Pirineos. Revista de Ecología de Montaña
vol. 176
Jaca, Enero-Diciembre, 2021, e064
ISSN-l: 0373-2568
https://doi.org/10.3989/pirineos.2021.176002

WATER POVERTY INDEX (WPI) EVALUATION IN BORUJERD-DOROOD WATERSHED (IRAN) TO REINFORCE LAND MANAGEMENT PLANS

Evaluación del índice de pobreza hídrica (WPI) en la cuenca de Borujerd-Dorood (Irán) para reforzar los planes de gestión del territorio

Mohammadreza Goodarzi [1*], Rabi H. Mohtar [2], Mahboobeh Kiani-Harchegani[3], Alireza Faraji[4], Faeze Mankavi[5], Jesús Rodrigo-Comino[6, 7]

[1] Department of Civil Engineering, Yazd University, Yazd, Iran
[2] W-E-F Nexus Research Group, Department of Biological and Agricultural Engineering, Texas A&M University, USA and Faculty of Agricultural and Food Sciences, American University of Beirut, Lebanon.
[3] Department of Watershed Management Engineering, Faculty of Natural Resources, Yazd University, Yazd Province, Iran.
[4] Department of Engineering, University of Basilicata, Via dell'Ateneo Lucano 10, 85100 Potenza, Italy.
[5] Department of Civil Engineering, Grand ayatollah Borujerdi University, Borujerd, Iran.
[6, 7] Department of Physical Geography, University of Trier, 54296 Trier, Germany and Soil Erosion and Degradation Research Group, Department of Geography, University of Valencia, Avda. Blasco Ibáñez, 28, 46010 Valencia, Spain.

ORCID badget of authors and e-mail
Mohammadreza Goodarzi: https://orcid.org/0000-0002-6296-2315. E-mail: Goodarzimr@yazd.ac.ir
Rabi H. Mohtar: https://orcid.org/0000-0002-4358-729X. E-mail: mohtar@tamu.edu
Mahboobeh Kiani-Harchegani: https://orcid.org/0000-0003-1075-1169. E-mail: Mahboobeh.kiyani20@gmail.com
Alireza Faraji: https://orcid.org/0000-0002-7335-2328. E-mail: Alireza.faraji@unibas.it
Faeze Mankavi: https://orcid.org/0000-0003-2999-4697. E-mail: faezemankavi@yahoo.com
Jesús Rodrigo-Comino: https://orcid.org/0000-0002-4823-0871. E-mail: jesus-rodrigo@uv.es
*Corresponding author

Recibido: 25-10-2020. **Aceptado:** 4-01-2021. **Fecha de publicación on-line:** 11/05/2021

Citation/ Cómo citar este artículo: Goodarzi M., Mohtar R. H., Kiani-Harchegani M., Faraji A., Mankavi F., Rodrigo-Comino J. (2021). Evaluación del índice de pobreza hídrica (WPI) en la cuenca de Borujerd-Dorood (Irán) para reforzar los planes de gestión del territorio. *Pirineos*, 176, e064. https://doi.org/10.3989/pirineos.2021.176002

ABSTRACT: Water poverty index (WPI) is widely considered a simple and clear tool to evaluate the effects of combined factors on water shortage and resources stress. In this research, we tried to focus on water tensions in the upstream part of the Karoon basin in Iran for analyzing the water status of the area. For this purpose, the required data were firstly obtained by preparing a report from the Water Authority, Agricultural part, and the Water and Wastewater Organization of Borujerd County. Then, the value of the WPI was estimated at the sub-basin scale of the large Karoon River in the Borujerd-Dorood Watershed (Iran) considering as a resource, the possibility to access, socio-economic capacity, uses, and environmental quality criteria. Results of this research indicated a variation range between 6.6 and 18.2, obtaining the lowest point for its current environmental condition and the highest point due to the easy access. The highest values of each criterion show the better conditions that lead to less water poverty in that sub-basin area. In general, the value of WPI in the study area is approximately 67.65, according to the classification of the Ecology and Hydrology center of Wallingford, this sub-basin is placed in a low to moderate range of water poverty. Given the multidimensional nature of the WPI and considering all the factors affecting the availability or lack of water resources as well as economic and social implications for the rural inhabitants devoted to agriculture and pasture, we conclude that this index can be considered as a useful tool in prioritizing the critical areas and an effective step to develop optimal use of water resources.

KEY WORDS: Water Scarcity; Hydrological issues; Karoon river basin; Mountain water resources

RESUMEN: El Índice de Pobreza Hídrica (WPI) se considera, en general, una herramienta simple y clara para evaluar los efectos de factores combinados sobre la escasez de agua y la tensión de los recursos hídricos. En esta investigación, intentamos centrarnos en las problemáticas hídricas en las cabeceras de montaña de la cuenca de Karoon en Irán para analizar el estado de los recursos hídricos. Para este propósito, los datos requeridos se obtuvieron en primer lugar mediante la preparación de un informe de la Autoridad del Agua, la parte Agrícola y la Organización de Agua y Saneamiento del Condado de Borujerd. Luego, se estimó el valor del WPI a escala de subcuenca del río Karoon considerando como recurso la posibilidad de acceso, capacidad socioeconómica, usos y criterios de calidad ambiental. Los resultados de esta investigación indicaron un rango de variación entre 6,6 y 18,2, obteniendo el punto más bajo por su condición ambiental actual y el punto más alto por el fácil acceso. Los valores más altos de cada criterio muestran las mejores condiciones que conducen a una menor pobreza hídrica en esa subcuenca. En general, el valor de WPI es aproximadamente 67,65, según la clasificación del centro de Ecología e Hidrología de Wallingford, esta subcuenca se ubica en un rango de pobreza hídrica de baja a moderada. Dado el carácter multidimensional del WPI y considerando todos los factores que afectan a la disponibilidad o falta de recursos hídricos, así como las implicaciones económicas y sociales para la población dedicada, principalmente a la agricultura y la ganadería, podemos concluir que este índice puede ser considerado como una herramienta útil para esta región priorizar las áreas críticas y un paso efectivo para el desarrollo y uso óptimo de sus recursos hídricos.

PALABRAS CLAVE: Índice de pobreza hídrica; problemática hídrica; cuenca del río Karoon; recursos hídricos de montaña.

