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Multi-Criteria Environmental Impact Assessment of Alternative Irrigation Networks with an Adopted Matrix-Based Method

Parisa-Sadat Ashofteh[1] · **Omid Bozorg-Haddad**[2] · **Hugo A. Loáiciga**[3]

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Abstract Environmental impact assessments (EIA) identify the type, importance, and severity of the environmental consequences of human activities. This study performs an EIA of the Shahriar dam irrigation project in Iran. Physical, biological, and social-economic-cultural criteria and parameters are evaluated in the short and long terms with the Leopold matrix method. Results show that short-term project implementation has its most negative impact in the biological realm (with a score of −48), while long-term implementation would impact most favorably the social-economic-cultural component (+233). A sensitivity analysis of the EIA was employed to determine the relative impacts of the physical, biological, and social-economic-cultural components of the Shahriar irrigation project.

Keywords Environmental impact assessment · Irrigation · Leopold matrix · Sensitivity analysis

✉ Omid Bozorg-Haddad
OBHaddad@ut.ac.ir

Parisa-Sadat Ashofteh
PAshofteh@ut.ac.ir

Hugo A. Loáiciga
Hugo.Loaiciga@ucsb.edu

[1] Department of Civil Engineering, University of Qom, Qom, Iran

[2] Department of Irrigation & Reclamation, Faculty of Agricultural Engineering & Technology, College of Agriculture & Natural Resources, University of Tehran, Karaj, Tehran, Iran

[3] Department of Geography, University of California, Santa Barbara, CA 93106, USA

1 Introduction

The purpose of EIAs is to identify the impacts of a project's various activities on the environment. Identifying these impacts helps prevention and decision making, and provides opportunities for monitoring and mitigation (Snell and Cowell 2006; Samarakoon and Rowan 2008). The implementation of EIAs has grown since the enactment of the U.S. National Environmental Policy Act (NEPA) in 1970 (Bailey 1997; El-Fadl and El-Fadel 2004). The NEPA serves as a guideline for EIA studies in many developed and developing countries.

Sabnis (2001) presented an overview of the various studies conducted to assess the environmental, ecological and social impacts, both positive and negative, of the Sardar Sarovar Project (SSP). Kuitunen et al. (2008) compared the results of EIA and strategic environmental assessment (SEA) for various types of projects (such as road construction) using the rapid impact assessment matrix (RIAM) method to compare the environmental and social impact of different projects. Liu and Lai (2009) proposed an integrated decision-support framework. This framework considered the overall acceptability of a development proposal determined by 3-major clusters: (1) environmental pollution, (2) ecological alteration, and (3) socioeconomic disturbance. The proposed approach was applied to the Taiwan High-Speed Rail project as a case study.

Hafez Moghaddas and Hajizadeh Namaghi (2011) determined candidate sites for hazardous landfills in the northeastern Khorasan Razavi province of Iran using the integration of geographic information system (GIS), landfill susceptibility zonation methods, and the Leopold Matrix method. Their results demonstrated that their method would reduce the environmental impact of the chemical process. Gilbuena et al. (2013) proposed the RIAM technique to evaluate the socio-economic and environmental impacts resulting from structural flood mitigation measures (SFMM) in the Manila Metro (the Philipines). Xu et al. (2013) applied China's environmental impact statement (EIS) for the Three Gorges Project (TGP). Their research examined five environmental criteria, which included human resettlement and the carrying capacity of local environments, water quality, reservoir sedimentation and downstream riverbed erosion, soil erosion, seismic activity, and geological hazards. Martínez-Graña et al. (2014) proposed a new procedure for the joint strategic environmental assessment (SEA) and EIA to analyze the importance and extent of the impact of human activities within protected areas. This method was applied to Las Batuecas-Sierra de Francia and Quilamas (Salamanca, Spain) protected areas. Jafarian et al. (2016) conducted a quantitative assessment of the effects of *Haloxylon persicum* planted area on the severity of wind erosion and desertification process in Khorasan Razavi (Iran). The latter authors applied a modified Mediterranean Desertification and Land Use (MEDALUS) and Iranian Research Institute of Forests and Rangelands' (IRIFR) models coupled with ArcGIS 9.3 in their study.

Large amounts of resources are commonly needed in water development projects involving the construction of dams and irrigation networks. Moreover, the construction of these projects commonly engenders environmental consequences (the World Bank Independent Evaluation Group 2008). This has led to the development and expansion of EIAs, whose applications have shown that they must be tailored to the idiosyncrasies of the systems being assessed (Ahmadi et al. 2014, 2015; Akbari-Alashti et al. 2014; Amirkani et al. 2016; Ashofteh et al. 2013a, 2013b, 2015a, 2015b, 2015c, 2016a, 2016b, 2016c; Beygi et al. 2014; Bolouri-Yazdeli et al. 2014; Bozorg-Haddad et al. 2013, 2014, 2015a, 2015b; Farhangi et al. 2012; Fallah-Mehdipour et al. 2013a, 2013b, 2013c, 2014; Jahandideh-Tehrani et al. 2015; Noury et al. 2014; Orouji et al. 2013, 2014a, 2014b; Shokri et al. 2013, 2014; Soltanjalili et al. 2013). The Shahriar dam's irrigation project is in the first stages of planning and feasibility assessment. This paper analyzes two options, namely, "do nothing" and "project implementation" for Shahriar dam. This analysis examines the potential regional consequences if the dam were built relying on the Leopold matrix method coupled with EIA.

2 Methodology

The EIA methodology followed in this work includes the identification, data assessment, and summary of findings about the environmental impacts of the Shahriar dam irrigation project. The results of this paper's assessment lead to the selection of the best project options. Sensitivity analyses of each of the components' parameters and of the project's activities are carried out and compared. A schematic of this study's logic is depicted in Fig. 1.

Two options concerning the Shahriar dam were considered: "do nothing" and "project implementation". The associated impacts of these options were determined, followed by a sensitivity analysis of the impact assessment.

2.1 Conventional Methods of EIA

Conventional methods of EIA include checklist methods, overlay-mapping, consequence tree, system analysis, decision support systems, and matrices (Canter 1982; Kuitunen et al. 2008).

