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ORIGINAL ARTICLE

Applying the enhanced Water Poverty Index (eWPI) to analyze water scarcity and income poverty relation in Beheshtabad Basin, Iran

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Abstract
The close relationship between water and poverty has been proven in several types of research. The Water Poverty Index is an interdisciplinary approach for quantifying the socioeconomic aspects of water scarcity. The enhanced Water Poverty Index (eWPI) is aggregated in five components: Resources, Access, Capacity, Use, and Environment in a Pressure-State-Response framework. In this research, eWPI is computed on two scales: for four community centers and for the Beheshtabad Basin. Because this index is weightless, and undoubtedly the importance of each parameter is different, the preference of different variables is included in the calculation. The importance of the parameters is based on the opinion of experts, and for this reason, Analytical Hierarchy Process (AHP) and Analytical Network Process (ANP) are used for weighting eWPI components in Beheshtabad Basin. According to the results, Use (*U*) and Capacity (*C*) have the lowest score among the main criteria. The average value of weightless eWPI for the watershed is 0.605 and Kiar and Farsan counties have gained less than this average. The results show the priority of the main criteria is as follows: *R*, *A*, *U*, *E*, and *C*, for AHP and *R*, *E*, *C*, *A*, and *U* for ANP. The weights obtained through ANP are more homogeneous and there is less difference between the main criteria, while in AHP, the Resources criterion (*R*) has gained relatively large weight compared to the other factors. The score of eWPI for AHP-weighted and ANP-weighted indices are 0.5944 and 0.626, respectively.

Keywords Human Development Index · Water resources management · Chaharmahal and Bakhtiari Province · Weighting method

Introduction

The relationship between poverty and water is complex (Ahmad 2003; Cook et al. 2009; Manandhar et al. 2012; Molle and Mollinga 2003; Pandey et al. 2012; Rijsberman 2003; Ward 2007) and many researchers believe that "water poverty" and "income poverty" are closely correlated (Ahmad 2003; Sullivan et al. 2003; Ward 2007). An interdisciplinary approach should be taken to integrate assessment of water scarcity, poverty, and the linkage between them (Mlote et al. 2002). Feitelson and Chenoweth (2002) defined Water Poverty and Mlote et al. (2002) discussed the theoretical background of the Water Poverty Index. Franks and Cleaver (2007) introduced an analytical framework to understand the positive/negative impacts of water governance on the poor. Several indicators were introduced named Water Poverty Index/Indicator (Perveen and James 2011; Yahaya et al. 2009). One of these was introduced by Sullivan (2002) and continued by Sullivan et al. (2003) which takes into account physical water scarcity/availability and the socioeconomic aspects of poverty (Lawrence et al. 2003; Rijsberman 2006). WPI is known as a strategic approach and a quantitative tool that can be relied on for decision making and understanding the complexity of water-related issues, especially the linkage between under-development and water scarcity (El-gafy 2018; Huang et al. 2017; Jafari Shalamzari and Zhang 2018). To be multidimensional, WPI is aggregated into five components: water Resources availability (*R*), water Accessibility (*A*), Capacity for access (*C*), water Use (*U*), and Environment (*E*) (Liu et al. 2017; Sullivan et al. 2003) as main criteria, and several sub-criteria that

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can be changed in different situations. For example, WWF Nepal (2012) used only five variables (each criterion has one variable), but in most studies, two to three variables are considered for each criterion (Mogheir and Aiash 2013; Thakur et al. 2017; Zhang et al. 2012). Lopez Alvarez et al. (2015) and Kini (2017) made a composition of six main components (*R*, *A*, *C*, *U*, *E*, and Quality/Cohesion). WPI was originally developed using the arithmetic mean, but other aggregating techniques were recommended or tested by researchers. Sullivan et al. (2002) applied four weighting systems to calculate WPI that were later utilized in other studies (Van et al. 2010). WPI can be applied on different scales: community, district, national, and watershed scales. This indicator can also be used to show temporal changes (Huang et al. 2017) and its results can be mapped (Van der Vyver and Jordaan 2012). Although WPI is approved as a comprehensive and strong index, there is always an attempt to get closer to an ideal index. In this regard, some innovations have been proposed to revise or improve it. New versions of WPI that have been implemented are modified WPI (Van et al. 2010), refined WPI (Jemmali and Sullivan 2012), simplified WPI (Cho et al. 2010), adapted WPI (Zhang et al. 2015), and inclusive WPI (Kini 2017).

enhanced Water Poverty Index

Garriga and Foguet (2010) introduced enhanced WPI (eWPI), a systematic approach that has a structured framework for evaluating water- and poverty-interconnected dimensions in basins. Water resources are dynamic and have cause-effect relations in hydro-cycle and socioeconomic interactions in the basin. The status of a watershed is the result of pressure (from the community) and this (undesirable and inappropriate) situation can lead to (protective and corrective) policymaking. The methodology of eWPI aggregated WPI indicators in a Pressure-State-Response model (Foguet and Garriga 2011). PSR was implemented in different fields such as the environment, water resources, and watershed management (Catano et al. 2009; Chaves and Alipaz 2007; Linster 2003; Rasi Nezami et al. 2013). In the PSR model, the hydrological, societal, and economic factors in a watershed have casual relationships. This means that the *Pressure* exerted in the past reflects the current *Status* of a resource (water resources), and if its status is not acceptable for any reason, it must receive a sustainable *Response* from the community/policymakers (Linster 2003).