1. Introduction

Water is an indispensable resource for the humankind and natural ecosystems, and its conservation is recorded in the sustainable development's goals (SDGs) and challenges number (SDG 6) (Mugagga & Nabaasa, 2016; Weststrate *et al*., 2019). According to, water scarcity is recognized as one of the most important issues of the current century, which can aggravate a future multifaceted crisis during the next half-century (OhIsson, 2000; Rijsberman, 2006). Therefore, the importance of water quality and quantity for terrestrial life and adequate water supply is a prerequisite for the sustainable socio-economic development and developing of efficient land management plans and, especially, also for water production and the maintaining in mountain areas as the water tower of humidity island (Viviroli *et al.,* 2003; Alessa *et al*., 2008; Vargas-Pineda *et al*., 2020; Yegemova *et al*., 2018). However, water stress is not limited to water aspects, but it also affects Water, Energy, and Food (WEF) chain (FAO, 2014), which is a challenge of developing countries emphasizing an urgent need for integration of these sectors (Pardoe *et al*., 2018) or soil quality (Kiani-Harchegani *et al*., 2019; Kiani-Harchegani & Sadeghi, 2020b; Rodrigo-Comino *et al*., 2020).

In the last decades, a worldwide evolution of urbanization has led to an increase in population rates and rising economic growth (Colantoni *et al*., 2016; Salvati & Carlucci 2016). Urbanization has shown a major effect on the production waste and decreased of water quality due to water contamination, deforestation, and human activities, as a result, water for human use has become in several territories inaccessible (Diwakar & Thakur, 2012). In this situation, water resources are exposed to various pollutants, and their quality is very low (Kumar *et al*., 2019).

Nowadays, proper and efficient management of water resources has become a sophisticated issue and it is impossible to acquire the fundamental aims of development, such as the elimination of poverty, fair development, and environmental protection without an accurate estimate and have a multidimensional view on water resources management (Koirala *et al.,* 2020). Likewise, droughts, like a natural calamity, are threats to human communities and environment, which will be influenced by a growing water demand (Sullivan *et al*., 2006; Brown & Matlock, 2011). The ongoing adverse trends in the status of water resources worldwide and the prediction of an intensifying critical situation in coming years have prompted researchers and international organizations to propose various indices for evaluating the quantitative and qualitative status in different parts of the world (Sullivan, 2002; Sullivan *et al*., 2003).

The vulnerability of water resources has become a major issue in recent studies. Brown & Matlock (2011) stated the importance of developing indices for water use, water existence, and water poverty. Among these mentioned indices introduced in this regard, the Water Poverty Index (WPI) is attracting considerable interest due to its comprehension (Sullivan *et al*., 2002). WPI evaluates the status of regional water resources based on specific criteria and determines the position of each region in comparison to other ones (Sullivan & Jemmali, 2014; Jemmali, 2017; El-Gafy, 2018; Koirala *et al*., 2020). This index consists of five main components, which each of them has different sub-criteria. These five components are a resource, access, capacity, use, and environment (Sullivan, 2002). Sullivan *et al*. (2006) pointed out some specific applications of WPI at various level including community, region, and basin area and emphasized the importance of different scales for water resources management. They proved that specified scale information might not necessarily reflect the same conditions on the other scales. The analysis of elements of WPI indicated that access and resource criteria in basin and uses, environment, and capacity criteria were the most variable. WPI is an interdisciplinary measure that illustrates the relationship between the welfare of a household and level of access to water, as well as, the impacts of water shortage on human societies (Wurtz *et al*., 2019). Such an index makes it possible to rank different countries and societies in terms of physical and socioeconomic factors (Jafari Shalamzari & Zhang, 2018).

Manandhar *et al*. (2012) calculated WPI to evaluate water resources in the Kali Gandaki river basin in Nepal. The results showed that WPI value varied from 37.1 to 56.5 within the studied basin. Shakya (2012) estimated the WPI and mapped the water poverty at low, medium, and high scales in the Inderawati River basin located in the central Nepal region. The average WPI over the whole basin was 52.5 (equal to medium water poverty) and the computational values of water resources existence and capacity were reported differently in upstream and downstream regions. It was revealed that water resources drying, minor access, deforestation and chemical fertilizers were the most important factors in water poverty in the studied area. Cho & Ogwang (2014) in their research in Canada expressed that the WPI is a tool based on quantitative data to measure the level of water poverty in a community, region, or country, and considered that the use of this method in the different regions needs more modifications. Thakur *et al.* (2017) evaluated the WPI in the upstream of the Bagmati River in Nepal and showed that WPI can be an effective tool in the integrated water resources and comprehensive plan of water consumption to achieve sustainable development aims. Also, van der Vyver (2013) researched in the Wall Trigol area of South Africa to determine the difference between the value of the poverty index by using the incremental function and the multiplication function. After calculating the indices for three cities, they concluded that the values of the computational indices had a small difference and also stated that future research should be based on the correction and development of existing functions for calculating WPI. Also, Kojiri (2008) examined the population growth along with economic, social, and environmental development and secondary challenges in water resources management. Due to an increase in the levels of available information and global communications, the methods and the quantitative and qualitative level of information, more comprehensive and precise indices are introduced and presented to develop an evaluation of global water resources status.

Assuming a population of 70 million inhabitants and annual renewable water resources of 130 billion cubic meters, the Falkenmark index for Iran indicated 1850 m^3, which, according to this index, the water tension should be lower. Considering the consumption of 88.5 billion m^3 of water in different parts of Iran, according to the United Nations index, Iran is characterized by a critical situation using 68% of its renewable water resources (Mohammad Jani & Yazdanian, 2014). On the one hand, the current facts regarding water resources and consumption in Iran indicate the necessity of compilation and calculation of more comprehensive criteria such as WPI to common indices. In this regard, in studies conducted by Asiabi-Hir *et al.* (2018) and Jafari Shalamzari & Zhang (2018) for Ardabil and Golestan provinces in Iran, the WPI was calculated as 43 and 41.1, respectively. For other basins without WPI, the value (60.4) was applied, presented by Lawrence *et al.* (2002).

