

Environmental Impact Assessment of the Shavur Irrigation Network Using Conventional and Modified ICOLD Matrices

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Article Info	ABSTRACT
<p>Article type:</p> <p>Research Article</p> <p>Article history: Received 10 December 2025 Revised 25 February 2026 Accepted 05 March 2026 Published online 22 December 2026</p> <p>Environmental Impact Assessment ICOLD Matrix Irrigation and Drainage Shavur Irrigation Network Khuzestan, Iran</p>	<p>Objective: This study evaluated the environmental impacts of the 5,000-hectare Shavur irrigation and drainage network in the central Karkheh Basin, Khuzestan Province. By utilizing both conventional and modified ICOLD/Leopold matrix methods, the assessment focused on the physical, biological, and socio-economic environments during the project's operation phase. To achieve this, the research utilized a panel of 15 senior environmental and engineering experts, applying a standardized scoring system (+5 to -5) alongside specific weighting coefficients within both conventional and modified matrix frameworks to systematically quantify and compare the operational environmental consequences.</p> <p>Results: The most significant positive outcomes occurred within the socio-economic sphere. For the physical environment, the conventional method yielded 161 positive and 226 negative scores, while the modified method showed 303.57 positive and 435.91 negative scores, suggesting the project offers physical benefits but poses adverse impacts requiring careful management. In the biological environment, the conventional method produced 80 positive and 148 negative scores, compared to 111.51 positive and 286.87 negative scores via the modified approach. This suggests that vegetation, wildlife habitats, and ecological balance may face negative pressures. Conversely, the socio-economic environment demonstrated superior positive outcomes; the conventional method recorded 532 positive and 26 negative scores, whereas the modified method showed 1212 positive and 72 negative scores. These data underscore the project's capacity to significantly boost agricultural productivity, employment, and local economic stability.</p> <p>Conclusion: Overall, the Shavur network acts as a catalyst for socio-economic growth, specifically increasing production, income, and employment. However, the project concurrently exerts negative pressures on physical and biological systems. Consequently, robust environmental management and mitigation strategies are vital to minimize ecological damage and ensure long-term environmental sustainability.</p>

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1.Introduction

Development is fundamentally associated with economic, social, and environmental transformations. Although its primary objective is to generate positive changes and improve human well-being, development processes may also produce unintended challenges and adverse consequences. In recent decades, aligning economic development policies with environmental protection goals has become a major global concern. Irrigation and drainage projects, in particular, are often accompanied by a series of ecological changes, some of which may benefit human societies, while others may adversely affect natural resource systems. These undesirable impacts are not limited to increased pollution or the degradation of habitats for native flora and fauna; they may also influence water, soil, air, energy resources, and socio-economic systems. Over the long term, such impacts can contribute to broader environmental challenges, including climate change (Naranjo et al., 2020). In recent decades, increasing urbanization and industrial advancements have not only led to higher water consumption but have also increased water pollution (Tamizi et al., 2025), resulting in adverse environmental effects. Given the increasing importance of environmental protection, international organizations and institutions have established regulatory frameworks and guidelines to prevent environmental degradation and pollution (Komasi & Beiranvand, 2019). Currently, Environmental impact assessment (EIA) is widely recognized and implemented in many countries as a systematic tool for evaluating development projects and infrastructure plans. EIA aims to identify, predict, and evaluate the potential environmental and social impacts of proposed projects to support informed decision-making and promote sustainable development (Nahvi et al., 2017). Bhadauria (2025) investigated India's Draft EIA Notification, focusing on how the proposed amendments might undermine environmental protections and restrict public engagement. The authors conclude by emphasizing the necessity of adopting a more transparent, participatory, and sustainable framework for environmental governance. Okeke et al. (2025) examined the role of Advanced Environmental Impact Assessment (AEIA) in promoting sustainable development, with particular emphasis on the use of tools such as GIS, remote sensing, life cycle assessment, and multi-criteria decision analysis. The study also noted that, despite its potential to enhance sustainability and stakeholder engagement, AEIA continues to face challenges related to data limitations, weak institutional capacity, and inadequate policy implementation. Fangyuan et al. (2025) conducted a study entitled "Assessment of ecological environment quality and their drivers in urban agglomeration based on a novel remote sensing ecological index." In this study, a novel remote sensing ecological index (NRSEI) was developed using Google Earth Engine, MODIS, and NPP-VIIRS data to assess ecological environmental quality in the Yangtze River Delta Urban Agglomeration from 2012 to 2021. The results showed an overall improvement in ecological environmental quality, while topographic complexity, economic development, and population density were identified as the main driving factors. The Ministry of Agriculture of Morocco presented the Environmental Impact Assessment report for the Main Canal Development Project and Branch Canal Development Project under the Global Hydro-Agricultural Development Project in the