The Leopold matrix (Leopold et al. 1971) has proven to be a cost effective and accurate method. It implements a two-dimensional checklist: the columns of the matrix contain the project's activities. The matrix's rows list the assessment parameters (environmental, economic, social, etc.) pertinent to the project's assessment. The impacts of the components' parameters are evaluated based on their scope and severity on a scale of 1 to 10 in the Leopold method (1 for very minor impact, 10 for very severe impact). The causal relations between activities and project components and their parameters are evaluated in the matrix, thus providing a simple yet clear scheme for displaying project activities and their impacts.

2.2 The Study Area

The project study area is the Shahriar dam's irrigation network with a service area of approximately 21,000 ha, located in the province East Azerbaijan, Iran (see Fig. 2). This area is bounded on the south by the Shahriar dam's lake, on the east by the Ghermi river, on the west by the Mianeh road, and on the north by the 1400 m contour line. The study area is situated in northeastern Iran between 47° 30′ to 47° 52′ eastern longitudes and 37° 34′ to 37° 24′ northern latitudes. The land within the study area slopes from north to south.

The average annual river discharge at the Shahriar dam site is about 1.5 billion cubic meters, and the capacity of the reservoir is 700 million cubic meters that regulates water for downstream stakeholders. The construction of the Shahriar dam will submerge some upstream agricultural lands, and, to compensate for that loss an irrigation network upstream of the reservoir has been proposed. This study implements the Leopold

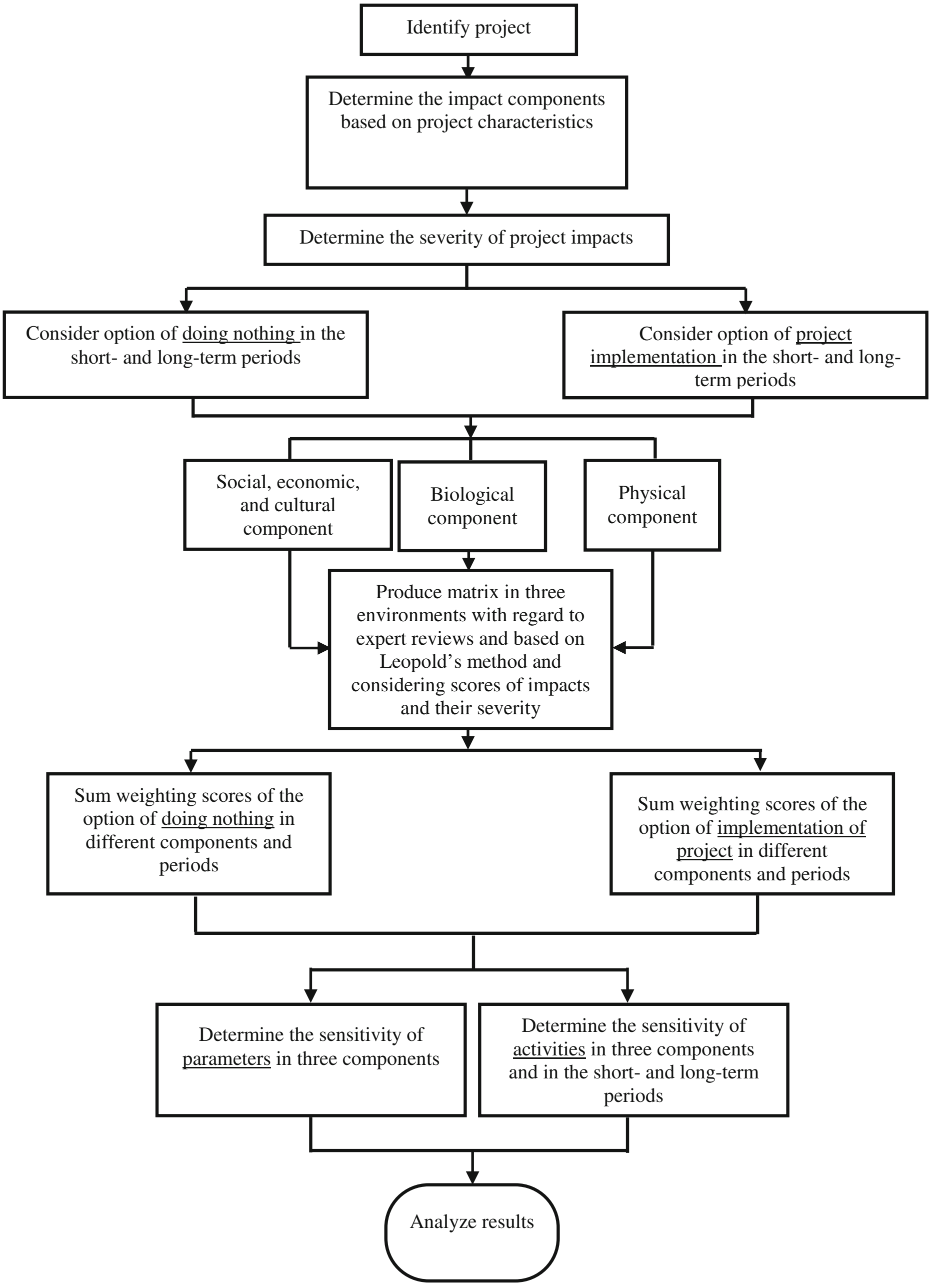

Fig. 1 Flowchart of methodology

matrix method to conduct and environmental impact assessment (EIA) of the proposal to construct an upstream irrigation network. The EIA assess the nature of the impacts of the proposed upstream irrigation network on the physical, biological, and social-economic-cultural resources of the study region.