Given the inappropriate distribution of water resources in Iran, the importance of this research should be considered as indispensable. Therefore, the main aim of this study is to apply the WPI and to determine the situation of water poverty in the large Karoon sub-basin. This area has experienced rapid transformations due to land-use changes and the intensification of some specific human activities such as urbanization or grazing, which is representative of some other watersheds from rapid developing countries. This index has not been calculated for a watershed like the Borujerd-Dorood Watershed in the west part of Iran. Therefore, this study could suppose a great advance if applied at the sub-basin scale to help land managers of other areas with similar conditions over the world. We hypothesize that these results could be comparable to other areas in Iran and over the world to develop a large inventory of watersheds with water quality issues. The multi-dimensional nature of WPI considering all affecting factors on water scarcity and availability behind social and economic characteristics would be a useful tool in prioritizing critical mountainous to develop effective steps in optimal planning of water resources.

2. Materials and Methods

2.1. Study area

The Borujerd-Dorood watershed area (2545.8 km^2) is located in the northern part of the Karoon Basin and the south of the Eshtronian. Borujerd-Dorood watershed is managed by the Lorestan Regional Water Company. Figure 1 showed the Borujerd-Dorood watershed location (A), in the Karoon basin (B) and Iran (C).

The Karoon Basin has an area of about 66,675.9 km^2, from which 16,908 km^2 are covered by relatively flat and wide plains and alluvial areas, and 49,766.9 km^2 by relatively rugged altitudes and alluvial zones to a limited extent. Therefore, 74.6% of the Karoon basin area consists of mountainous and highlands and 25.4% of the plain and lowland regions. The Karoon basin is located between the longitude 48° 2' and 55° 00', and latitude 29° 55' to 34° 10'. The highest elevation is the Dena peak in the northeast of the basin, which reaches 4,409 m a.s.l. The lowest elevation of the basin is less than 2 m a.s.l. corresponding to the outlet point of the basin (Persian Gulf connection). According to the hydrological and hydrogeological features, the Karoon basin used to be divided into 42 study areas (Ministry of Energy, 2005), which five are managed and surveyed by the Lorestan province.

The Eshtronian study area is characterized by an extent of 360.4 km^2 and is located in the large Karoon basin including 204.5 km^2 of a plain region and 155.9 km^2 of altitudes. According to the Köppen System for climate classification, the Borujerd-Dorood watershed was located in the BSk region (arid cold) (Peel *et al.*, 2007). There are 18 rain gauge stations in the Borujerd-Dorood study area. For the selection of representative station in plains and heights, these stations have been used because of its long-term period of data. Marek station with a 36-year (1981-2017) record of rainfall events in Mirqasem and the Vanei Station (White Seabury) with 42 years (1975-2017) have been selected as representative stations in the Borujerd-Dorood region. The average annual rainfall in both plains and altitude ranges from 492.8 mm and 510 mm, respectively and also a mean annual temperature of 13°C. Geology is characterized by a karst formation and includes Quaternary alluvial sediments. Soil texture is sand clay and, loamy classes with good fertility and the major land cover is the agricultural land (Taghipour & Sarchoghaei, 2015). Therefore, considering that the upstream areas of this watershed were mostly mountainous and its average annual rainfall is higher than Iran; human interventions for the development of recreation areas and the creation of residential areas has also increased. Also, pasture areas are very common and grazing intensity has led to the destruction of vegetation like other authors mentioned in the past in other countries (Minea *et al.*, 2019; Minea & Moroşanu, 2014). The economy of this region is mostly based on regional and extra-regional trade, agriculture and animal husbandry, as well as the production of industrial and mineral products (Ariapour *et al.*, 2014; Jahangir & Yarahmadi, 2020).

2.2. Water Poverty Index

Water resources management and planning without a proper assessment of its status lead to the loss of water re-