southeast zone of the Gharb Plain in the Kingdom of Morocco (2024). The study followed a standard EIA framework, combining baseline environmental surveys, legal and institutional review, alternatives analysis, scoping, field investigations, stakeholder consultation, and impact evaluation, while assessing key components such as air quality, noise, surface water, groundwater, soil, ecology, waste, social conditions, and climate-related aspects. The results indicated that the project would generate both construction and operational impacts, mainly affecting air, noise, water resources, soils, and biodiversity; however, these impacts were considered manageable through proposed mitigation measures, environmental monitoring, and grievance mechanisms to support sustainable irrigation development.

Firmansyah et al. (2022) conducted a comprehensive risk assessment of the Saguling Dam by comparing three distinct methodologies: the traditional method, the event tree method, and the modified ICOLD method. Their findings reveal that the dam's safety classification varies significantly depending on the approach applied, ranging from 'unacceptable' under the traditional method to 'acceptable' via the event tree method, and 'moderate risk' through the modified ICOLD method. The study underscores the critical importance of optimal operation and maintenance practices, highlighting the utility of risk assessment frameworks in prioritizing safety management for hydraulic infrastructure.

Achieving sustainable development requires that projects be designed and implemented in a manner that maximizes benefits while minimizing environmental damage in both the short and long term (Padash & Ataee, 2019). In irrigation projects, the magnitude and nature of positive and negative impacts, as well as the effectiveness of environmental management measures, depend on several factors, including socio-cultural conditions, public health status in the project area, applied technologies, legal and institutional frameworks, political context, and downstream environmental conditions (Gadissa, 2018). Zoratipour et al. (2022) evaluated the environmental impacts of the Kowsar irrigation and drainage network using both the conventional Leopold matrix and a modified Leopold matrix. Their findings indicated that the most significant positive impacts were associated with the socio-economic environment. The total positive scores obtained from the conventional and modified Leopold matrices were 793 and 458.9, respectively, while the corresponding negative scores were 447 and 258.8. The results demonstrated that both matrices provided reasonable and reliable assessments, supporting the implementation of the Kowsar irrigation and drainage project.

Komasi and Beiranvand (2019) conducted an EIA of the Eyvashan Dam in Lorestan Province during both the construction and operation phases, assessing impacts across biological, physicochemical, socio-economic, cultural, and strategic environments. The findings indicated that the overall results were acceptable in both phases, although the highest negative scores were associated with the physical environment. Ultimately, the application of the Leopold matrix confirmed the validity of the EIA results for the Eyvashan Dam. Similarly, Ashofteh et al. (2016) conducted a multi-criteria environmental impact assessment of the irrigation networks of Shahriar Dam in East Azerbaijan Province using the conventional matrix method. Their results showed that long-term implementation of the project would yield favorable effects

on socio-economic and cultural components, with the highest positive scores attributed to this environment. Moreover, the total positive impact scores in the physical, biological, and socio-economic environments exceeded the negative impacts, supporting the project's overall feasibility. The majority of the country's irrigation and drainage infrastructure is concentrated in Khuzestan Province. A review of the history of environmental assessment in Iran indicates that, in the past, development projects were often implemented without considering their environmental consequences due to the absence of specific environmental assessment regulations. In 1994, the Supreme Council for Environmental Protection assigned the Department of Environment (DOE) the responsibility of preparing the framework for Environmental Impact Assessment (EIA) reports. Since then, project developers have been required to prepare EIA reports along with feasibility studies and site selection reports prior to project implementation. Several legal provisions are also related to environmental protection and environmental assessment in Iran. These include Article 6 and Article 7 of the Environmental Protection and Enhancement Act, as well as Article 50 of the Constitution of the Islamic Republic of Iran (1997), which emphasizes the protection of the environment as a public duty.