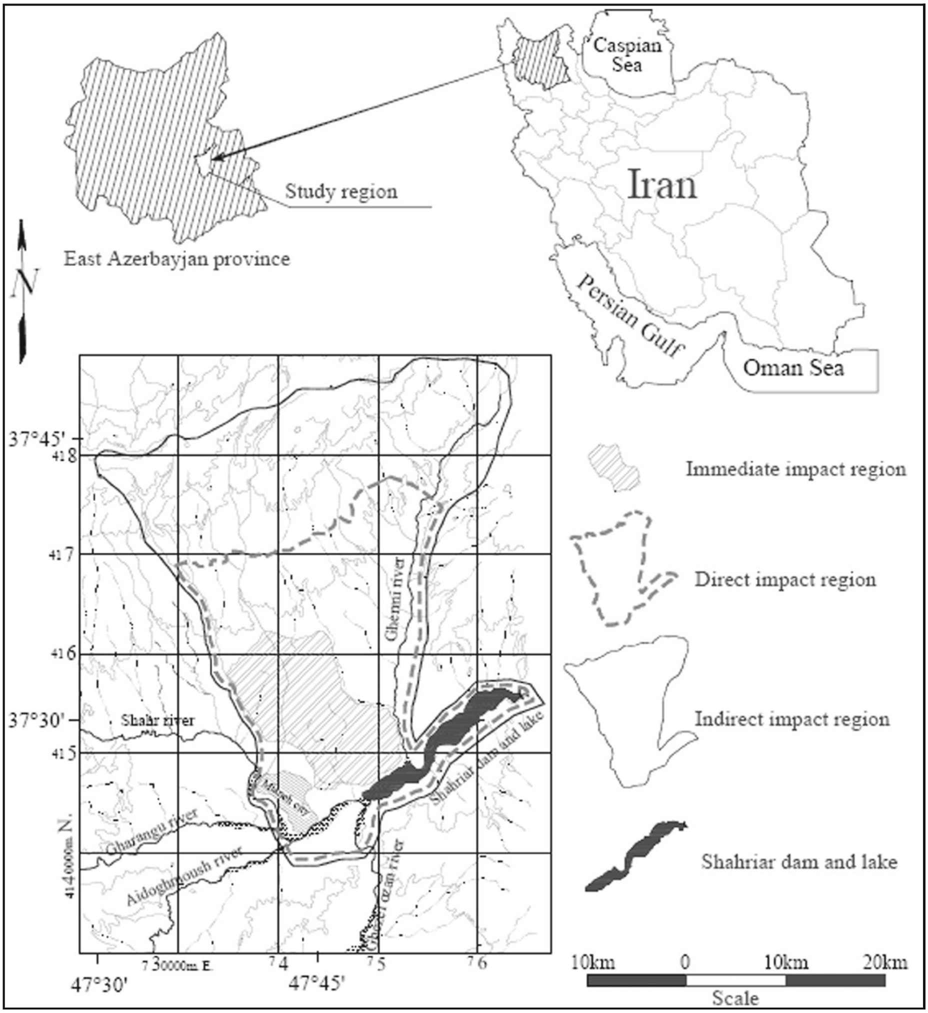

Fig. 2 Impact regions of the Shahriar project

2.3 The Irrigation Network of the Shahriar Dam

The Shahriar dam's irrigation network will be one of the poles of agriculture in the Iran, thus the network will be important in terms of food security. The network consists of two main parts: (a) intake and water transmission system (including pipelines, pumping stations, and storage reservoirs); (b) and the irrigation network (including main pipelines, lateral pipelines, reservoirs, major and minor pumping stations, valves and accessories and pressurized irrigation network).

2.4 The Shahriar Dam

The source of the irrigation water supply is the water stored in the Shahriar reservoir. The Shahriar dam is currently under construction on the Ghezel Ozan river, about 50 km northeast of Mianeh city (see dam characteristics in Table 1).

Table 1 Key characteristics of the Shahriar dam

Type of dam	Concrete arch
Depth of foundation	135 m
Level of crown	1045 m above sea level
Length of crown	180 m
Crown width	5 m
Dam's structural volume	700,000 m^3
Reservoir volume at normal level	650×10^6 m^3
Normal water level	1035 m above sea level
Maximum water level	1041 m above sea level
Minimum water level	1020 m above sea level

2.5 Determination of the Scope of the Case Study

The environmental impacts of the project on the study area (Fig. 2) were classified by geographical impact regions (immediate, direct, and indirect impact regions). The characteristics of these impact regions are as follows:

(a) **Immediate impact region**
This region corresponds with that proposed for the Shahriar dam's irrigation network, where all implementation operations and major project changes will take place. This includes natural and human-affected environments, and includes the proposed region of construction of the irrigation network, intake facilities, and water transmission lines.

(b) **Direct impact region**
Changes within this region are considerable in the short- and long-term terms. This region includes the project's immediate impact region, the range of influence of the Shahriar dam, and project habitats.

(c) **Indirect impact region**
This region harbors impacts on the physical component such as the watershed area that originates at high elevations and abuts against the Shahriar reservoir lake. Social, economic, and cultural impacts would be felt in Mianeh city. No specific or important biological impacts were identified in this region.

2.6 EIA with the Leopold Matrix

The Leopold matrix was herein implemented for the quantitative assessment of the impacts of the Shahriar dam's irrigation project. The selection of project components and impact parameters was done according to the Leopold et al. (1971) approach aided by recent expert reviews.

There are many types of activities in this project. They are listed in the columns of the matrix. The impact parameters of the physical, biological and social-economic-environmental components constitute the rows of the matrix. The impacts' scopes are represented by the numbers 1, 2, and 3 corresponding to the immediate impact region, the direct impact region, and the indirect impact region, respectively (see Fig. 2 for example of such regions). Impact importance scoring is based on five weights (1 through 5). A weight equal to 1 indicates minimal impact and a weight equal to 5 indicates a very important impact, with mild, moderate and high importance having weights 2, 3 and 4, respectively. Negative scores indicate harmful impacts and positive scores indicate beneficial impacts. There are two numbers above and below the diagonal of each cell of the matrix, respectively indicating scope and importance of the impact. The score of each cell is obtained by multiplying scope and importance numbers. The summation of the values in a row's cells reflects the overall impact of activities on the parameter corresponding to the chosen row.

2.7 Evaluation of the EIA Options for the Irrigation Project

The Shahriar dam's irrigation project is in the first stage of study, and activities related to its construction have not yet begun. Therefore, only two options for comparison of the project's implementation status in EIA studies were considered. The first option is "lack of project implementation" (or "do nothing"). The second option is "project implementation" that requires examining the potential regional consequences if the dam were built based on the physical, biological and social-economic-cultural components.