Weighting issue

This index has 27 sub-criteria that are weightless in the original version. While the importance of each variable is different, this relative importance may vary from one watershed to another. Therefore, if we can recognize the relative weight of each factor, the result can be closer to reality. There are several ways to weigh criteria. In this research, Analytical Hierarchy Process (AHP) and Analytical Network Process (ANP) have been used. These two methods were chosen because they require less field data and utilize expert opinions. Therefore, AHP and ANP approaches were carried out for understanding experts' attitudes to achieve more reliable decisions.

Scale issue

The issue of scale has been widely discussed in the literature (Kini 2017; Manandhar et al. 2012; Pandey et al. 2012). Garriga and Foguet (2010) presented the eWPI on two different scales: the community scale and the watershed level, and used different criteria and sub-criteria for each. Li et al. (2011) showed that WPI could meet the need of district scales.

In this research, we pursue three goals.

1- Selecting a comprehensive index to examine all aspects of water poverty (as much as possible) and depict the relationship between water scarcity and social, economic, organizational, and managerial dimensions;
2- Calculating the index and determining the values of its components on the two scales of community and watershed; and
3- Weighing the index components and calculating the weighted index.

To achieve the research objectives, we chose eWPI, which has 27 variables (Tables 1, 2 and, 3). We calculated it in both community and watershed scales and then weighed its variables using two methods: AHP and ANP, and calculated the weighted index. The innovation of this research is the use of eWPI, which has more variables than other indicators. Also, two weighting methods have been tested that do not require much field data. Rather, they are designed based on the opinions of experts who are aware of the situation and are usually available.

Materials and methods

Study area

The Beheshtabad Basin is located in Chaharmahal and Bakhtiari Province, Iran, and covers 3860 km^2 (Fig. 1). In terms of geomorphological structure, 56% of the area is plain and 44% is mountains. This watershed has a semi-cold humid climate in terms of Amberje classification (Alizadeh et al. 2016). The average maximum temperature is 20.43 °C and the average minimum temperature is 2.32 °C. The average

Table 1 eWPI pressure parameters and their values

Indicator	Sub-indicator	Parameter	Level	Value/score
Resources	Population	Population growth rate (%) (2011–2016)	PG > 4%	0
			4% > PG > 2%	0.25
			2% > PG > 0%	0.5
			0% > PG > − 2%	0.75
			PG < − 2%	1
	Water	Variation in per capita water availability (%) (2011–2016)	Δ < − 10%	0
			− 10% < Δ < 0%	0.25
			0% < Δ < 10%	0.5
			10% < Δ < 20%	0.75
			Δ > 20%	1
Access	Safe water	Variation in access to safe water (%) (2011–2016)	Δ1 < − 10%	0
			− 10% < Δ1 < 0%	0.25
			0% < Δ1 < 10%	0.5
			10% < Δ1 < 20%	0.75
			Δ1 > 20%	1
	Sanitation	Variation in improved sanitation accessibility (%) (2011–2016)	Δ2 < − 10%	0
			− 10% < Δ2 < 0%	0.25
			0% < Δ2 < 10%	0.5
			10% < Δ2 < 20%	0.75
			Δ2 > 20%	1
Capacity	Social	Variation in the HDI (%) (2011–2016)	Δ < − 10%	0
			− 10% < Δ < 0%	0.25
			0% < Δ < 10%	0.5
			10% < Δ < 20%	0.75
			Δ > 20%	1
	Economic	Economically active population (%) (2016)	AEP > 40%	0
			30% < AEP < 40%	0.25
			20% < AEP < 30%	0.5
			10% < AEP < 20%	0.75
			AEP < 10%	1
Use	Agriculture	Per capita agricultural water use (%) (2011–2016)	Δ1 < − 5%	0
			− 5% < Δ1 < 0%	0.25
			0% < Δ1 < 5%	0.5
			5% < Δ1 < 10%	0.75
			Δ1 > 10%	1
	Domestic	Variation in domestic water use (%)(2011–2016)	Δ2 < − 10%	0
			− 10% < Δ2 < 10%	0.25
			0% < Δ2 < 10%	0.5
			10% < Δ2 < 20%	0.75
			Δ2 > 20%	1
Environment	EPI (2011–2016)		EPI > 15%	0
			15% < EPI < 10%	0.25
			10% < EPI < 5%	0.5
			5% < EPI < 0%	0.75
			EPI < 0%	1

precipitation of this basin is 420 mm and the maximum precipitation occurs in December and January. The type of precipitation has changed from snow to rain in recent years and the province generally has a long run of drought. The topographic map shows a maximum height of 3606 m and a minimum height of 1654 m above sea level and an average