While large-scale irrigation and drainage networks are pivotal to agricultural productivity, their environmental consequences—particularly during the post-construction, operational phase—remain insufficiently characterized in the literature. Although such systems are primarily designed to optimize output and efficiency, their potential to induce long-term environmental degradation across physical and biological media necessitates rigorous, holistic assessment. Notably, despite the strategic importance of the Shavur irrigation and drainage network in Khuzestan Province, Iran, there is a distinct lack of comprehensive Environmental Impact Assessment (EIA) studies evaluating its consequences during the operational phase. To address this critical gap, this study systematically evaluates the environmental impacts of the Shavur network, providing a multi-dimensional assessment that integrates physical, biological, and socio-economic domains

2.Method

2.1.Geographic Location of the Study Area

The 5,000-ha Shavur irrigation and drainage network is located on relatively flat agricultural lands within the Shush County watershed in Khuzestan Province, Iran. The project area is approximately located between the following geographic coordinates:

Easting: 252414.555 – 258381.3320

Northing: 3520397.9650 – 3533869.6796

The irrigation and drainage network covers an area of approximately 5,000 hectares, with a total project area of about 6,880 hectares. The water intake capacity of the system is 6.74 m³/s. The water supply sources for the project are the Shavur and Kheirabad dams.

To assess the human bioclimatic conditions of the study area, the Physiologically Equivalent Temperature (PET) was estimated using the Munich Energy-balance Model for Individuals (MEMI). Since the Safiabad synoptic station is the nearest meteorological station to the study area, the meteorological observations and climatic statistics obtained from this station were used for PET calculation. The input parameters included mean air temperature (25.98°C), mean relative humidity (49.08%), mean wind speed at 10 m height (3 m/s), average daily sunshine duration (8.7 h), elevation above sea level (87 m), latitude (31.45°N), and longitude (48.29°E). Wind speed was adjusted from the standard meteorological height of 10 m to the human-biometeorological reference height of 1.1 m, resulting in an estimated wind speed of approximately 2.2 m/s. Based on these parameters, the PET of the study area was estimated at approximately 29.8°C, indicating slightly warm to warm thermal conditions. Since mean radiant temperature (T_{mrt}) was not directly measured, PET was estimated using available sunshine duration and geographical parameters; therefore, the obtained value should be interpreted as an approximation. Accordingly, the derived PET value should be interpreted with caution as an approximate indicator of the thermal perception conditions in the study area.

2.2. Project Objectives

The main objective of the project (the irrigation and drainage network) is the optimal utilization of the available soil and water resources and the agricultural potential of the region. In addition, the project aims to eliminate limiting factors and to revive and expand agricultural activities through the development of irrigation and drainage infrastructure. Other objectives of the project include:

1. Creating jobs and reducing rural-to-urban migration; 2. increasing the production of strategic agricultural crops; 3. enhancing beneficial soil microbial activity and improving soil quality; 4. reducing surface runoff and soil erosion; 5. improving field traffic conditions for agricultural machinery; 6. reducing soil structural degradation; 7. decreasing soil compaction and energy consumption for agricultural operations; 8. improving water management and plant access to nutrients; and 9. increasing crop productivity.

2.3. Research Methodology

Various methods are available for Environmental Impact Assessment (EIA) of development projects. Common environmental assessment techniques include: 1-Ad hoc (expert judgment) methods 2-Checklists 3-Networks 4-Overlay methods 5-Matrices.