2.8 The Do-Nothing (Non-implementation) Option

The characteristics and impacts of do-nothing in the short term (construction phase) and long term (operation phase) are analyzed based on the physical, biological, and social-economic-cultural components with the Leopold matrix. The matrices of the do-nothing and full-implementation options for decision-making are presented in separate tables.

(a) **The physical component**

The physical parameters in the do-nothing option include land shape, microclimate, river morphology, erosion, soil resource quality, suspended load and sediment, water flow, surface water quality and quantity, groundwater quality and quantity, air and noise pollution. Soil and water resource quality are the most important parameters in this option. The surface water quality and agricultural soils would be preserved in the short term with the do-nothing option.

(b) **The biological component**

The biological parameters include vegetation density and diversity, plant species at risk, aquatic plants, location of growth, weeds, variety of animal species, animal species at risk, land and water habitats, invasive species, and ecological and economic values. The biological component would not be changed in the do-nothing option.

Do-nothing in the short term would not significant impact on regional vegetation cover. Normally, the immediate impact region contains a variety of habitats that do not have indicator plant species. It is predicted that due to water shortage the density and diversity of vegetation and habitats would be reduced in the long term with the do-nothing option.

Do-nothing would not significantly impact wildlife in the short-term. In the long-term, however, gradual destruction of vegetation and loss of agricultural lands would cause wildlife to decline, with inevitable impacts on animal food cycles and general ecosystem viability.

(c) **The social-economic-cultural component**

The parameters with the do-nothing option include the region's population and its characteristics: knowledge and expertise, migration, earnings, occupation, welfare facilities, health and disease, land use, land value, religious practices and monuments, customs and traditions, tourism and recreation, possible accidents, social acceptance, and public participation. There would be continued population reduction with the do nothing option. This would have an adverse impact on the earnings, quality of life, and welfare facilities of the local people. Also, without project implementation, popular participation and social acceptance would be discouraged.

Employment enhancements that would occur in the long term with do nothing would not be realized. Local populations would decrease with decreasing agricultural yields resulting from drought and declining soil quality. This would lead to earnings reduction, and declining soil quality through continued farming, presumably, worsening economic situation, and declines in land value. In addition, the development of tourism would not occur with do-nothing.

2.9 Project Implementation Option

Characteristics and impacts of the project implementation option are performed in the short term and long term for the physical, biological, and social-economic-cultural components. The impacts of this option are assessed with the Leopold matrix.

(a) **The short-term period**

The short-term period (construction phase) involves activities such as vegetation removal along the pipeline, earthworks and soil resources, trenching, construction of access roads, land tenure, network construction and equipment, recruitment, construction and equipping workshops, disposal of sewage, garbage and trash, and noise and vibration.

Concerning the physical component involved assessing the short-term impacts of each activity on parameters such as land shape, microclimate, river morphology, erosion, soil resource quality, suspended load and sedimentation, water flow, quality and quantity of surface water, groundwater quality and quantity, and air and noise pollution.

The short-term biological impacts of each activity were assessed for characteristics such as vegetation density and diversity, plant species at risk, aquatic plants, location of growth, and weeds in the botanical section. In the zoological section the assessed characteristics were variety of animal species, animal species at risk, land and water habitats, invasive species, and ecological and economic values.

Also, impacts resulting from short-term activities associated with the social-economic-cultural component on dependent parameters were evaluated. The characteristics assessed in this component were population impacts, knowledge and expertise, migration, earnings, employment, welfare facilities, health and disease, land use, land value, religious beliefs and monuments, customs and traditions, tourism and recreation, possible accidents, social acceptance, and public participation.

(b) **The long-term period**

The long-term period (operation phase) involves activities such as dam operation, water use in agricultural lands, agricultural development, agricultural drainage, noise, transport, disasters, manpower employment, and health and safety facilities.

3 Results

This section summarizes the short- and long-term impacts of the physical, biological, and social-economic-cultural components.

3.1 Analysis of the Do-Nothing Option

This section reports the degree of impacts of do-nothing on various parameters (of the physical, biological, and social-economic-cultural components) in the short and long terms, for a total of six assessment matrices, of which only two are discussed herein. Table 2 lists the impact matrix for do-nothing in the short term on physical parameters. Table 3 lists the impact matrix for do nothing in the long term on biological parameters. This analysis assumes that human activities would continue following current trends into the future.

Activities related to the construction of access roads affect soil quality in the physical environment (Table 2). In each cell of the matrix, there are two numbers above and below the diagonal of each cell, respectively, indicating scope (1) and importance of impact (+1). Therefore, the impact weight of access road construction on soil resource quality equals +1 [1 × (+1) = +1]. The sum of the scores of all activities in this parameter would be equal to +1. Also, the scores of activities on air and noise pollution parameters would equal +3. Therefore, the sum of the scores (positive and negative) of the do-nothing option in the short term on the physical environment equals +7 [(+1) + (+3) + (+3) = (+7)] (in Table 6 this is the row related to the sum of scores in the short term).

Long-term do-nothing scores in terms of biological parameters including vegetation density and diversity, plant species at risk, aquatic plants, location of growth, weeds, variety of animal species, and land and water habitats are listed in Table 3. Summation of the parameters' weights yielded the scores of −16, −2, −5, −13, −2, −5, and −4, respectively.

3.2 Analysis of the Option of Project Implementation

The degree of impacts on the physical, biological, and social-economic-cultural components' parameters in the short term with project implementation were assessed (in total, three matrices of the EIA). Table 4, for example, presents the matrix for the option of project implementation in the short term on social-economic-cultural parameters. Analysis of project implementation in the short term on social-economic-parameters indicates positive impacts on earning, employment/social acceptance, and public participation, with scores of +28, +26 and +18, respectively (see Table 4), whereas it has the most negative impact on land use and possible accidents, with scores of −6 and −5, respectively.