Table 2 eWPI State parameters and their values

Indicator	Sub-indicator	Parameter	Level	Value/ Score
Resources	Population	Water availability (balancing use and demand) (qualitative) (2011–2016)	Very poor	0
			Poor	0.25
			Acceptable	0.5
			Good	0.75
			Excellent	1
	Water	Per capita water availability (m^3/year) (2011–2016)	WA < 500	0
			500 < WA < 100	0.25
			1000 < WA < 1700	0.5
			1700 < WA < 3500	0.75
			WA > 3500	1
Access	Safe water	Population with access to safe water (%) (2011–2016)	PWA < 35%	0
			35% < PWA < 35%	0.25
			50% < PWA < 65%	0.5
			65% < PWA < 80%	0.75
			PWA > 80%	1
	Sanitation	Population with access to sanitation (%) (2011–2016)	PSA < 35%	0
			35% < PSA < 50%	0.25
			50% < PSA < 65%	0.5
			65% < PSA < 80%	0.75
			PSA > 80%	1
Capacity	Social	HDI (2011–2016)	HDI < 0.40	0
			0.40 < HDI < 0.55	0.25
			0.55 < HDI < 0.70	0.5
			0.70 < HDI < 0.85	0.75
			HDI > 0.85	1
	Economic	Jobless population (%) (2016)	UR > 20%	0
			15%˂ UR < 20%	0.25
			10% < UR < 15%	0.5
			5% < UR < 10%	0.75
			UR < 5%	1
Use	Agriculture	Arable land as a percent of potential arable land (%) (2011–2016)	Wu > 85%	0
			85% > Wu > 75%	0.25
			70% > Wu > 55%	0.5
			55% > Wu > 40%	0.75
			40% < Wu	1
	Domestic	Per capita domestic water consumption (liter) (2011–2016)	DW > 250	0
			200 < DW < 250	0.25
			150 < DW < 200	0.5
			100 < DW < 150	0.75
			DW < 100	1
Environment	Area with natural vegetation (%) (2011)		Av < 15%	0
			15% < Av < 30%	0.25
			30% < Av < 45%	0.5
			45% < Av < 60%	0.75
			Av > 60%	1

slope of 21.7%. A population of about 500,000 lives in urban and rural areas. According to the latest census conducted in 2016, urban and rural populations in this province have reached 467,123 and 63,408 people, respectively. The most important economic activities in this area are agriculture and animal husbandry.

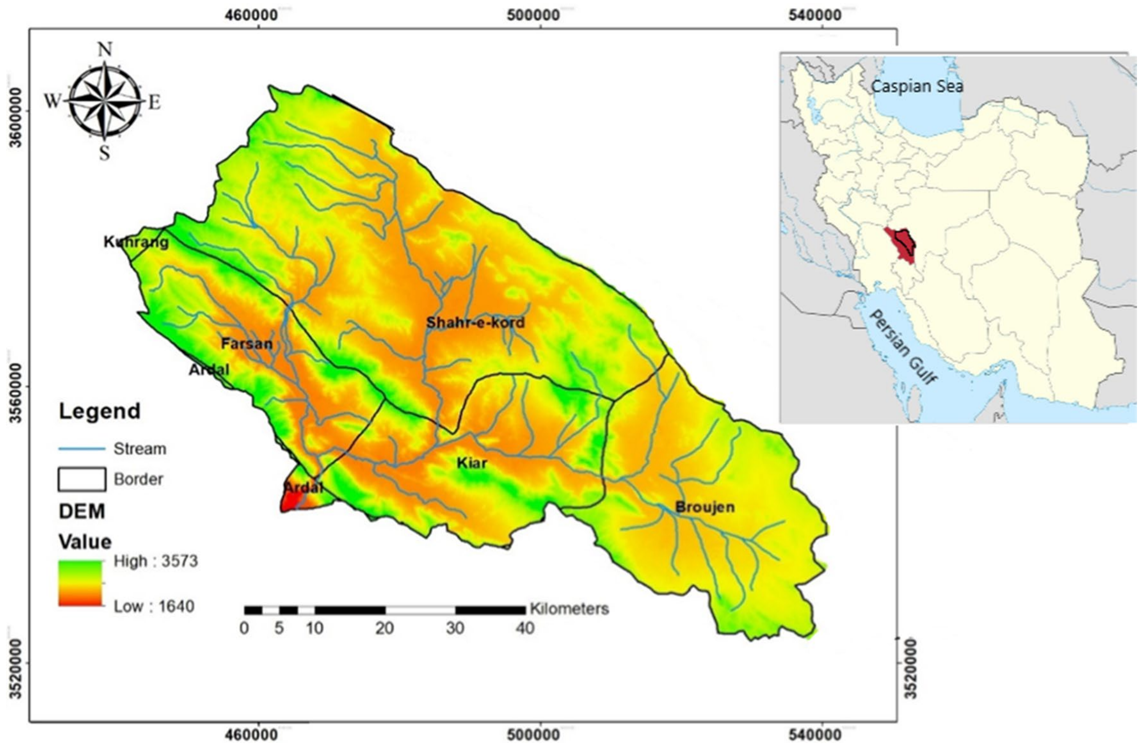


Fig. 1 Location of Beheshtabad Watershed (Black Boundary) in Chaharmahal and Bakhtiari Province (Red Area), Iran

Combining the map of Beheshtabad sub-basins and the map of political divisions of Chaharmahal and Bakhtiari Province, it was determined that the cities of Shahrekord, Borujen, Farsan, and Kiar have the largest share of the basin and the study will be performed on these cities. However, weighing methods were performed based on experts' opinions about the whole watershed and the final results are presented on a watershed scale.

Methods

To assess the situation of water resources at the watershed and the community scales, and investigating the relationship between water and poverty in Beheshtabad Basin, enhanced Water Poverty Index (eWPI) was calculated. Because this index is weightless, two weighting methods were applied. The methodology of this research contains calculating the weightless eWPI and then applying the weights of components in the index. Figure 2 shows the brief flowchart of this research.