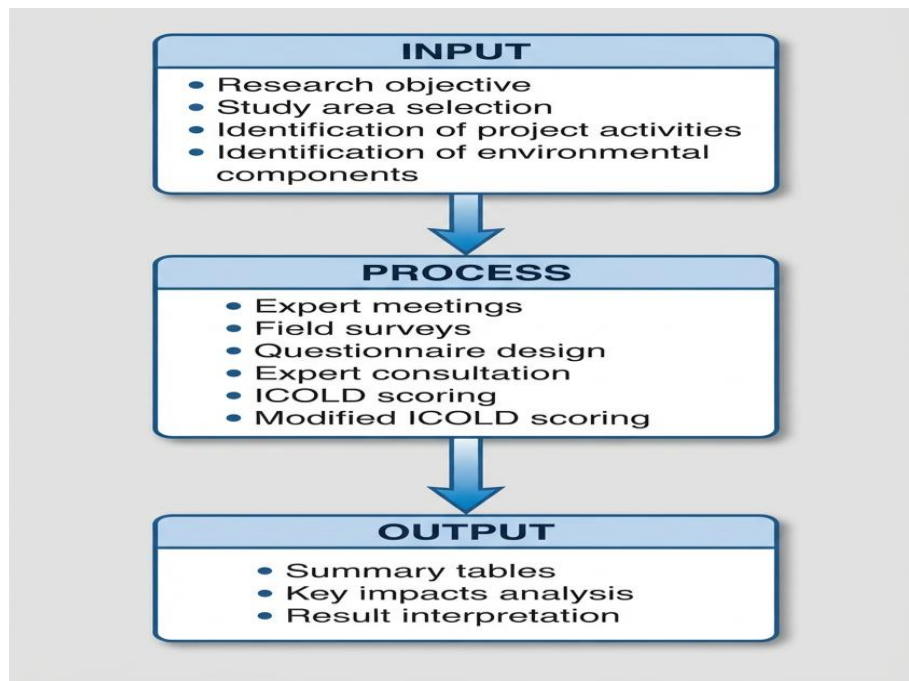
Among these methods, matrices can be considered an advanced form of two-dimensional checklists. In matrix-based approaches, one dimension represents the activities associated with the project, while the other dimension includes environmental, economic, and social parameters that may be affected by project implementation. The intersection of each activity with an environmental parameter indicates the potential impact of that activity on the corresponding parameter. One of the advantages of matrix methods over simple checklists is their ability to evaluate environmental impacts at different stages of a project according to the type of activity being performed. Matrices illustrate the cause–effect relationships between project activities

and environmental components. Furthermore, by integrating project activities on one axis and environmental parameters on the other, matrices provide a relatively simple and comprehensible framework for environmental analysis. In matrix evaluation, after defining the relevant activities and environmental parameters along the axes, the impact of each activity on environmental components is assessed. When an impact is expected to occur, a mark is placed at the intersection cell. Each cell is then divided diagonally to assign two numerical values representing the magnitude and importance of the impact, typically ranging from 1 to 10. These values are determined based on expert judgment and comparative evaluation of environmental parameters. If the evaluator is uncertain about the occurrence of a particular impact, the potential effect can still be recorded to provide an overview of possible or probable environmental consequences. After completing the matrix, the sum of the numerical values in each column represents the overall impact of a specific activity on all environmental parameters. By summing these values, both individual activity impacts and the overall project impacts can be assessed in terms of magnitude and importance.

This study, conducted in 2025, presents an Environmental Impact Assessment (EIA) of the Shavur irrigation and drainage network, situated in the central Karkheh Basin of Khuzestan Province, Iran. Given that this network has been operational for over 15 years, this research employs both conventional and modified Leopold matrix methodologies to evaluate its long-term environmental consequences. The Leopold matrix is a robust and widely utilized approach that facilitates the conversion of qualitative environmental impacts into quantitative assessments. A key advantage of this method lies in its ability to systematically characterize the interactions between project activities and specific environmental parameters.

In the modified Leopold matrix approach, quantitative coefficients are assigned to the impacts of project activities on different environmental components based on specific symbols used in the conventional Leopold matrix. The impact coefficient in this method is calculated by multiplying the numerical values assigned to the time of occurrence and duration of the impact (Dehnavi & Kouzehgar, 2019).

-Flowchart of the whole research process:



In this research, environmental impacts during the operation phase were evaluated across physical, biological, and socio-economic components using a structured matrix framework. To ensure methodological robustness, 15 specialized questionnaires were administered and successfully completed by a panel of senior experts selected via a purposive sampling strategy. These experts, possessing a minimum of 15 years of professional seniority and advanced academic credentials, represented key disciplines including environmental science, irrigation and drainage engineering, hydraulic structures, geology, water resources, surveying, and socio-economic studies. This expert-based assessment utilized a scoring system ranging from +1 to +5 and –1 to –5 to quantify the magnitude of impacts. In the matrix design, project activities (rows) were intersected with environmental parameters (columns), where each interaction was meticulously described using specific descriptors: impact nature, intensity, time of occurrence, and duration.

Positive and negative impacts were indicated by the symbols (+) and (–), respectively. The intensity of impact, representing the degree of influence of each activity, was categorized as follows: very high (5), high (4), moderate (3), low-moderate (2), and weak (1). The duration of impact was categorized as permanent (P) or temporary (T). The time of occurrence was represented by the symbols I, M, and L, indicating long-term, medium-term, and short-term impacts, respectively (Komasi & Beiranvand, 2019). To quantify the qualitative descriptors of the Leopold Matrix, weighting coefficients were assigned based on the modified methodology proposed by Monavari (2008) and Pastakia (1998). For instance, a coefficient of 1.5 was assigned to Permanent impacts to reflect their long-term environmental significance, while

temporary impacts received a coefficient of 0.7, accounting for the environment's recovery potential.