The impacts of the three assessment components of project implementation in the long run were determined (in total, three matrices EIA). Table 5 lists the results for the physical environment. The most positive impacts are on groundwater level, erosion, and microclimate, with scores equal to +14, +12, and +11, respectively (Table 5). Also, project implementation has the most negative impacts on noise pollution, water flow, and river morphology, with scores of −2, −1, and −1, respectively.

Table 2 Impacts matrix for the do-nothing option and the physical component in the short term

Environmental parameters	Activity									
	Removal of vegetation along the pipeline	Earthworks and borrow harvest	Trenching	Construction of access road	Land tenure of project	Construction and equipment of network	Recruitment	Construction and equipping workshops	Sewage, garbage and trash disposal	Noise and vibration
Land shape										
Microclimate										
River morphology										
Erosion										
Soil resources quality				1 + 1						
Suspended load and sediment										
Water flow										
Surface water quality										
Surface water quantity										
Groundwater quality										
Groundwater level										
Air pollution		1 + 1	1 + 1	1 + 1						
Noise pollution		1 + 1	1 + 1	1 + 1						

Table 3 Impacts matrix for the do-nothing option and the biological component in the long term

Environmental parameters		Activity									
		Operation of dam	Water use in agriculture lands	Agricultural development	Changes in river regime	Agricultural drainage	Noise	Transport	Events	Manpower Employment	Health and safety facilities
Plants	Vegetation density and diversity	3–2	2–2	2–2		2–1					
	Plant species at risk					2–1					
	Aquatic plants	1–2	1–2		1–1						
	Location of growth	1–2	2–2	2–2	1–1	2–1					
	Weeds	1–1	1–1								
Animals	Variety of animal species	1–1	1–1	1–1		1–1	1–1				
	Animal species at risk										
	Land and water habitats	1–1	1–1			1–1	1–1				
	Invasive species										

Table 4 Impacts matrix of the project implementation option for the social-economic-cultural component in the short term

Environmental parameters	Activity									
	Removal of vegetation along the pipeline	Earthworks and borrow harvest	Trenching	Construction of access road	Land tenure of project	Construction and equipment of network	Recruitment	Construction and equipping workshops	Sewage, garbage and trash disposal	Noise and vibration
Population and its characteristics		1 + 2		1 + 2		1 + 1	2 + 2			
Knowledge and expertise						1 + 1	1 + 1	1 + 1		
migration		1 + 2	1 + 2	1 + 2		2 + 1	2 + 2			
Earnings		2 + 2	2 + 2	2 + 2		3 + 2	3 + 2	2 + 2		
Employment		2 + 2	2 + 2	2 + 1		3 + 2	3 + 2	2 + 2		
Welfare facilities				2 + 1					1–1	
Health and Disease		1–1								
Land use	1–1	1–1	1–1	2–1	1–1					
Land value						1 + 3				
Religious and monuments										
Customs and traditions										
Tourism and recreation										
Possible accident	1–1	1–2	1–2	1 + 1						1–1
Social acceptance and public participation		2 + 2	2 + 2	1 + 1		2 + 1	2 + 3	1 + 1		

Table 5 Impacts matrix of the project implementation option for the physical component in the long term

Environmental parameters	Activity								
	Operation of dam	Water use in agriculture lands	Agricultural development	Agricultural drainage	Noise	Transport	Events	Manpower Employment	Health and safety facilities
Land shape	1 + 1								
Microclimate	1 + 2	2 + 2	2 + 2			1–1			2 + 1
River morphology	1–1								
Erosion	2 + 2	2 + 2	2 + 2						
Soil resources quality	2 + 2	2 + 2	2 + 2	2–1		2–1			
Suspended load and sediment	2 + 2	1 + 1							
Water flow	1–1								
Surface water quality	2 + 2			2–1					1 + 1
Surface water quantity	2 + 2								
Groundwater quality	2 + 2		2 + 2	1–1					
Groundwater level	3 + 2	2 + 2	2 + 2						
Air pollution			1 + 1			1–1			
Noise pollution			1 + 1		1–2	1–1			

Table 6 Summation of impacts' weighted scores for the physical component of the project and the do-nothing option

Results	Environmental parameters													
	Land shape	Microclimate	River morphology	Erosion	Soil resources quality	Suspended load and sediment	Water flow	Surface water quality	Surface water quantity	Groundwater quality	Groundwater surface	Air pollution	Noise pollution	Total
Number of negative scores in short-term	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of positive scores in short-term	0	0	0	0	1	0	0	0	0	0	0	3	3	7
Number of negative scores in long-term	0	0	0	2	3	1	0	4	2	2	1	0	0	15
Number of positive scores in long-term	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum of scores in the short term	0	0	0	0	+1	0	0	0	0	0	0	+3	+3	+7
Sum scores in the long term	0	0	0	-12	-18	-4	0	-18	-12	-12	-6	0	0	-82
Total scores of do nothing	0	0	0	-6	-18	-4	0	-18	-12	-12	-6	+3	+3	-70

Table 7 Summation of impacts' weighted scores for the biological component of the project and the do-nothing option

Results	Environmental parameters										
	Vegetation density and diversity	Plant species at risk	Aquatic plants	Location of growth	Weeds	Variety of animal species	Animal species at risk	Land and water habitats	Invasive species	Ecological and economic values	Total
Number of negative scores in short-term	0	0	0	0	0	0	0	0	0	0	0
Number of positive scores in short-term	0	0	0	0	0	0	0	0	0	0	0
Number of negative scores in long-term	4	1	3	5	2	5	0	4	0	0	24
Number of positive scores in long-term	0	0	0	0	0	0	0	0	0	0	0
Sum scores in the short term	0	0	0	0	0	0	0	0	0	0	0
Sum scores in the long term	-16	-2	-5	-13	-2	-5	0	-4	0	0	-47
Total scores of do nothing	-16	-2	-5	-13	-2	-5	0	-4	0	0	-47

Table 8 Summation of impacts' weighted scores for the social-economic-cultural component of the project and the do-nothing option

Results	Environmental parameters													
	Population and its characteristics	Knowledge and expertise	Emigration	Earnings	Occupation	Welfare facilities	Health and Disease	Land use	Land value	Religious and monuments	Customs and traditions	Tourism and recreation	Possible accidents	Social acceptance and public participation	Total
Number of negative scores in the short term	0	0	0	1	1	1	0	0	0	0	0	0	0	1	4
Number of positive scores in the short term	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of negative scores in the long term	0	2	5	4	5	3	1	2	4	0	0	5	0	1	32
Number of positive scores in the long term	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum scores in the short term	0	0	0	-3	-3	-3	-16	0	0	0	0	0	0	-3	-12
Sum scores in the long term	0	-12	-42	-36	-42	-24	-6	-10	-19	0	0	-22	0	-9	-222
Total scores of do nothing	0	-8	-42	-39	-45	-27	-6	-16	-19	0	0	-22	0	-12	-236

3.3 Analysis and Summation of Impacts, Determination of Adverse and Unavoidable Impacts

This section presents the results of the summation of scores for do-nothing and full-project implementation of the various parameters in the short and long terms.