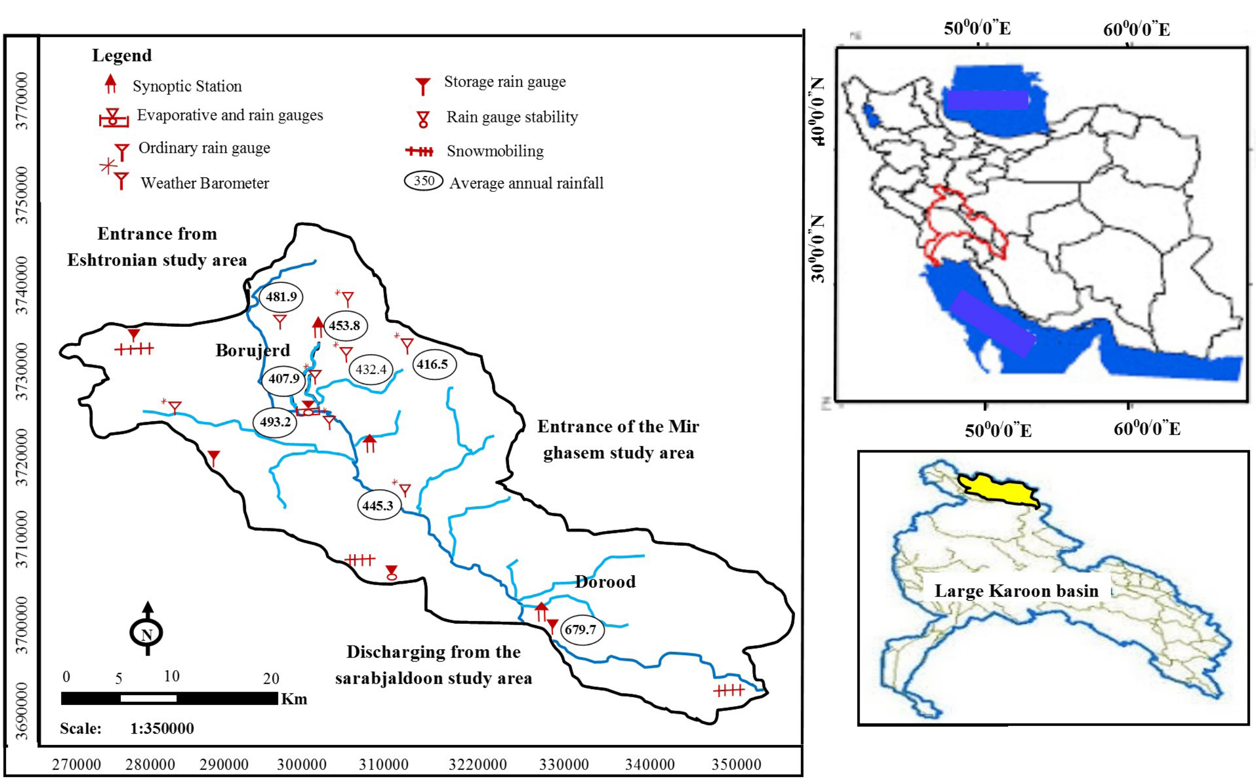


Figure 1. Borujerd-Dorood watershed location (A), in the Karoon basin (B) and Iran (C). (Source data: Water Authority, Agricultural part, and the Water and Wastewater Organization of Borujerd County)
Figura 1. Localización de la Cuenca del Borujerd-Dorood, Iran

sources. Considering the lack of clear-cut criteria for water poverty issues and representative indices of it at different spatial scales, accurate selection of indices and data availability to apply the poverty index is an urgent matter (Manandhar *et al.*, 2012). Various indices are used to evaluate the vulnerability of water resources. In this study, the WPI, a multilateral combination of indices of water and human welfare, has been applied. The WPI consists of five key elements; each of them has several sub-criteria. In the current study, criteria and sub-criteria have been selected based on the situation of current data in the Iranian water bodies. The required information and data in the computation of WPI were obtained from the Water Office, Agricultural part, and Water and Wastewater Organization of Borujerd County. This index includes five major components: Resource (R), Access (A), Capacity (C), Use (U), and Environment (E) (Juran *et al*., 2017).

The WPI can be posed in terms of an equation (1) applied for a specific location as presented by Sullivan *et al.* (2003) and Sullivan *et al.* (2006) as follows.

$$WPI = \frac{W1 \times R + W2 \times A + W3 \times U + W4 \times C + W5 \times E}{\sum_{i=1}^{5} wi} \quad (01)$$

It is possible to define the weight (W1, W2,… W5) for each criterion including Resource (*R*), Access (*A*), Use (*U*), Environment (*E*) and Capacity (*C*) where the weights are non-negative (Asiabi-Hir *et al.,* 2018). The weighting of various criteria is given in Table 1.

Table 1. Weighting of various criteria to calculate the WPI (Water poverty index).
Tabla 1. Ponderación de varios criterios para calcular el IPH (Índice de pobreza hídrica).

	Resource	Access	Use	Environment	Capacity
Same weight	20	20	20	20	20
Emphasis on resource	40	15	15	15	15
Emphasis on access	15	40	15	15	15
Emphasis on use	15	15	40	15	15
Emphasis on environment	15	15	15	40	15
Emphasis on capacity	15	15	15	15	40

In this study, it has been used the same weight for assessing WPI because of that prioritizing is not considered for evaluation of this sub-basin. So that, equation (1) is described as follows:

$$WPI = R + A + U + E + C \quad (02)$$

The results of WPI were calculated out of 100 and were compared to research carried out by the Ecology and Hydrology centre of Wallingford. In 2003, the Ecology and Hydrology centre of Wallingford (Sullivan *et al*., 2003, see also http://www.nerc-wallingford.ac.uk/research/WPI/) classified various countries in terms of water poverty based on the WPI index into five categories: i) low (68-78); ii) low-moderate (62-67.9); iii) moderate (56-61.9); iv) high (48-55.9) and severe (35-47.9).

Resources (R)

This criterion determines natural access to water resources in the studied area. The high values of this criterion show that there is a great potential for using the annual and seasonal variability that is assessed by two criteria of availability and variability. The availability (R_1) indicates how population pressures on available water resources (Alessa *et al*., 2008). As shown in equation (3), this criterion is measured by per capita water resources and will be normalized using the maximum method.

$$R_1 = \frac{x_i - x_{min}}{x_{max} - x_{min}} \quad (03)$$

Where X_i is the number of water resources per capita (m^3), X_{min} and X_{max} are maximum and minimum values of all the studied districts.

The second variable, the variability (R_2) means the coefficient of rainfall variation, which is used to estimate this criterion. The higher value of rainfall variation shows the lower availability of water resources in temporal and spatial scale. Less certainty implies the hazards of climate change and the vulnerability of resources (Hamouda *et al*., 2009). To compute this parameter, the monthly recorded rainfall data were arranged considering 18 rain-gauge stations from Borujerd-Dorood watershed during the 42-year up to 2017. After that, in the purpose of computing rainfall variation coefficient of these rain-gauge stations, the mean annual rainfall and standard deviation for each station were calculated. When the standard deviation is equal to or more than 30%, we considered that it occurs the most vulnerable situation (Babel & Wahid, 2009). Using equation (4), the values of the mentioned index were normalized (Van Ty *et al*., 2010).

$$R_2 = \frac{x_i}{0.3} \quad (04)$$

Where X_i is the coefficient of rainfall variation related to each region and, if $X_i \geq 0.3$, R_2 represents equal to 1. Finally, the resources rating (R) results from the following equation (5):

$$R = \frac{R_1 + R_2}{2} \times 20 \quad (05)$$

Access (A)

Ample access to water resources and sanitation will persuade society to a better comply with health policies. This index shows a population with adequate access to enough amounts of safe drinking water and health to get greater well-being (Hamouda *et al*., 2009). Enough access to water leads to less time in collecting water, which can be used for economic and productive activities. This part is calculated using two criteria for access to drinking water supply (A_1) and improved sanitation (A_2) as shown in equation (6).

$$A_1 = \frac{x_w}{x}, A_2 = \frac{x_s}{0.3} \tag{06}$$

Where X_s and X_w identify the population having access to sanitation and safe drinking water in the studied territory, respectively. Finally, the access criterion (A) is calculated following the next equation (7):

$$A = \frac{A_1 + A_2}{2} \times 20 \tag{07}$$

Use (U)

Water consumption examines the amount of water usage and the way of exploitation of water resources. The main parts of water uses are domestic water use and agricultural water use. Firstly, the domestic water use (U_1) represents the current situation of consuming water resources in daily activities (cooking, sanitation, and washing) as well as its future prediction (Cullis & Regan, 2004; Jemmali, 2017). This index is measured by daily water consumption per capita and is normalized by the maximum method equation (8).