Table 1- Symbols and coefficients used in the modified ICOLD matrix

Type of effect	Symbol	Condition	Coefficient	Impact intensity	
Effect duration	T	Temporary	0.7	Very high	±5
	P	Permanent	1.5	High	±4
	I	Short-term	1.0	Moderate	±3
Effect time	M	Medium-term	1.25	Low	±2
	L	Long-term	1.5	Weak	±1

2.4.Environmental Parameters

The socio-economic parameters considered in this study included commerce, industry, income level, employment, population, migration, landscape, tourism, culture, land use, land value, diseases, public health, agriculture and livestock production, social welfare, literacy, and education. The physical environmental parameters included surface water, groundwater, soil characteristics (erosion, texture, and quality), landform, river morphology, air quality, and noise quality, all of which are essential environmental components.

The biological environment parameters included sensitive habitats, aquatic fauna, terrestrial wildlife, aquatic plants, and terrestrial vegetation. In addition, with the assistance of environmental experts, a list of project activities relevant to the operation phase of the Shavur irrigation and drainage network was prepared. These activities included water abstraction and transfer, employment and workforce engagement, development of different land uses, vehicle traffic and transportation activities, drainage water production, and various agricultural operations.

3.Results

The results of the environmental impact assessment indicate a clear trade-off between socio-economic benefits and environmental pressures in the Shavur irrigation and drainage network. Both the conventional and modified Leopold matrices show that the project has predominantly positive effects on the socio-economic environment, while its effects on the physical and biological environments are mainly negative. This consistency between the two methods suggests that the observed pattern is robust and is not merely an artifact of the scoring system. It should be noted that all abbreviations used in this study are defined in Table 1.

3.1.Physical environment

In the physical environment (Tables 2 and 5), the project had mixed but predominantly adverse impacts. The relatively high positive score assigned to soil quality can be explained by the local agricultural context of the Shavur plain, where irrigated farming is the dominant land use. A more reliable water supply generally improves soil moisture status, facilitates crop establishment, and enhances nutrient uptake, which can ultimately increase land productivity.

In semi-arid regions such as Khuzestan, these effects are particularly important because regulated irrigation reduces crop water stress and supports more stable agricultural production. Therefore, the positive effect on soil quality reflects a plausible agronomic response to improved irrigation conditions rather than a merely numerical outcome. Similar positive soil-related responses under irrigation development have also been reported in previous studies, although the magnitude of improvement depends strongly on local management and environmental conditions.

Despite these potential benefits, the physical environment remains dominated by negative impacts, mainly due to pressures on surface water resources. This finding is consistent with earlier studies reporting that irrigation and drainage projects often impose substantial stress on water bodies through agricultural return flows. In the present case, the strongest negative effects are associated with the discharge of drainage water containing salts, fertilizers, pesticides, and suspended solids. Under the regional conditions of intensive cultivation, relatively low slope, and likely fine-textured soils in parts of the command area, pollutant transport and accumulation may be intensified, while natural drainage may remain inefficient. These conditions provide a scientific explanation for why surface water received the highest negative score. The predominance of adverse physical impacts observed here is in agreement with Dezab Consulting Engineers (2009), Komasi and Beiranvand (2019), and Ataei et al. (2019). Any differences from other studies, such as Zartipour et al. (2022), may be attributed to variation in drainage performance, cropping pattern, land management, and local hydro-edaphic conditions.

3.2. Biological environment

In the biological environment (Tables 3 and 6), the results indicate that negative impacts outweigh positive ones, especially in relation to aquatic ecosystems. This pattern is scientifically reasonable because aquatic habitats are directly and continuously exposed to the consequences of drainage discharge. Increased salinity, nutrient enrichment, pesticide residues, and suspended particles can degrade habitat quality, alter water chemistry, reduce dissolved oxygen, and impose physiological stress on aquatic organisms. These mechanisms can disrupt growth, reproduction, and survival, thereby making aquatic fauna particularly vulnerable. This interpretation is consistent with previous studies, including Komasi and Beiranvand (2019), Ataei et al. (2019), and Zartipour et al. (2022), which likewise reported that aquatic receptors are among the most sensitive components in irrigation-related environmental assessments.