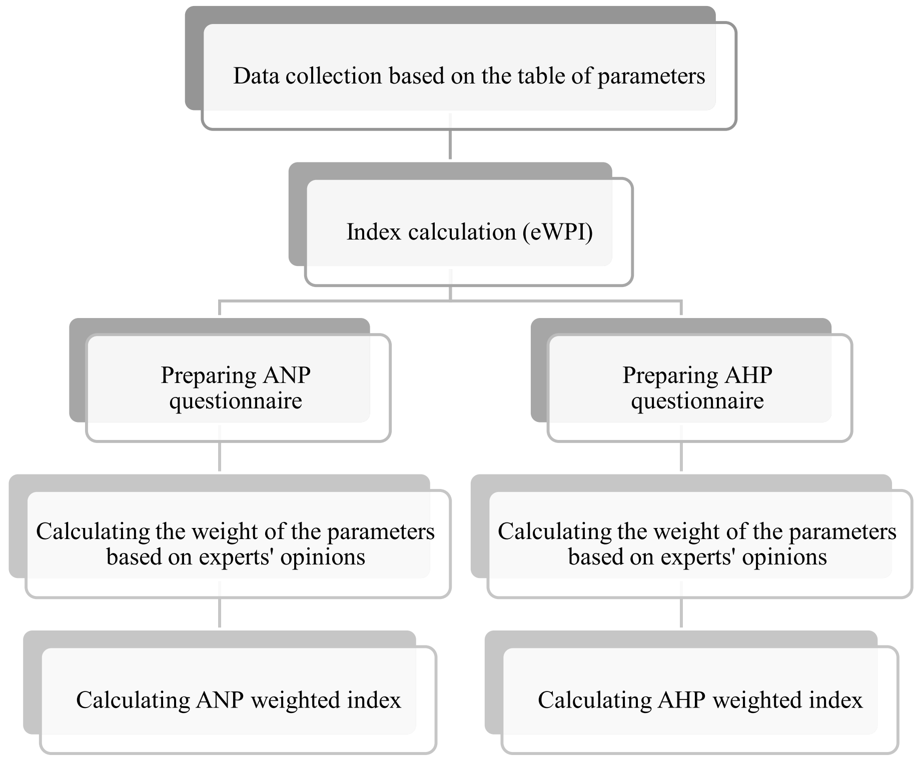
Data collection based on eWPI components

Choosing relevant variables is a vital part of implementing multidimensional indicators (Foguet and Garriga 2011). The enhanced Water Poverty Index used in this research has three different categories of parameters that are organized in the Pressure-State-Response (PSR) framework. The indicators, sub-indicators, and relevant parameters implemented by Garriga and Foguet (2010) are listed in Tables 1, 2 and 3 below.

To apply the eWPI to the Beheshtabad Basin, required data were obtained from relevant organizations. Hydrological data was obtained from the Iran Meteorological Organization and the Ministry of Energy of Iran. Data on population, education, income, water consumption, water distribution pattern, and health benefits were obtained from the Planning and Budget Organization of Iran. Environmental data such as land use and land cover and conservation plans were obtained from the Environmental Organization and the Natural Resources and Watershed Management Bureau of Chaharmahal and Bakhtiari Province.

The spatial and temporal scales of these variables are very diverse. For example, per capita income in Iran is reported nationally. Data related to population, including household size, education, economic activity, income, and cost, are recorded in the political boundaries and may be available separately for each city or village. However, hydrological and meteorological data should be sought at watershed boundaries. Community-based information is collected once every 5 years during the general population and housing census. However, hydrological data are available daily, monthly, and yearly.

Fig. 2 The flowchart of the research



Calculation of eWPI

The parameters of the eWPI have two categories. Many of them are parameters that show changes over time and are expressed as a percentage of changes. There is a general form for calculating them (Eq. 1). The other category shows the value of the parameter in the study year. As the final census report in Iran is available for 2016, it was considered the base year and the percentage of variation in the five years (2011–2016) are evaluated here.

$$\Delta = \frac{\text{Parameter value in 2016} - \text{Parameter value in 2011}}{\text{Parameter value in 2011}}.100 \quad (1)$$

The value of each parameter is divided into five classes based on its amplitude or based on the increase or decrease of the variable compared to its past. Each class is assigned a number between zero and one as its score in index calculation (Tables 1, 2 and 3). Thus, there is no need to normalize the values of the index parameters.

After determining the score of the variables for four community centers (according to Tables 1, 2 and 3), weightless eWPI was calculated for them and the whole watershed. All components of eWPI, Resources, Access, Capacity, Use, and Environment could be considered to have the same weight (Eq. 2) (Cho et al. 2010).

$$X_i = \frac{\sum_{i=1}^{5} x_i}{5} \quad (2)$$

In this equation, x_i is the component score ($x_i = R, A, C, U, E$) and X_i is the state score ($X_i = P, S, R$). Also, the *Pressure*, *State*, and *Response* categories are weightless. Therefore, the arithmetic mean is used to calculate the final value of the index. The next step combines all the sub-indices to calculate the final eWPI according to Eq. 3.

$$\text{WPI} \frac{\sum_{i=1}^{3} X_i}{3} \quad (3)$$

Weighing by AHP and ANP

One of the available scientific methods that can help researchers in confronting multidimensional issues is the analysis of expert attitudes. The viewpoints of experts can be combined in the form of criteria/sub-criteria weights using the Analytical Hierarchy Process (AHP) (Srdjevic et al. 2002; Tarigan et al. 2018; Xi and Poh 2014) and Analytical Network Process (ANP) (Razavi Toosi and Samani 2012; Wu et al. 2017) in multi-component issues. For this purpose, the sub-criteria mentioned in Table 1 were provided in the form of two questionnaires—AHP and ANP—to more