$$U_1 = \frac{X_i - X_{min}}{X_{max} - X_{min}} \tag{08}$$

Where X_i stands the domestic water use and X_{min} is defined as the minimum of required water for domestic sanitation. The daily water per capita for each person was set up to 20 litres (WHO/UNICEF, 2000). X_{max} represents the maximum amount of water that meets all the needs of domestic water use reaching 100 litres per capita per day (Howard & Bartram, 2003). Agricultural water use (U_2) is included in this sub-category, which indicates the available irrigation facilities in a given area. The developing of agriculture plays an important role in the economic growth and reduction of poverty, in other words, agriculture has led to a huge contribution to living improvement (Han & Zhao, 2005). For evaluation of agricultural water use, the ratio between irrigated land and the total cultivated land (equation 9) is used (Sullivan et al., 2003):

$$U_2 = \frac{X_i}{X} \tag{09}$$

Where X_i illustrates the irrigated land and X is the total cultivated land, which is calculated as follows (equation 10):

$$U = \frac{U_1 + U_2}{2} \times 20 \tag{10}$$

Environment (E)

The maintenance of the environmental quality and health of ecosystems has great importance for achieving sustainable water resources uses. Considering the exploitation of surface water resources as well as serious concerns about severe damage to the river ecosystems, the evaluation of river hydrological changes is a priority in Iran. This criterion is described by three sub-criteria. The base flow (E_1) is a part of the streamflow that responds to the rainfall and is mostly related to evacuated water from underground water storage. In this study, a one-parameter algorithm method was used which is a type of return-numerical filter method. This method merely needs the determination of the recession constant parameter (K), which is calculated in this study using the subsonic flow branch (equation 11) (Eckhardt, 2008).

$$q_{b(i)} = \frac{k}{2-k} q_{b(i-1)} + \frac{1-k}{2-k} \tag{11}$$

Where K is an abbreviation for recession constant parameter and q_b means the values of the discharge.

The vegetation coverage (E_2) represents a key factor controlling the disruption of the natural ecosystem and hydrological cycle, soil erosion and river sedimentation (Hamouda *et al*., 2009). It was calculated following the equation (12).

$$E_2 = \frac{\mathrm{X_i}}{\mathrm{X}} \tag{12}$$

Where X_i is the amount of vegetation coverage and X represents the total area including vegetation coverage and other land uses.

The Q_{95} index of flow is the precise estimation of streamflow in rivers. It is one of the basic elements for the management of surface water resources, especially, the implementation of proper measures as a result of flood and droughts. Overall, the reduction of the environmental flow in a stream during a long period will have negative and domino effects on vegetation and animal societies on the margins of rivers and aquatic life (Smakhtin, 2001). The Q_{95} index is equal to the discharge with a probability of occurrence of more than 95% in a flow duration curve. This sub-criterion is standardized using the equation below:

$$E_3 = \frac{\mathrm{X_i} - \mathrm{X_{min}}}{\mathrm{X_{max}} - \mathrm{X_{min}}} \tag{13}$$

Where X_i is the value of Q_{95} in each basin and X_{min} and X_{max} are the lowest and highest values of Q_{95} in each basin, respectively. Then, the environment criterion is obtained from equation 14:

$$E = \frac{E_1 + E_2 + E_3}{2} \times 20 \tag{14}$$

Capacity (C)

It can be defined by the ability of people to manage water. Two sub-criteria of social capacity and economic capacity are used to assess this part. The Social capacity (C_1) is divided into two sub-indexes including literacy rate (C_{1i}) and economically active population (C_{1ii}). The literacy rate is defined as the percentage of the educated population aged 15 and over. The highest values of this index represent the more literate people who can read, access to information, understand water issues, and, in some cases, can take proceedings on water management (Brooks *et al*., 2005). Computation process is based on the equation 15, where X_i is the literate population and X is the total population.

$$C_{1i} = \frac{X_i}{X} \quad (15)$$

The economically active population is described as a percentage of the population of 10-60 years with the physical power that can face with poverty and water tension and the higher values represent people with a high capacity to struggle against water changes (Pandey *et al*., 2011). It was calculated using equation 16, where X_i is the population between 10 and 60 years old and X is the total population.

$$C_{1ii} = \frac{X_i}{X} \quad (16)$$

On the other, the economic capacity (C_2) represents a sub-criterion related to the workforce information in non-agricultural employment (C_{2ii}). The diversity of livelihoods in non-agricultural sectors increases the reliability of income and consequently, the economic capacity of people for the water management conflicts (Brooks *et al*., 2005). Equation 17 presents the final computation:

$$c_{2ii} = \frac{X_i}{X} \quad (17)$$

Where X_i is the population who works in non-agricultural sectors and X is the total population. Finally, the capacity can be achieved using equation 18:

$$C = \frac{C_{1i} + C_{1ii} + C_{2ii}}{3} \times 20 \quad (18)$$

3. Results and discussion

3.1. WPI calculation for the Borujerd-Dorood Watershed

Based on the WPI variables presented in Table 2, we show the Borujerd-Dorood watershed WPI based on five components of "Resources", "Access", "Use", "Environment" and "Capacity" respectively 13.70, 18.20, 12.55, 6.60 and 16.60. The scores on each component were then aggregated using the weighted multiplicative function, assuming equal weights for all components. The overall WPI was evaluated to be 67.65. In this regard, the assigned score for each element of WPI for the Borujerd-Dorood Watershed is presented in Figure 2. For the Borujerd-Dorood watershed, the WPI is 67.65 which are classified as low-moderate water poverty.