By contrast, terrestrial wildlife received relatively more positive scores, which can be linked to localized improvements in vegetation cover, food availability, and moisture conditions within cultivated landscapes. In dry environments, expansion of irrigated fields may temporarily create more favorable habitats for some terrestrial species. However, these benefits are limited and conditional, because they may be offset by habitat disturbance, agrochemical exposure, and changes in natural ecological processes. Accordingly, the biological impacts of the project should be interpreted as the net result of modest terrestrial habitat gains versus more pronounced

degradation in aquatic systems, which explains the overall negative balance of this environmental component.

3.3.Socio-economic environment

In the socio-economic environment (Tables 4 and 7), the project showed a strongly positive pattern, which is expected for irrigation and drainage schemes designed to improve agricultural production and rural livelihoods. Reliable irrigation water increases cropping intensity, reduces the probability of crop failure, and enables more stable and profitable farming systems. In the Shavur region, where agriculture is a key economic activity, these changes can directly improve household income and indirectly stimulate employment in input supply, harvesting, processing, transportation, and local trade. The particularly high score for income therefore reflects the central role of water availability in strengthening farm productivity and rural economic security. This positive socio-economic pattern is consistent with the findings of Komasi and Beiranvand (2019), Ataei et al. (2019), Zartipour et al. (2022), and Ashofteh and Bozorg-Haddad (2019), all of whom highlighted the developmental benefits of irrigation projects.

Nevertheless, the socio-economic component is not free from negative effects. Disease-related risks emerged as the main adverse issue, which can be explained by the formation of stagnant water in poorly managed irrigation and drainage systems. Such conditions may facilitate vector breeding and increase the risk of water-related and vector-borne diseases, while contamination from agrochemicals may further threaten public health. Thus, although the project acts as a strong driver of local socio-economic development, the sustainability of these benefits depends on effective drainage maintenance, water quality control, and public-health protection.

- Overall, the results of both the conventional and modified Leopold matrices indicate a clear trade-off: the Shavur irrigation and drainage network provides substantial socio-economic benefits, but these gains are accompanied by predominantly negative impacts on the physical and biological environments. The consistency of this pattern across both matrices strengthens confidence in the interpretation. It also suggests that the environmental challenges identified in this study are structural rather than incidental. From a management perspective, the findings underscore the need for controlled drainage disposal, monitoring of water quality, regulation of agrochemical use, salinity and waterlogging prevention, ecological protection of aquatic systems, and public-health safeguards. Without such measures, the long-term environmental sustainability of the project may be compromised despite its clear developmental advantages.

Table 2- Impact scores for the project's operational phase in the physical environment using the conventional ICOLD matrix

Environmental parameters	Sound quality	Air quality	River morphology	Landform	Soil			Groundwater	Surface water	Total
Assessment Parameters					Quality	Texture	Erosion			
Number of permanent positive impacts	2	6	3	6	7	6	5	1	5	41
Number of permanent negative impacts	6	5	6	7	5	6	6	8	9	58
Sum of permanent positive values	3	16	12	18	23	21	23	5	17	138
Sum of permanent negative values	12	14	14	16	20	21	19	27	40	183
Number of temporary positive impacts	0	2	1	2	2	2	0	2	1	12
Number of temporary negative impacts	3	0	3	1	0	0	3	6	3	19
Sum of temporary positive values	0	4	2	2	3	3	0	4	5	23
Sum of temporary negative values	4	0	4	3	0	0	8	16	8	43
Total number of positive impacts	2	8	4	8	9	8	5	3	6	53
Total number of negative impacts	8	5	9	8	5	6	9	14	12	76
Sum of positive values	3	20	14	20	26	24	23	9	22	161
Classification labels for positive values	PL	PL	TM	PL	PL	PL	PL	PL	PL	
Sum of negative values	16	14	18	19	20	21	27	43	48	226
Classification labels for negative values	TM	PL	PL	PL	PL	PL	PL	PL	PL	

Table 3- Impact scores for the project's operational phase in the biological environment using the conventional ICOLD matrix