3.4 The Do-Nothing Option

The columns and rows of the matrix contain the project's activities and assessment parameters (environmental, economic, social, etc.), respectively. The impacts of the components' parameters are evaluated based on their scope and severity based on their scope (the number at the top of the diameter of each cell) and severity (the number at the bottom of the diameter of each cell) based on numbers ranging between 1 and 10. The scope and severity impact scores were multiplied together and then summed for all activities and parameters. Impacts of the do-nothing option on the three components are shown in Tables 6, 7 and 8. Score summaries are listed in Table 9. These results establish that the physical parameters with negative impacts include quality and quantity of surface water, groundwater quality, soil resource quality and erosion. In relation to biological parameters it was determined that vegetation density, diversity and location of growth, exhibit the most negative biological impacts. Employment, immigration, earnings and welfare facilities are the parameters with negative impacts in the social-economic-cultural component.

3.5 The Project Implementation Option

The summation of score impacts for project implementation in the short term and long term for the three components was performed and it is summarized in Tables 10, 11, and 12, which list the scores for the physical, biological, and social-economic and cultural components, respectively. The short-term and long-term scores of the latter tables were summed and the total score of project implementation was obtained. Another feature of these tables is the presentation of positive and negative values (scores) in the short term and long term, which has two advantages: (1) identification of project weaknesses and preparedness to minimize adverse impacts; and (2) project planners and decision makers will be better informed of project impacts before selecting the best project option.

The results for project implementation demonstrated that the impacts of physical parameters: air pollution, soil resource quality, microclimate, surface water quality, noise pollution, erosion, land shape, river morphology, and suspended load and sedimentation would be negative in the short term. Biological environment parameters such as location of growth, diversity of animal species, density and diversity of vegetation, habitat, plant species at risk, and ecological and economic values have negative impacts. The most positive impacts of

Table 9 Summation of scores for the do-nothing option in different periods and for components

Description	Physical component		Biological component		Social, economic, and cultural component		Sum scores		Sum scores
	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term	Short and long terms
Score	+7	-82	0	-47	-12	-222	-5	-351	-356

Table 10 Summation of impacts' weighted scores for the physical component of the project with project implementation

Results	Environmental parameters													
	Land shape	Microclimate	River morphology	Erosion	Soil resources quality	Suspended load and sediment	Water flow	Surface water quality	Surface water quantity	Groundwater quality	Groundwater surface	Air pollution	Noise pollution	Total
Number of negative scores in the short term	2	4	1	2	5	1	0	3	0	0	0	5	3	26
Number of positive scores in the short term	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of negative scores in the long term	0	1	1	0	2	0	1	1	0	1	0	1	2	10
Number of positive scores in the long term	1	4	0	3	3	2	0	2	1	2	3	1	1	23
Sum scores in the short term	-2	-4	-1	-2	-5	-1	0	-3	0	0	0	-5	-3	-26
Sum scores in the long term	+1	+11	-1	+12	+8	+5	-1	+3	+4	+7	+14	0	-2	+61
Total scores of project implementation	-1	+7	-2	+10	+3	+4	-1	0	+4	+7	+14	-5	-5	+35

Table 11 Summation of impacts' weighted scores for the biological component of the project with project implementation

Results	Environmental parameters										
	Vegetation density and diversity	Plant species at risk	Aquatic plants	Location of growth	Weeds	Variety of animal species	Animal species at risk	Land and water habitats	species	Ecological and economic values	Total
Number of negative scores in the short term	8	5	2	8	1	8	2	5	3	5	47
Number of positive scores in the short term	0	0	0	0	0	0	0	0	0	0	0
Number of negative scores in the long term	1	2	1	1	1	3	0	2	0	1	13
Number of positive scores in the long term	3	1	2	3	0	2	2	3	2	3	21
Sum scores in the short term	-8	-5	-2	-9	-1	-8	-2	-5	-3	-5	-48
Sum scores in the long term	+13	0	+7	+15	-1	+9	+11	+19	+2	+5	+80
Total scores of project implementation	+5	-5	+5	+6	-2	+1	+9	+14	-1	0	+32

Table 12 Summation of impacts' weighted scores for social-economic-cultural component of the project with project implementation

Results	Environmental parameters							
	Population and its characteristics	Knowledge and expertise	Migration	Earnings	Occupation	Welfare facilities	Health and Disease	Land use
Number of negative scores in the short term	0	0	0	0	0	1	1	5
Number of positive scores in the short-term	4	3	5	6	6	1	0	0
Number of negative scores in the long term	1	0	0	0	0	0	2	0
Number of positive scores in the long term	4	3	4	5	5	2	3	3
Sum scores in the short term	+9	+3	+12	+28	+26	+1	-1	-6
Sum scores in the long term	+27	+21	+28	+45	+40	+10	+7	+12
Total scores of project implementation	+36	+24	+40	+73	+66	+11	+6	+6

Results	Environmental parameters						
	Land value	Religious and monuments	Customs and traditions	Tourism and recreation	Possible accidents	Social acceptance and public participation	Total
Number of negative scores in the short term	0	0	0	0	4	0	11
Number of positive scores in the short-term	1	0	0	0	1	6	33
Number of negative scores in the long term	2	0	0	0	3	0	8
Number of positive scores in the long term	3	0	1	2	0	3	38
Sum scores in the short term	+3	0	0	0	-5	+18	+88
Sum scores in the long term	+27	0	+4	+8	-3	+7	+233
Total scores of project implementation	+30	0	+4	+8	-8	+25	+321

Table 13 Summation of scores for project implementation in different periods and for components

Description	Physical component		Biological component		Social, economic, and cultural component		Sum scores		Sum scores
	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term	Short and long terms
Score	-26	+61	-48	+80	+88	+233	+14	+374	+388

project implementation are in the social-economic-cultural parameters, such as earnings, employment, social acceptance and public participation, and migration.