Table 3 eWPI Response parameters and their values

Indicator	Sub-indicator	Parameter	Level	Value/score
Resources	Population	HDI- Education (2016)	EI < 0.45	0
			0.45 < EI < 0.60	0.25
			0.60 < EI < 0.75	0.5
			0.75 < EI < 0.85	0.75
			EI > 0.85	1
	Water	Adequacy of water storage capacity (qualitative) (2016)	Very poor	0
			Poor	0.25
			Acceptable	0.5
			Good	0.75
			Excellent	1
Access	Safe water	Improvement in water sector financing (qualitative) (2016)	Very poor	0
			Poor	0.25
			Acceptable	0.5
			Good	0.75
			Excellent	1
	Sanitation	Improvement in sanitation financing (qualitative) (2016)	Very poor	0
			Poor	0.25
			Acceptable	0.5
			Good	0.75
			Excellent	1
Capacity	Social	Educational level of household head (2016)	HEL < 0	0
			0 < HEL < 0.25	0.25
			0.25 < HEL < 0.50	0.5
			0.50 < HEL < 0.75	0.75
			HEL > 0.75	1
	Economic	Per capita daily income (US$) (2016)	In < 1	0
			1 < In < 2.5	0.25
			2.5 < In < 5	0.5
			5 < In < 10	0.75
			In > 10	1
Use	Agriculture	Improvement in agricultural water use efficiency (qualitative) (2011–2016)	Very poor	0
			Poor	0.25
			Acceptable	0.5
			Good	0.75
			Excellent	1
	Domestic	Domestic water use efficiency (qualitative) (2016)	Very poor	0
			Poor	0.25
			Acceptable	0.5
			Good	0.75
			Excellent	1
Environment	Variation in protected area (%) (2011–2016)		PPA < − 10%	0
			10% < PPA < − 5%-	0.25
			− 5% < PPA < 0%	0.5
			0% < PPA < 10%	0.75
			PPA > 10%	1

than 30 experts who were familiar with the conditions of the watershed. Their answers were analyzed in the *super decision software* to obtain the weights of the components. Then, the eWPI was calculated by:

$$X_i = \sum_{i=1}^{n} x_i w_i \tag{4}$$

$$WI = \sum_{i=1}^{n} X_i w_i \tag{5}$$

where X_i is the component score and w_i is the corresponding weight. The summation of w_i is equal to 1.

Results

eWPI for community and watershed scales

According to the map (Fig. 1), Beheshtabad Basin was divided into four districts and eWPI was calculated based on the community scale. Table 4 represents the parameters' values of eWPI for Shahrekord, Borujen, Farsan, and Kiar in detail.

Table 4 shows that the variables of this index have obtained scores between 0 and 1, but most scores are seen in the average range (0.5).

A score of 0 or even 0.25 in a variable indicates a severe weakness in that dimension. For example, the *Pressure* score for agricultural water use is zero. This means that, at present, the agricultural sector in these areas is putting significant pressure on water resources. Fortunately, *Status* and *Response* scores indicate that the current situation of this parameter is stable and that we hope to receive appropriate responses for improvement in the future. On the contrary, achieving a score of 1 is the best for any variable. For example, the *Pressure* and *Status* scores of the Environment, and the *Status* score of Access, are the maximum.

Table 5 presents the results of index calculations for different cities and the whole watershed. The values of each main criterion along with the final value of the index as well as the value of the Human Development Index (HDI) and the population of each sector are presented for comparison.

The results show that the value of eWPI in the watershed is slightly higher than the average (Table 5). The average score indicates that the situation in Beheshtabad watershed and its communities is similar to many other parts of the world in terms of access to water and wealth, as other researchers have reported.

Taking a closer look at the different dimensions of the eWPI, one can determine that the criterion of Use (*U*) has the lowest score, followed by the criterion of Capacity (*C*) in second place. The low score of the Use parameter confirms the abnormal situation of water consumption in different parts of this region. Using water, both in the agricultural and domestic sectors, puts great pressure on the water resources

Table 4 eWPI parameters' scores for districts of Beheshtabad Watershed

Criteria	Sub-criteria	Pressure				State				Response			
		Shahrekord	Borujen	Farsan	Kiar	Shahrekord	Borujen	Farsan	Kiar	Shahrekord	Borujen	Farsan	Kiar
Resources	Water	0.5	0.5	0.5	0.5	0.25	0.5	1	1	0.75	0.75	0.75	0.75
	Population	0.5	0	0	0.5	0.5	0.5	0.5	0.5	0.75	0.5	0.5	0.5
Access	Safe water	0.5	0.5	0.5	0.5	1	1	1	1	0.5	0.5	0.5	0.5
	Sanitation	0.5	0.5	0.5	0.5	1	1	1	1	1	0.75	0.5	0.5
Capacity	Social	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	Economic	0.75	0.75	0.75	0.75	0.25	0.25	0	0.25	0.75	0.5	0.5	0.75
Use	Agriculture	0	0	0	0.25	0.5	0.75	0.5	0.5	0.5	0.75	0.25	0.25
	Domestic	0.5	1	0.75	0	0.5	0.75	0.75	0.25	0.5	0.5	0.5	0.5
Environment		1	1	1	1	1	1	1	1	0.5	0.5	0.5	0.5

Table 5 eWPI main criteria for districts of Beheshtabad and the whole Basin (community and watershed scales)