Environmental parameters	Habitats and sensitive	Aquatic plants	Terrestrial wildlife	Aquatic animals	Terrestrial plants	Total
Assessment Parameters						
Number of permanent positive impacts	6	6	5	3	1	21
Number of permanent negative impacts	9	8	8	8	7	40
Sum of permanent positive values	19	15	19	5	3	61
Sum of permanent negative values	27	28	23	27	23	128
Number of temporary positive impacts	0	2	1	1	5	9
Number of temporary negative impacts	2	1	1	4	2	10
Sum of temporary positive values	0	3	3	2	11	19
Sum of temporary negative values	2	2	3	9	4	20
Total number of positive impacts	6	8	6	4	6	20
Total number of negative impacts	11	9	9	12	9	50
Sum of positive values	19	18	22	7	14	80
Classification labels for positive values	PL	PL	PL	PL	PL	
Sum of negative values	29	30	26	36	27	148
Classification labels for negative values	PL	PL	PL	PL	PL	

Table 4- Impact scores for the project's operational phase in the socio-economic environment using the conventional ICOLD matrix

Environmental parameters	Landscape / Outlook	Tourism	Culture	Land use	Land value	Diseases	Health	Agriculture and animal	Social welfare	Literacy and education	Population and migration	Commerce	Industry	Income level	Employment	Total
Assessment Parameters																
Number of permanent positive impacts	15	14	15	4	14	6	6	15	16	8	10	12	15	16	14	190
Number of permanent negative impacts	0	0	0	1	1	3	3	1	0	0	1	0	0	0	2	12
Sum of permanent positive values	38	18	27	28	42	7	7	42	57	15	30	33	42	68	60	514
Sum of permanent negative values	-	0	0	1	2	4	4	2	0	0	2	0	0	0	4	19
Number of temporary positive impacts	0	0	1	0	0	1	2	0	0	5	0	3	1	0	0	13
Number of temporary negative impacts	0	0	0	0	0	6	0	1	0	0	0	0	0	0	0	7
Sum of temporary positive values	0	0	2	0	0	1	3	0	0	5	4	2	1	0	0	18
Sum of temporary negative values	0	0	0	0	0	6	0	1	0	0	0	0	0	0	0	7
Total number of positive impacts	15	14	16	14	14	7	8	15	16	13	10	15	16	16	14	203
Total number of negative impacts	0	0	0	1	1	9	3	2	0	0	1	0	0	0	2	19
Sum of positive values	38	18	29	28	42	8	10	42	57	20	34	35	43	68	60	532
Classification labels for positive values	PL	PL	PM	PL	PL	P	PL	PL	PL	PM	PL	PL	PL	PL	PL	
Sum of negative values	0	0	0	1	2	10	4	3	0	0	2	0	0	0	4	26
				PL	TL	PL	PM	P			P				PM	

Table 5- Impact scores for the project's operational phase in the physical environment using the modified ICOLD matrix

Environmental parameters	Sound quality	Air quality	River morphology	Landform	Soil			Groundwater	Surface water	Total
Assessment Parameters					Quality	Texture	Erosion			
Number of permanent positive impacts	2	6	3	6	7	6	5	1	5	41
Number of permanent negative impacts	6	5	6	7	5	6	6	8	9	58
Sum of permanent positive values	5.62	36	27	31.5	45	47.5	43	9.37	38.25	283.24
Sum of permanent negative values	27	30.37	27.75	30.75	43.87	47	45	60.75	90	402.49
Number of temporary positive impacts	0	2	1	2	2	2	0	2	1	12
Number of temporary negative impacts	2	0	3	1	0	·	3	6	4	19
Sum of temporary positive values	0	3.5	1.75	2.62	0	2	0	4.2	5.25	19.32
Sum of temporary negative values	3.5	0	1.4	1.4	2.45	·	3.32	14	7.35	33.42
Total number of positive impacts	2	8	4	8	9	8	5	3	6	53
Total number of negative impacts	8	5	8	9	5	6	9	14	13	77
Sum of positive values	6	40	29	34	45	49.5	43	13.57	43.5	303.57
Sum of negative values	30.5	30.37	29.15	32.15	46.32	47	48.32	74.75	97.35	435.91

Table 6- Impact scores for the project's operational phase in the biological environment using the modified ICOLD matrix