In the long term our results demonstrate that positive impacts of irrigation network construction on the three components would apply to parameters such as groundwater level, erosion, microclimate, soil resource quality, groundwater quality, suspended load and sedimentation, and surface water quantity and quality. Biological environment parameters such as habitats, locations of growth, vegetation density and diversity, animal species at risk, diversity of animal species, aquatic plants, ecological and economic values, and invasive species would benefit from positive impacts. In the long term and short terms the most positive impacts would be in terms of social-economic-cultural parameters including earnings, occupation, migration, population, land value, and welfare facilities.

The results of Table 13 indicate that project implementation has the most negative impact on the biological environment (with a score of −48) followed by the physical environment (−26) in the short term. In the long run the most positive impact corresponds to the social-economic-cultural component (+233).

3.6 Final Option Choice

Implementation of the Shahriar dam's irrigation project would have negative impacts, but overall, our results indicate that implementation is preferable to doing nothing. Our assessment established that the Shahriar dam's irrigation project has many favorable and positive impacts that justify its implementation (see Table 14). Project implementation has a positive score of +388, while lack of implementation has a negative score of −356. Project implementation is therefore desirable because its positive impacts surpass those of doing nothing.

3.7 Sensitivity Analysis

Sensitivity analysis of project implementation was conducted to study the strengths and weakness of the irrigation project based on its influence on the three impact components.

Table 14 Final results of the project's options assessment

Project options	Physical component		Biological component		Social, economic, and cultural component		Sum scores		Sum scores
	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term	Short and long terms
Implementation	-26	+61	-48	+80	+88	+233	+14	+374	+388
Do nothing	+7	-82	0	-47	-12	-222	-5	-351	-356

The impact of each parameter on final results of project assessment was investigated to analyze parameter sensitivity.

For this purpose, each of the environmental parameters (matrix rows) was removed one at a time and the impact of each parameter removal on the final results of the project assessment was calculated (see Fig. 3). The physical parameters of air pollution would have the greatest impact on the final result of project assessment, followed by erosion, soil resources quality, groundwater level. Concerning the biological environment the parameters of density and diversity of vegetation, location of growth, and land and water habitats would have the greatest impacts. The parameters of earnings, employment, and migration, would have the greatest impacts on the social-economic-cultural component.

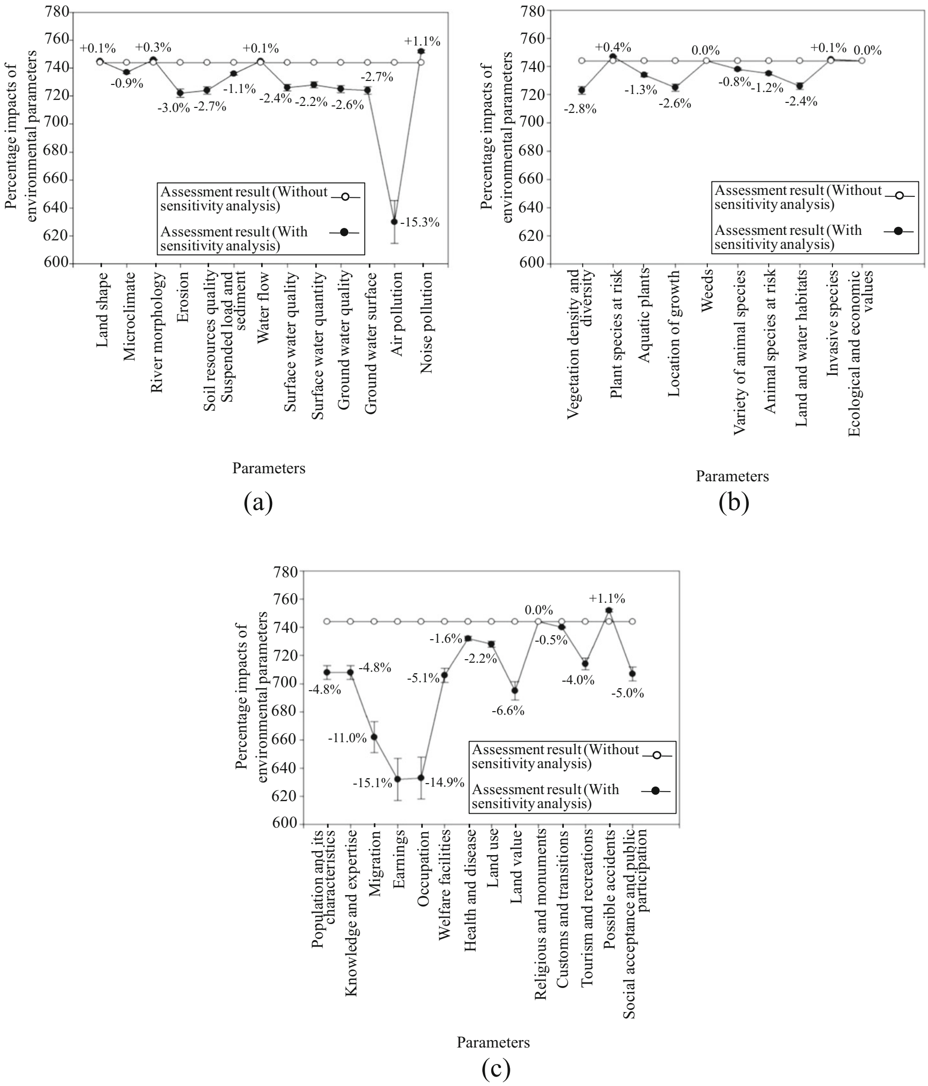

Fig. 3 Percentage impact of each parameter on the final results of the project assessment for the **a** physical, **b** biological and **c** social-economic-cultural components

The sensitivity to activities was also assessed by removing each activity (matrix columns) one at a time and the impact of the removal of each activity on the final results of the project's three components in the short term and long term was calculated (see Fig. 4). Earthworks and construction of access roads are most important concerning short-term physical impacts. The removal of vegetation is most significant in the biological component. The parameter of manpower employment would have the greatest impact on the social-economic-cultural component. The physical component would be affected most by the operation of the Shahriar dam in the long term, whereas water use in agriculture would be most significant in the long term with respect to the biological and the social-economic-cultural components.