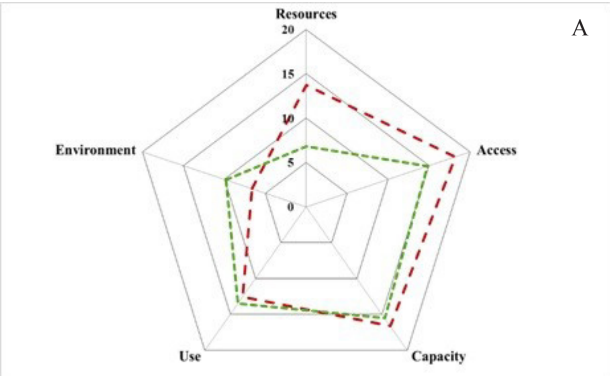
3.2. Comparison between Borujerd-Dorood watershed and other regional and global studies

The values of each element of WPI and the value of WPI are presented for different countries by Lawrence *et al*. (2002). In Figure 2, a comparison between the general conditions of Iran and the studied watershed is included. For the total of Iran, the water poverty index summarized 60.4 points (resources: 8.6, access:

Table 2. Water Poverty Index (WPI) variables used in the study.
Tabla 2. Variables del índice de pobreza hídrica (IPM) utilizadas en el estudio.

Resource	Availability (l/day)	The average height of long-term rainfall (mm)	Percentage of rainfall difference with a long-term average	Annual Rainfall (mm)	
	587.53	456.15	-31.90	286.20	
Access	Drinking water supply (%)	Indicator of healthy drinking water (%)	Water-covered population (%)		
	74.14	76.40	99.80		
Uses	Agriculture (10^6 m^3)	Industry (10^6 m^3)	Drinking (10^6 m^3)		
	508.30	2.43	4.76		
Environment	Average discharge (m^3/s)	Shallow discharge (1000 m^3)	Deep discharge (1000 m^3)	Number of deep wells	Number of shallow wells
	4.46	38838	130464	800	605
Capacity	Literate population	Active economic population	Population working in the non-agricultural sector		
	317758	293617	65321		

Data source: Water Office, Agricultural part, and Water and Wastewater Organization at Borujerd County.



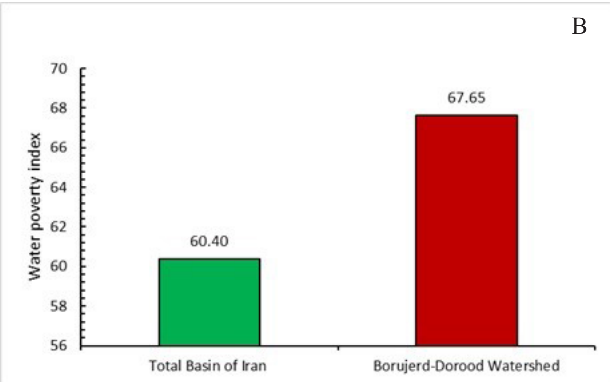


Figure 2. Comparison of Indicator Criteria of Water Poverty (A) and WPI (B) in the Total Basin of Iran (green dotted line and green bar) and the Borujerd-Dorood Watershed (red dotted line and red bar).

Figura 2. Comparación de los criterios del indicador de pobreza hídrica en el total de Irán (línea de puntos y barra verdes) y la cuenca de Borujerd-Dorood (línea de puntos y barra rojas).

14.8, capacity: 15.5, use: 13.5 and environment: 9.8), which was ranked the 58th among 147 countries (Lawrence *et al.*, 2002). This comparison emphasizes that due to the unfair situation of the spatial distribution of water resources, as well as, other related factors in different parts of the country (Mohammad Jani & Yazdanian, 2014), the value of WPI cannot be an appropriate representative for all the spots. As mentioned above, geographic variations in relevance to water consumption and access to it are of great importance, so that, it exists a remarkable difference among regions and countries in terms of access to water resources (Mohammad Jani & Yazdanian, 2014). These variations are highly significant and evident in communities even in nearby neighbourhoods (Sullivan *et al.,* 2006). The WPI values for 147 countries, which are to some extent provided with sufficient data on different components of the index, can be summarized as follows:

a. The highest index belonged to Finland with 78 and the lowest was for Haiti with 35.1 (the more score countries rank, the less water poverty they will face).
b. Most countries that have high WPI are between developed or developing countries with sharp growth.
c. South Africa, despite its low rating (5.6) in terms of its resources, has been able to get a good sum by gaining a high score on other indicators such as Human Development Index (HDI) and Falkenmark. This matter reflects applicable and effective policies in this country for the expansion and management of water resources.
d. A large number of countries, especially populated countries such as China and India, face high and severe water poverty, which shows the urgent need to develop water resource management policies in these countries (Cho *et al.,* 2010; Connor, 2015; Asiabi-Hir *et al*., 2018; Koirala *et al*., 2020).

3.3. Challenges and future goals to be achieved

WPI paves a way for decision-makers to prioritize prospect development plans in the water management and planning, as well as, to determine sectors of greatest need (Mohammad Jani & Yazdanian, 2014). According to Figure 2, the Environmental conditions ranked the lowest score with 6.60 followed by Uses with 12.55. Therefore, these two elements should be considered as a high priority over other elements.

Human activities in Iran undoubtedly can manipulate water environment diverted from water flows and storage capacity. The major issue is using huge amounts of water for food production, which naturally belongs to sustain environmental services purposes (Mlote *et al.*, 2002). These environmental goods and services ease life for most Iranian people, and water managers and policy-makers ought to maintain these functions properly by taking informed decisions. Furthermore, it is considered that the maintenance of the ecosystem plays a more vital role in the survival of other species especially in 'key species' (WCED, 1987). This more eccentric view is also included in the structure of the WPI, "as water for the environment is considered as a fundamental prerequisite for sustainability and the principles of Agenda 21 (UNCED, 1992)".

In general, land degradation process in Iran, changes in plant cover for agriculture, grazing and/or logging, urbanization, infrastructural development, are accelerating desertification, which is the main responsible anthropogenic process devastating the natural and rural ecosystems (Kiani-Harchegani & Sadeghi, 2020a). Population growth and improvement in economic activities result in big changes in vegetation (Muoghalu, 2009). This problem could be addressed by monitoring the causes of vegetation degradation in the watersheds at the Borujerd County, and determining the possible dramatic changes in natural vegetation types, which have occurred, as well as taking necessary measures to reduce hem (Ariapour *et al*., 2014). Also, new developments related to wastewater treatment and reuses should be considered as other authors in arid areas recommended when issues related to the balance model among transfers, groundwater, desalination and consumption appears (Jodar-Abellan *et al*., 2019b, 2019a).

