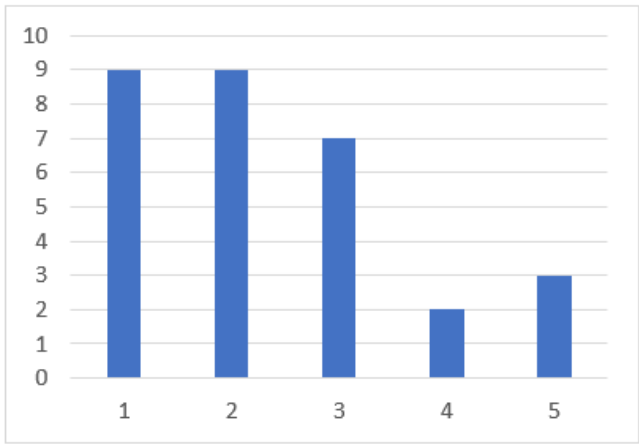

Figure 7. Questionnaire results for the fourth indicator

8. RESULTS AND DISCUSSION

The studies of Zare and Kalantari [11], Li et al. [9], and Maavara et al. [10] can be considered environmental studies related to the subject of dams, as the study of Maavara et al. [10] focuses on the issue of ecosystems without linking it to the issue of population, and we do not find clear policies in it. The study of Li et al. [9] discussed the loss of biodiversity and imbalance in the ecosystem. The study of Zare and Kalantari [11] provides theoretical solutions and does not address sustainability clearly. As for what can be classified as studies with social and health dimensions, it is the study of Arthur et al. [5] relied on household and official surveys that focused on negative impacts without linking them to sustainable management. The study by Kirchherr and Charles [6] is a theoretical analysis of several articles. The study by Lerer and Scudder [15] attempted to obtain its results from health studies, which is considered a relatively old study that requires more recent data. The other studies are economic studies that do not focus on social impacts and equitable distribution. Most previous studies often lack an integrative vision that takes into account the integration of these dimensions, especially in the Iraqi context. The lack of community engagement and the voice of local experts in these studies also constitutes an additional gap that this research seeks to address by analyzing sustainable management strategies using a questionnaire in the Haditha Dam as a model.

9. CONCLUSIONS AND RECOMMENDATIONS

1- Strengthening the local community's contribution to the decision-making process. To develop water and energy resources fairly and sustainably, such initiatives must be accepted by the public.

2- Sustainable management strategies must include constantly evaluating and adapting solutions to changing circumstances, to maximize benefits, address social issues, and improve measures that reduce environmental damage.

3- Conduct a "follow-up" environmental impact assessment when constructing dams and planning for their construction. The downstream and upstream basins must also be placed in consideration of environmental and social impacts in order not to displace the population and affect their lives and agriculture, and to take measures and solutions to the problems that the dam may cause in all dimensions of economic, social, and environmental sustainability.

4- Improving the evaluation of options and creating and improving mechanisms for sharing benefits. There should be an overall balance between positive and negative impacts, and be taken as the sole criterion for project acceptance. The distribution of costs and benefits is also important, and groups that are significantly affected (especially those downstream) should not bear uncompensated costs without balancing the benefits.

REFERENCES

[1] World Commission on Dams. (2000). Dams and development: A new framework for decision-making: The report of the World Commission on Dams. Earthscan.

[2] Vittas, D. (1994). Resettlement and development: The Bankwide review of projects involving involuntary resettlement 1986-1993, AGRIS - International System for Agricultural Science and Technology. https://agris.fao.org/search/en/providers/122582/records/647366302c1d629bc980085a.

[3] Ge, W., Sun, H., Jing, L., Li, Z., et al. (2024). Economic life evaluation of reservoir dams based on comprehensive costs and benefits analysis considering potential dam breach: A case study of the Luhun reservoir in China. Journal of Hydrology, 639: 131613. https://doi.org/10.1016/j.jhydrol.2024.131613

[4] Baurzhan, S., Jenkins, G.P., Olasehinde-Williams, G.O. (2021). The economic performance of hydropower dams supported by the World Bank Group, 1975–2015. Energies, 14(9): 2673. https://doi.org/10.3390/en14092673

[5] Arthur, J.L., Murray, G., Rollins, R., Dearden, P., Stahl, A. (2020). Differential impacts of dam construction on livelihoods in Ghana. African Geographical Review, 39(3): 267-281. https://doi.org/10.1080/19376812.2020.1719367

[6] Kirchherr, J., Charles, K.J. (2016). The social impacts of dams: A new framework for scholarly analysis. Environmental Impact Assessment Review, 60: 99-114. https://doi.org/10.1016/j.eiar.2016.02.005

[7] Kadhim, S.H., Al-Jawari, S.M., Razak Hasach, N.A. (2024). Analyzing earth's surface temperatures with relationship to land urban land cover (LULC) to enhance sustainability. International Journal of Sustainable Development & Planning, 19(1): 123-130. https://doi.org/10.18280/ijsdp.190110

[8] Magilligan, F.J., Nislow, K.H. (2005). Changes in hydrologic regime by dams. Geomorphology, 71(1-2): 61-78. https://doi.org/10.1016/j.geomorph.2004.08.017

[9] Li, B., Chen, N., Wang, W., Wang, C., Schmitt, R.J.P., Lin, A., Daily, G.C. (2021). Eco-environmental impacts of dams in the Yangtze River Basin, China. Science of the Total Environment, 774: 145743. https://doi.org/10.1016/j.scitotenv.2021.145743

[10] Maavara, T., Chen, Q., Van Meter, K., Brown, L.E., Zhang, J., Ni, J., Zarfl, C. (2020). River dam impacts on biogeochemical cycling. Nature Reviews Earth & Environment, 1(2): 103-116. https://www.nature.com/articles/s43017-019-0019-0

[11] Zare, R., Kalantari, B. (2018). Original paper evaluating negative environmental impacts caused by dam construction. Urban Studies and Public Administration, 1(1): 42-50. https://doi.org/10.22158/uspa.v1n1p42

[12] Paul, S., Singh, H.B., Hazarika, R. (2013). Environmental impacts in the construction of dams. International Journal of Innovative Research and Development, 2(11): 278-280.