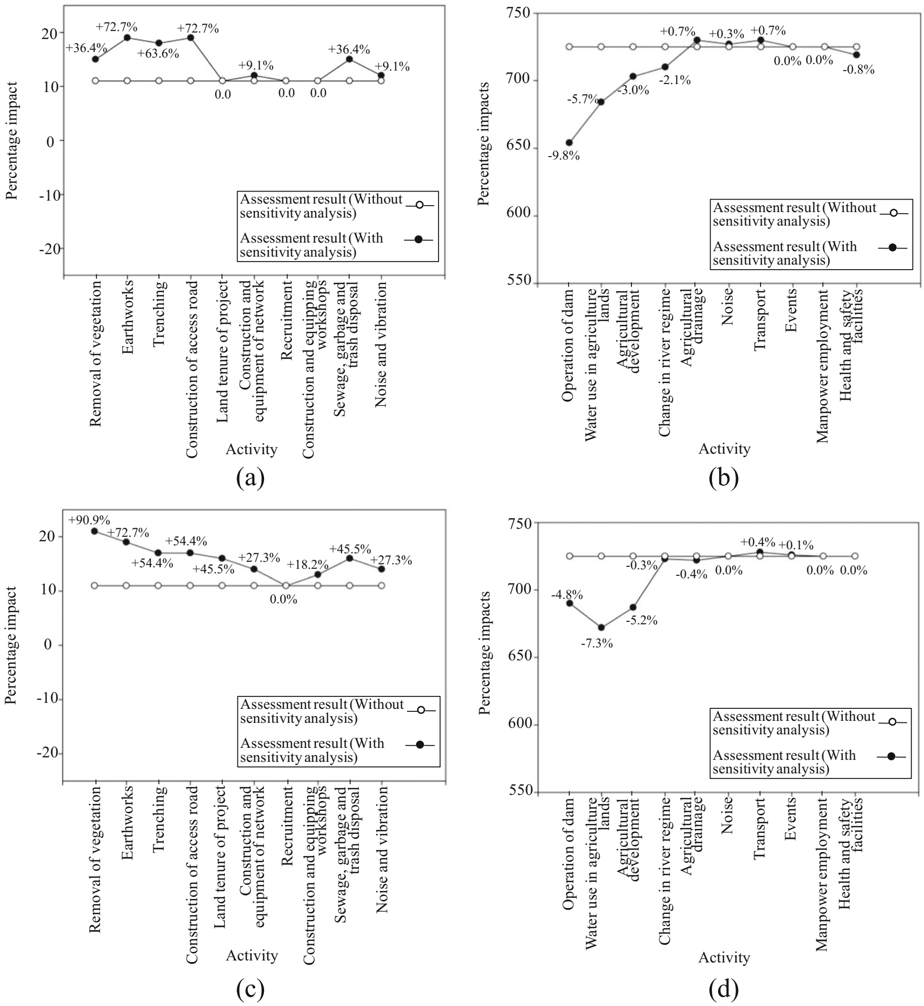

Fig. 4 Percentage impact of each activity on the final results of the project assessment for in the three components in the short term and the long term **a** Short-term, physical component, **b** Long-term, physical component, **c** Short-term, biological component, **d** Long -term, biological component, **e** Short-term, social, economic, and cultural component, and **f** Long-term, social, economic, and cultural component

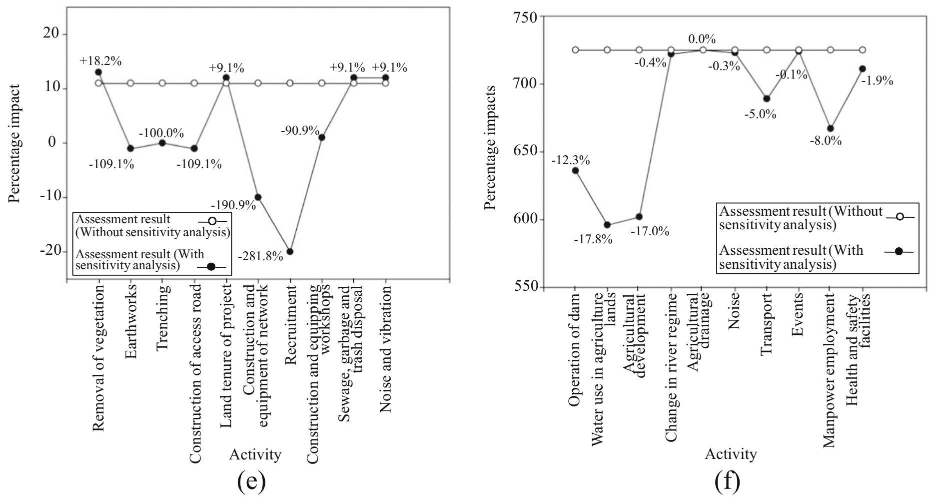

Fig. 4 (continued)

4 Conclusion

This paper's results have demonstrated the application of the Leopold EIA matrical analysis to evaluate the do-nothing and project implementation options concerning the Shahriar dam's irrigation project in Iran. The impacts of the two options on physical, biological and social-economic-cultural components were evaluated in the short term (construction) and long term (operation). Our overall results have shown that the implementation of the proposed Shahriar's dam irrigation project achieved a total score equal to 388 thus making more beneficial than the do-nothing option, which achieved a score of −356.

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