City	Population (2016)	HDI	Resources	Access	Capacity	Use	Environment	eWPI
Shahrekord	310,396	0.784	0.541	0.749	0.541	0.416	0.833	0.616
Borujen	87,535	0.77	0.458	0.708	0.5	0.625	0.833	0.624
Farsan	95,287	0.755	0.541	0.666	0.458	0.458	0.833	0.591
Kiar	35,015	0.742	0.625	0.666	0.541	0.291	0.833	0.591
Beheshtabad	*528,233*	*0.763*	*0.541*	*0.697*	*0.51*	*0.447*	*0.833*	*0.605*

of Beheshtabad watershed. This is the most important reason for minimizing the score of this criterion compared to other criteria. The score of social capacity in this area is 0.5. Compared to the value of the Human Development Index, which is more than 0.7, it seems that the capacity of these communities to reduce the pressure on water resources has not been considered, and therefore an acceptable response is not received to improve the current situation. These two factors are known as the weakness of the management system and need to be improved and invested in. Investing in these criteria, which can be both organizational and cultural, will certainly improve the situation of the Beheshtabad watershed in terms of the Water Poverty Index.

In the Beheshtabad Basin, the total score of Resources (*R*) is 0.541 with a range of 0.458 for Borujen to 0.625 for Kiar. This indicate an unstable and unacceptable situation, and emphasizes that in this regard, the watershed is not in good condition. The reason is the increase in population and the resulting pressure on water resources. On the other hand, population growth has reduced the per capita water availability over the years of study.

Access criteria received a better score. Achieving an acceptable score by the Access criterion is the result of the good condition of the communities living in the Beheshtabad watershed, in terms of access to safe water and sanitation. But the *Pressure* and *Response* points in these two areas are worrying.

Finally, the highest score is given to the Environment (*E*). *Pressure* and *Status* scores of the Environment are good, but unfortunately this has not led to a proper response to environmental issues. The score of Environment (*E*) is higher than other main criteria, which can lead to a misunderstanding of the Beheshtabad watershed, because other studies report some environmental issues in this watershed, such as soil erosion, severe groundwater depletion, and noncompliance with environmental water rights.

The variables whose scores in this watershed are worrying are water efficiency, employment, and income. Also, reviewing the scores in the PSR framework shows pressure on watershed resources. Therefore, increasing employment, especially sustainable non-water-dependent jobs, will help reduce pressure on water resources and increase watershed capacity to overcome water poverty.

Weighted eWPI

The binary comparison of the parameters in the AHP system is hierarchical, while each parameter in ANP can be compared with other parameters in the network. Figures 3 and 4 show a comparison of the priority of parameters of each sub-criterion by AHP and ANP, respectively.

The priorities of eWPI main factors are displayed in Fig. 5. The difference between the weights of the criteria obtained in AHP is greater than in ANP. In AHP, the Resources criterion gained relatively more weight than the remaining criteria. The weight of Resources in AHP is more than 0.4, while the remaining four components gain a weight of about 0.15 or less. The weights of the criteria of the eWPI are more homogeneous in ANP and there is a small difference between the criteria. According to experts, the most important factor in ANP is Resources (*R*).

The structure of this index resembles a matrix. So, in addition to criteria and sub-criteria, analysis of variables according to the PSR framework can also lead to interesting results about the watershed situation. Figure 6 shows the average weight of eWPI parameters in the PSR framework. Analysis of variables, from this point of view, can be emphasized such that the weight of the *Response* is different from those of the *Pressure* and *State* parameters. This means that experts familiar with the issues of this watershed believe that the responses that society or decision makers give to the current situation are more important than the factors of pressure and the current status.

Finally, the eWPI was recalculated according to the obtained weights, and the results are shown in Tables 6 and 7 for AHP and ANP, respectively.

The unweighted eWPI in the Beheshtabad Basin was 0.605. Weighting the index components with the AHP and ANP has, respectively, led to a decrease (0.594) and an increase (0.626) in the final value. The reason for the lower value of the AHP weighted index compared to the simple index is the relatively low weight of Environment and the relatively high weight of Resources, compared to the other components. The reason for the increase in the value of the ANP weighted eWPI compared to the simple index is the greater weight of the Environment and the decrease in the weight of the Resources. As a rule of thumb, a final value of 0.6 was obtained for the Beheshtabad Basin.

The overall value of the index was assessed as an average, considering five criteria, i.e., Resources, Access, Capacity, Use, and Environment, in the Pressure-State-Response framework. WPI values calculated by other researchers indicate a higher frequency of average values around the world. Garriga and Foguet (2010) computed an average eWPI of 0.62 for Bolivia. Lawrence et al. (2003) applied the WPI worldwide and reported a value of 64.4 for Iran (on a 0–100 scale).

Conclusion

The relationship between poverty and access to water is complex and one that has unique characteristics in each society. However, eWPI has features that can shed light on the dimensions of this complex relationship. This index is a robust multidisciplinary tool for assessing a community