Environmental parameters	Habitats and sensitive areas	Aquatic plants	Terrestrial wildlife	Aquatic animals	Terrestrial plants	Total
Assessment Parameters						
Number of permanent positive impacts	6	6	5	3	1	21
Number of permanent negative impacts	9	8	8	8	7	40
Sum of permanent positive values	25	27.37	33.37	9.75	6.75	102.24
Sum of permanent negative values	30	66.75	51.75	66	51.37	265.87
Number of temporary positive impacts	0	2	1	1	5	9
Number of temporary negative impacts	2	1	1	4	2	10
Sum of temporary positive values	0	2.8	3.15	2.1	1.22	9.27
Sum of temporary negative values	2.8	1.7	3.15	8.75	5.6	21
Total number of positive impacts	6	8	6	4	6	30
Total number of negative impacts	11	9	9	12	9	50
Sum of positive values	25	30.17	36.52	11.85	7.97	111.51
Sum of negative values	32.8	67.45	54.9	74.75	56.97	286.87

Table 7- Impact scores for the project's operational phase in the socio-economic environment using the conventional ICOLD matrix

Environmental parameters Assessment Parameters	Landscape / Outlook	Tourism	Culture	Land use	Land value	Diseases	Health	Agriculture and animal husbandry	Social welfare	Literacy and education	Population and migration	Commerce	Industry	Income level	Employment	Total
Number of permanent positive impacts	15	14	15	14	14	6	6	15	16	8	10	12	15	16	14	190
Number of permanent negative impacts	0	0	0	1	1	3	3	1	·	·	1	0	0	0	2	12
Sum of permanent positive values	70.5	72	65	105	46	27	36	127.13	60	39.75	79.12	33	135.3	156.5	138.7	1191
Sum of permanent negative values	0	0	0	9	4	17	11	6.75	·	·	3.75	0	·	·	9.37	61
Number of temporary positive impacts	0	0	1	0	0	1	2	0	·	5	·	3	1	·	·	13
Number of temporary negative impacts	0	0	0	0	0	6	0	1	·	·	0	0	0	0	0	7
Sum of temporary positive values	0	0	1.8	0	0	0.7	5	0	0	8.92	·	2	1.75	0	0	20.2
Sum of temporary negative values	0	0	0	0	0	9	·	1.75	0	0	0	0	0	0	0	11
Total number of positive impacts	15	14	16	14	14	7	8	15	16	13	10	15	16	16	14	203
Total number of negative impacts	0	0	0	1	1	9	3	2	0	0	1	0	0	0	2	19
Sum of positive values	70.5	72	67	105	46	28	41	127.13	60	48.67	79.12	35	137.1	156.7	138.7	1212
Sum of negative values	0	0	0	9	4	26	11	8.5	0	0	3.75	0	0	0	9.37	72

4. Conclusion

This study evaluated the environmental impacts of the Shavur irrigation and drainage network during its operational phase using both the conventional and modified Leopold matrices. The results obtained from both approaches consistently demonstrated that the project delivers considerable socio-economic benefits, particularly through enhanced agricultural productivity, increased household income, expanded employment opportunities, and strengthened rural development.

However, the findings also revealed that the project exerts predominantly negative effects on the physical and biological environments. Among the assessed components, surface water and aquatic ecosystems were identified as the most vulnerable, mainly due to the discharge of agricultural drainage water containing salts, nutrients, pesticides, and suspended solids into receiving water bodies. In contrast, the positive effects observed on soil quality and terrestrial wildlife were not unconditional, but rather dependent on the continuation of appropriate irrigation practices, efficient drainage performance, and sound environmental management.

Accordingly, the long-term sustainability of the Shavur irrigation and drainage network depends on achieving a balance between developmental benefits and environmental protection. Priority should therefore be given to controlled and optimized drainage management, reduction of pollution from agricultural chemical inputs, continuous monitoring of water quality and ecological conditions, and the implementation of effective public health safeguards.

One of the main limitations of this study is that the assessment was based on expert judgment within a matrix-based framework. Although this approach provides a structured and systematic basis for identifying and evaluating impacts, it does not directly capture temporal fluctuations or field-based environmental variations. Therefore, future studies should integrate this framework with long-term monitoring of water quality, soil salinity, biodiversity, and health-related indicators in order to provide a more comprehensive and reliable foundation for the sustainable management of this network and similar irrigation systems.

Author Contributions

Conceptualization, methodology, supervision, and project administration, A.R. Hooshmand; software, investigation, data curation, formal analysis, and writing, H. Khosravi; funding acquisition, Shahid Chamran University of Ahvaz. All authors have read and agreed to the published version of the manuscript.

Data Availability Statement

The data were obtained from questionnaires completed by experts from various project departments.

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Conflict of Interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analysis, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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