According to the FAO (2008) report, the distribution of water withdrawal by Iran for the three-large water-consuming sectors includes agriculture 93% (irrigation and livestock watering), water supply 6% (domestic/municipal use) and industry 1% (Figure 3A). It is evident that if the amount of water allocated to agriculture sectors can be organized efficiently by local authorities, it can play a leading role in sustainable development scenarios in Iran and the studied area. The total area provided for irrigation is roughly 8.13 million ha in 2003, compared to 7.26 million ha in 1993. About 62% of that region is irrigated by groundwater (Figure 3B). Surface irrigation is the main irrigation technology used in Iran, including 92% of the area equipped for irrigation (Figure 3C). Localized and sprinkler irrigation cover 5 and 3% respectively, compared to only 0.6% each in 1993 (FAO, 2008).

Irrigation efficiency is commonly low, 33% on the total average at the national level. This makes waterlogging and salinization in the irrigated areas, which are significant problems in Iran, especially in the Karoon basin. This implies that the government heavily subsidized delivered water, which is essentially one of the underlying reasons for the low irrigation efficiency throughout the country (FAO, 2008). Since further abstraction of water storage will be costly and in future more amounts of water need to be assigned in other water use portions (drinking water, industry, and environment), more attention must be given to water-saving patterns than to further improvement of the irrigated area: more demand management, as opposed to the current supply management, practised, canal and watercourse lining, sprinkling and other types of pressurized field irrigation, land levelling and so on (Smedema, 2003).

Paying attention to our results and the literature used to develop Table 1 (Manandhar *et al.*, 2012; van der Vyver, 2013; Cho & Ogwang, 2014; Thakur *et al.,* 2017; Jafari Shalamzari, & Zhang, 2018; Asiabi-Hir *et al.*, 2018; Koirala *et al*., 2020), we summarized the possible recommended and strategies that can be followed in the studied watershed:

- Drinking water need should be considered as a high priority in mountain areas.
- Assuring the future urban water requirements by changing the agricultural water in mountain areas rights into using freshwater (from brooks, rivers, springs well, etc.) with using treated effluents.
- Avoiding using high-quality urban water to build green spaces, and allocating low-quality water for this plan. Cut off the water supply to industries, which have not taken practical stratagems for treating and reusing their wastewater.
- Carrying out research programs in mountain territories for the establishment of flexible criteria for the safe and sound reuse of wastewater.
- Replacing freshwater with treated effluents in agriculture requires introducing farmers to the positive and economic benefits of using wastewater, and consequently encouraging them to replace freshwater with effluents. This in itself requires research and study on the sanitary, economic and environmental impacts of using wastewater for agriculture and the artificial recharging of groundwater resources.

4. Conclusions

To sum up, the value of WPI was calculated in the Borujerd-Dorood considering as effective factors: water resources, access, capacity, use, and environment. The WPI summarized

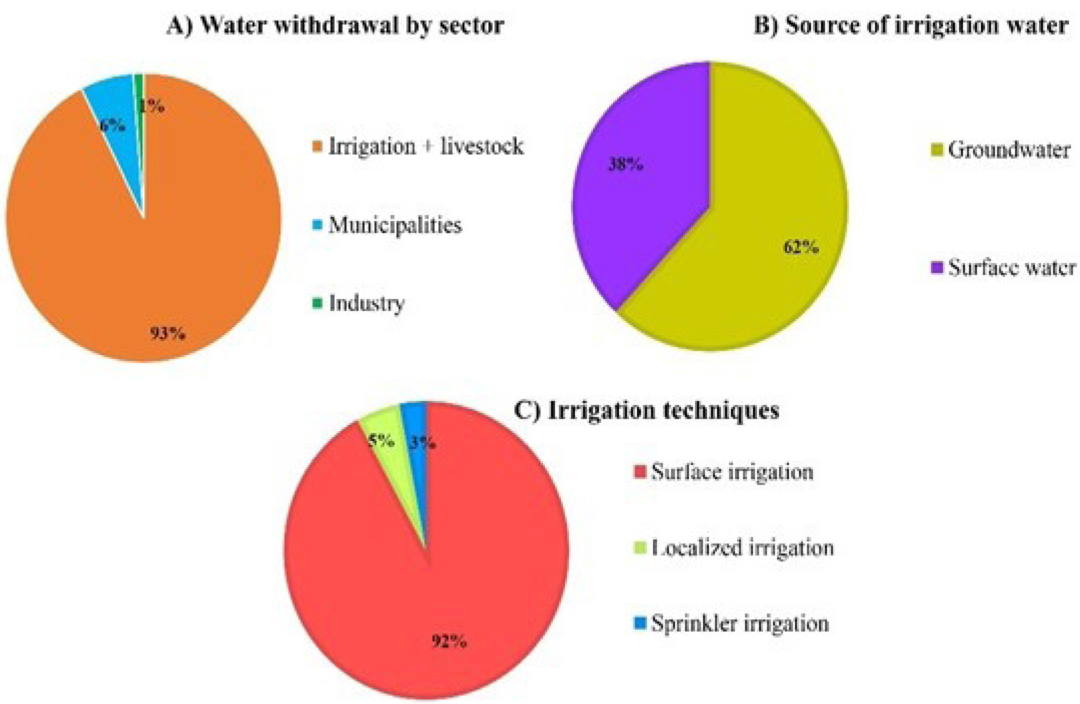


Figure 3. Water status in Iran (withdrawal by sector, source and techniques of irrigation) (FAO, 2008).
Figura 3. Estado del agua en Irán (extracción por sector, fuente y técnicas de riego) (FAO, 2008).

67.65 which represents low to moderate water poverty (Sullivan *et al.*, 2003). The issue of the water quality resources was confirmed, but also its upward trend of degradation by the sources of pollution from different parts of the urban, industrial, and agricultural areas. Therefore, we suggest urgent actions and increasing attention to develop and manage water resources in the Borujerd-Dorood Watershed. The rate of discharge in the studied area may be higher than other arid basins, but the amount of use, access, environment, and capacity is in such a situation that will put the water status in poor conditions. We stated that our findings might be effective for the decisions related to the development and management of water resources in different mountainous regions of Iran, especially in the studied area. It is recommended that further research should be undertaken in the following areas: i) calculation of WPI using different weights and using hierarchical analysis method in different areas; ii) considering the sub-index of draught in the resource section.