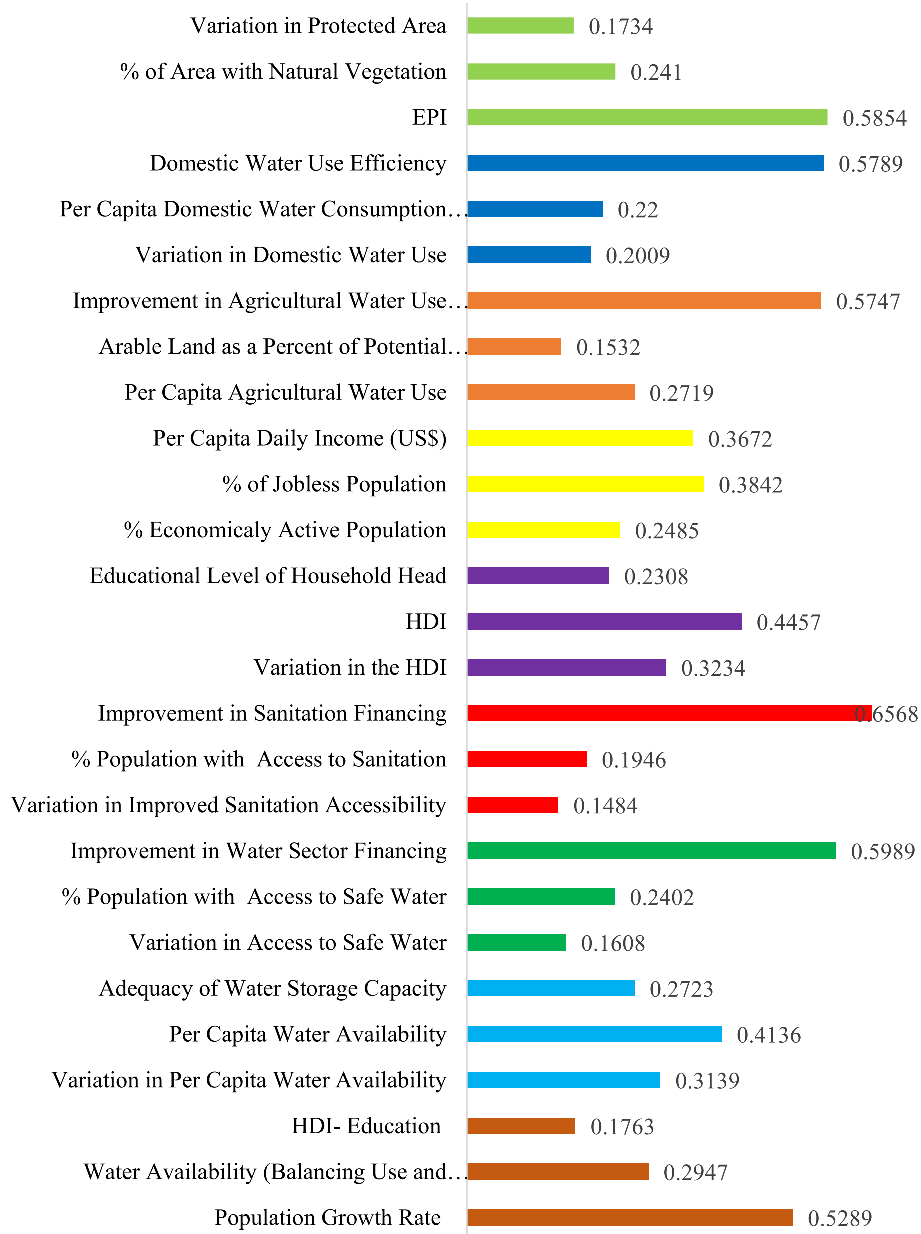


Fig. 3 eWPI parameters' weights in AHP

or a watershed in terms of natural and socioeconomic capital. The final value of the index—both weightless and weighted—shows that the situation of the study area is average and slightly better than average. However, to find the relationship between poverty and access to water resources, it is necessary to analyze the dimensions of this index.

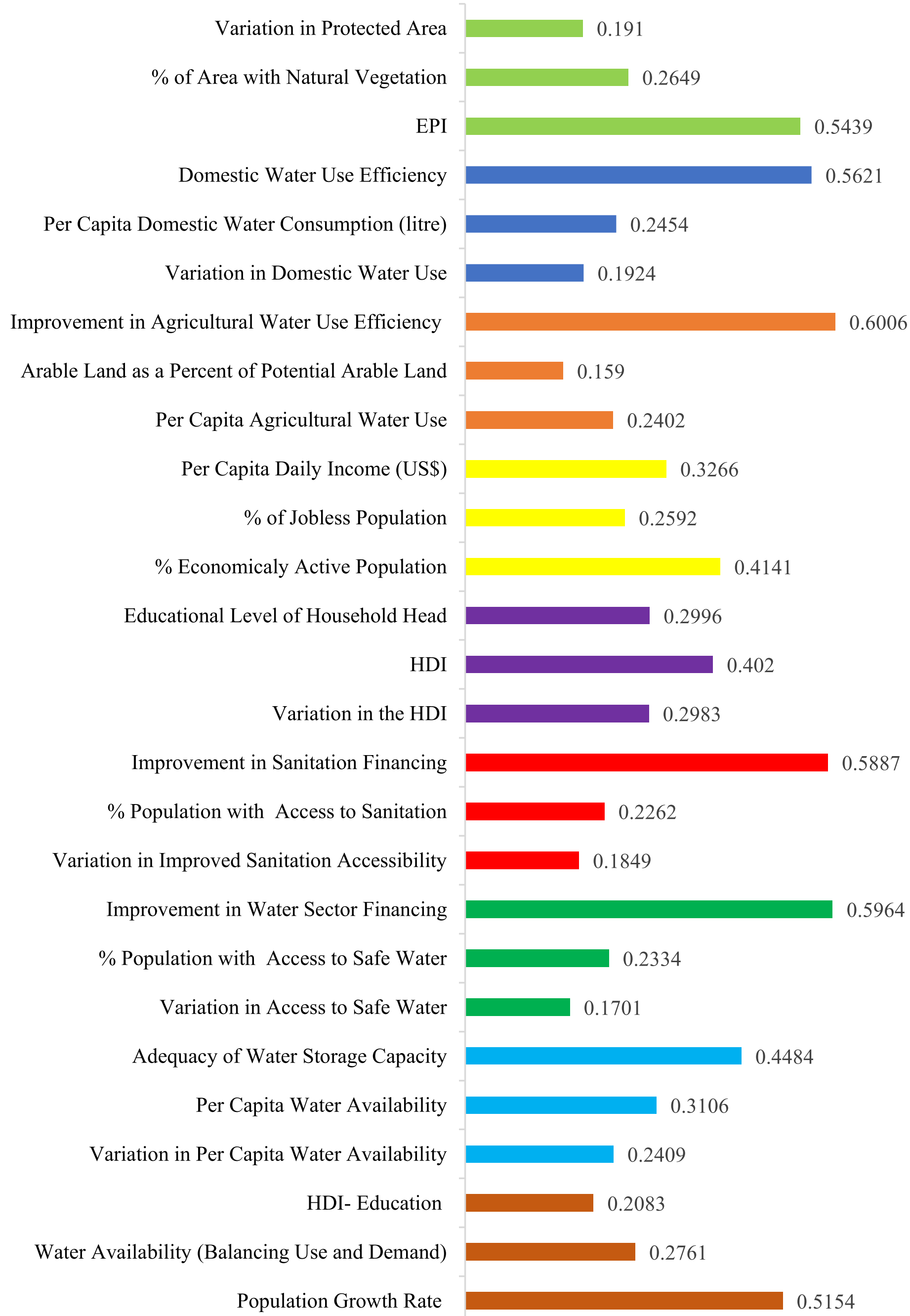
In the experts' opinions, the importance of the Resources (*R*) criterion in this index is more than the other criteria. This difference is greater in the AHP weighting method.