[13] Baird, I.G., Silvano, R.A., Parlee, B., Poesch, M., et al. (2021). The downstream impacts of hydropower dams and indigenous and local knowledge: Examples from the peace–Athabasca, Mekong, and Amazon. Environmental Management, 67(4): 682-696. https://doi.org/10.1007/s00267-021-01440-7

[14] New, T., Xie, Z. (2008). Impacts of large dams on riparian vegetation: Applying global experience to the case of China's Three Gorges Dam. Biodiversity and Conservation, 17(13): 3149-3163. https://doi.org/10.1007/s10531-008-9416-2

[15] Lerer, L.B., Scudder, T. (1999). Health impacts of large

dams. Environmental Impact Assessment Review, 19(2): 113-123. https://doi.org/10.1016/S0195-9255(98)00041-9

[16] Al-Jawari, S.M., Kadhim, F.M., Razak Albasri, N.A. (2024). Urban safety is a tool for containing slums to reach a sustainable urban structure. International Journal of Safety & Security Engineering, 14(1): 191-200. https://doi.org/10.18280/ijsse.140119

[17] Jedi, Z.A.J., Al-Jawari, S.M. (2023). Prediction of formal transformations in city structure (Kufa as a model) based on the cellular automation model and Markov chains. International Journal of Sustainable Development & Planning, 18(5): 1417-1424. https://doi.org/10.18280/ijsdp.180512

[18] Razak Hasach Albasri, N.A., Shakir, H.S., Al-Jawari, S.M. (2023). Monitoring and prediction of functional change of land uses toward urban sustainability. International Journal of Sustainable Development & Planning, 18(7): 2015-2023. https://doi.org/10.18280/ijsdp.180703

[19] Khudhur, D.H.A., Al-Jawari, S.M. (2023). Empowerment and its impact on affordable housing sustainable planning: A case study of Al-Sultan housing complex in Al-Najaf. AIP Conference Proceedings, 2776: 0600001. https://doi.org/10.1063/5.0135982

[20] Richter, B.D., Postel, S., Revenga, C., Scudder, T., Lehner, B., Churchill, A., Chow, M. (2010). Lost in development's shadow: The downstream human consequences of dams. Water Alternatives, 3(2): 14.

[21] McCartney, M.P., Sullivan, C., Acreman, M.C. (2001). Ecosystem impacts of large dams: Background Paper No. 2. International Union for Conservation of Nature and Natural Resources and the United Nations Environment Programme.

[22] Tilt, B., Braun, Y., He, D. (2009). Social impacts of large dam projects: A comparison of international case studies and implications for best practice. Journal of Environmental Management, 90: S249-S257. https://doi.org/10.1016/j.jenvman.2008.07.030

[23] Égré, D., Senécal, P. (2003). Social impact assessments of large dams throughout the world: Lessons learned over two decades. Impact Assessment and Project Appraisal, 21(3): 215-224. https://doi.org/10.3152/147154603781766310

[24] Geneletti, D. (2002). Ecological Evaluation for Environmental Impact Assessment.

[25] Williams, B.K., Brown, E.D. (2014). Adaptive management: From more talk to real action. Environmental Management, 53(2): 465-479. https://doi.org/10.1007/s00267-013-0205-7

[26] Ghafel, A.H., Al-Jawari, S.M. (2024). The role of road elements in providing a safe environment for pedestrians. AIP Conference Proceedings, 3092(1): 060024. https://doi.org/10.1063/5.0199832

[27] Sissakian, V.K., Fiyad, A.S., Al-Zubaidi, A.A. (2023). Karstification processes in Haditha Vicinity, west Iraq. The Iraqi Geological Journal, 56(1B): 153-166. https://doi.org/10.46717/igj.56.1B.12ms-2023-2-20

[28] Dulaimi, E.J.S.N.A. (2020). Haditha Dam and its social impacts on the cities of Haditha and Ana. Journal of Research in Educational and Human Sciences, Literature and Languages, 1(4): 393-403.

[29] Jalal, A.D., Al Ani, Y., Thameel, S.S., Ismael, Z.M. (2023). Study of the Euphrates river's water quality in front of and behind the Haditha dam in Anbar province, Iraq. IOP Conference Series: Earth and Environmental Science, 1222(1): 012042. https://doi.org/10.1088/1755-1315/1222/1/012042/meta

[30] Ibrahim, A.M., Salih, S.A., Irzooki, R.H. (2022). Evaluation of seepage on the right side of Haditha dam, west of Iraq. IOP Conference Series: Earth and Environmental Science, 1080(1): 012012. https://doi.org/10.1088/1755-1315/1080/1/012012/meta

[31] Hason, M.M., Abbas, M.R., Ahmad, B.B., Abbas, T.R. (2020). Monitoring of water surface change of Haditha dam's lake using satellite data technique. IOP Conference Series: Materials Science and Engineering, 928(2): 022018. https://doi.org/10.1088/1757-899X/928/2/022018