Preferential analysis of the sub-criteria in the PSR framework showed that the higher total weights were assigned to the *Response* parameters. This means that experts believe in the positive effects of appropriate measures to reduce water poverty in the region.

In this study, two methods based on experts' opinions were used to determine the priority of criteria and sub-criteria of eWPI. Other methods such as PROMETEE or Best Worst Model (BWM) can be used.

The most important limitations of this study are the inconsistency of natural and political boundaries and the inconsistency of temporal and spatial scales of the required data. Another limitation is the lack of economic and financial information at the micro-spatial scale. This data is difficult to separate for small communities and households. The relatively large time interval (5 years) between the population and housing census and the delay in its release is another limitation of this study.

Fig. 4 eWPI parameters' weights in ANP



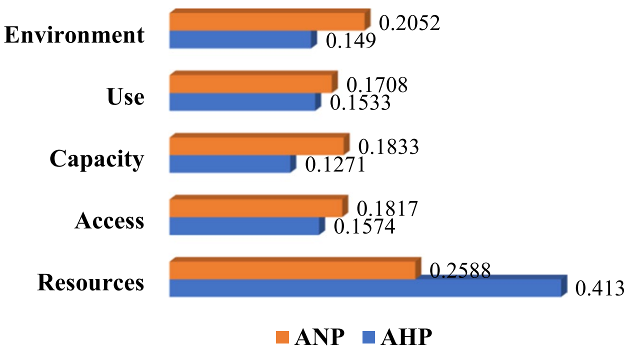


Fig. 5 eWPI main criteria weights

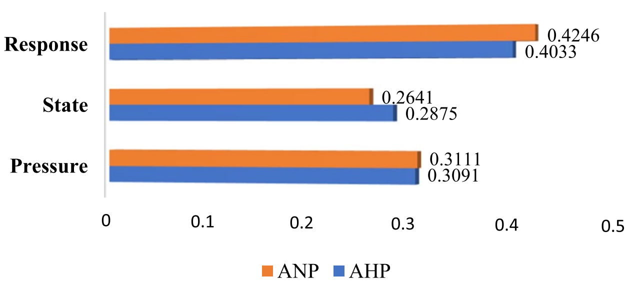


Fig. 6 The weight of Pressure, State, and Response in AHP and ANP

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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Table 6 eWPI components weighted by AHP (Watershed Scale)

Criteria	Sub-criteria	Pressure score	State score	Response score	Parameter score	AHP weights	Weighted score	eWPI
Resources	Water	0.078	0.284	0.204	0.539	0.413	0.222	0.5944
	Population	0.264	0.147	0.099				
Access	Safe water	0.080	0.240	0.299	0.670	0.157	0.105	
	Sanitation	0.074	0.194	0.451				
Capacity	Social	0.161	0.223	0.115	0.494	0.127	0.063	
	Economic	0.186	0.072	0.229				
Use	Agriculture	0.017	0.086	0.251	0.440	0.153	0.067	
	Domestic	0.113	0.124	0.289				
Environment		0.585	0.241	0.086	0.913	0.149	0.136	

Table 7 eWPI components weighted by ANP (Watershed Scale)

Criteria	Sub-criteria	Pressure score	Status score	Response score	Parameter score	ANP weights	Weighted scores	eWPI
Resources	Water	0.060	0.213	0.3363	0.561	0.258	0.145	0.626
	Population	0.257	0.138	0.117				
Access	Safe water	0.085	0.233	0.298	0.670	0.181	0.121	
	Sanitation	0.092	0.226	0.404				
Capacity	Social	0.149	0.201	0.149	0.531	0.183	0.0974	
	Economic	0.310	0.048	0.204				
Use	Agriculture	0.015	0.089	0.262	0.447	0.171	0.076	
	Domestic	0.108	0.138	0.281				
Environment		0.544	0.264	0.095	0.904	0.205	0.185	

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