Acknowledgements

We gratefully acknowledge the help provided by Water Authority, Agricultural part, and the Water and Wastewater Organization of Borujerd County, without whose help this work would never have been possible.

References

Alessa, L., Kliskey, A., Lammers, R., Arp, C., White, D., Hinzman, L. & Busey, R., 2008. The arctic water resource vulnerability index: an integrated assessment tool for community resilience and vulnerability with respect to freshwater. *Environmental Management*, 42(3): 523. https://doi.org/10.1007/s00267-008-9152-0.

Ariapour, A., Ghermezcheshmeh, B., Nasaji, M. & Piroozi, N., 2014. Effect prediction of rangeland condition changes on runoff by HEC-HMS model in Sarab-Sefid basin of Borujerd. *RS & GIS for Natural Resources*, 4(4): 62-78.

Asiabi-Hir, R., Mostafazadeh, R. & Esmali Ouri, A., 2018. Multi-criteria evaluation of water poverty index spatial variations in some watersheds of Ardabil Province. *Iranian Journal of Ecohydrology*, 4(4): 943-1268.

Babel, M.S. & Wahid, S.M., 2009. Freshwater under threat: South Asia. Vulnerability assessment of freshwater resources to environmental change. United Nations Environment Programme and Asian Institute of Technology, Bangkok.

Brooks, N., Adger, W.N. & Kelly, P.M., 2005. The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. *Global Environmental Change*, 15(2): 151-163. https://doi.org/10.1016/j.gloenvcha.2004.12.006.

Brown, A. & Matlock, M.D., 2011. A review of water scarcity indices and methodologies. White paper, 106: 19.

Cho, D.I., Ogwang, T. & Opio, C., 2010. Simplifying the water poverty index. *Social Indicators Research*, 97(2): 257-267. https://doi.org/10.1007/s11205-009-9501-2.

Cho, D.L. & Ogwang, T., 2014. *Water Poverty Index*. Encyclopedia of Quality of Life and Well-Being Research, Springer Netherlands: 7003-7008.

Colantoni, A., Grigoriadis, E., Sateriano, A., Venanzoni, G. & Salvati, L., 2016. Cities as selective land predators? A lesson on urban growth, deregulated planning and sprawl containment. *Science of The Total Environment*, 545–546: 329–339. https://doi.org/10.1016/j.scitotenv.2015.11.170.

Connor, R., 2015. The United Nations world water development report 2015: *water for a sustainable world* (Vol. 1). UNESCO publishing: 139 pp.

Cullis, J. & Regan, O.D., 2004. Targeting the water-poor through water poverty mapping. *Water Policy*, 6(5): 397-411. https://doi.org/10.2166/wp.2004.0026.

Diwakar, J. & Thakur, J.K. 2012. Environmental system analysis for river pollution control. *Water, Air, & Soil Pollution*, 223(6): 3207-3218. https://doi.org/10.1007/s11270-012-1102-z.

Eckhardt, K., 2008. A comparison of baseflow indices, which were calculated with seven different baseflow separation methods. *Journal of Hydrology*, 352(1-2): 168-173. https://doi.org/10.1016/j.jhydrol.2008.01.005.

El-Gafy, I.K.E.D., 2018. The water poverty index as an assistant tool for drawing strategies of the Egyptian water sector. *Ain Shams Engineering Journal*, 9(2): 173-186. https://doi.org/10.1016/j.asej.2015.09.008.

FAO, 2008. Food and Agriculture Organization of the United Nations: Irrigation in the Middle East region in figures. AQUASTAT Survey, Rome, Italy.

FAO, 2014. The Water-Energy-Food Nexus, A new approach in support of food security and sustainable agriculture, Rome, 2014, 28 p.

Hamouda, M.A., El-Din, M.M.N. & Moursy, F.I., 2009. Vulnerability assessment of water resources systems in the Eastern Nile Basin. *Water Resources Management*, 23(13): 2697-2725. https://doi.org/10.1007/s11269-009-9404-7.

Han, H. & Zhao, L., 2005. Rural income poverty in Western China is water poverty. *China World Economy*, 13(5): 76-88.

Howard, G. & Bartram, J., 2003. Domestic water quantity, service level and health (No. WHO/SDE/WSH/03.02). World Health Organization.

Jafari Shalamzari, M. & Zhang, W., 2018. Assessing water scarcity using the water poverty index (WPI) in Golestan province of Iran. *Water*, 10(8): 1079. https://doi.org/10.3390/w10081079.

Jahangir, M.H. & Yarahmadi, Y., 2020. Hydrological drought analyzing and monitoring by using Streamflow Drought Index (SDI) (case study: Lorestan, Iran). *Arabian Journal of Geosciences*, 13(3): 110. https://doi.org/10.1007/s12517-020-5059-8.

Jemmali, H., 2017. Mapping water poverty in Africa using the improved Multidimensional Index of Water Poverty. *International Journal of Water Resources Development*, 33(4): 649-666. https://doi.org/10.1080/07900627.2016.1219941.

Jodar-Abellan, A., Fernández-Aracil, P. & Melgarejo-Moreno, J., 2019a. Assessing Water Shortage through a Balance Model among Transfers, Groundwater, Desalination, Wastewater Reuse, and Water Demands (SE Spain). *Water,* 11: 1009. https://doi.org/10.3390/w11051009.

Jodar-Abellan, A., López-Ortiz, M.I. & Melgarejo-Moreno, J., 2019b. Wastewater Treatment and Water Reuse in Spain. Current Situation and Perspectives. *Water,* 11: 1551. https://doi.org/10.3390/w11081551

Juran, L., MacDonald, M.C., Basu, N. B., Hubbard, S., Rajagopal, R., Rajagopalan, P. & Philip, L., 2017. Development and application of a multi-scalar, participant-driven water poverty index in post-tsunami India. *International Journal of Water Resources Development*, 33(6): 955-975. https://doi.org/10.1080/07900627.2016.1253543.

Kiani-Harchegani, M. & Sadeghi, S.H., 2020a. Practicing land degradation neutrality (LDN) approach in the Shazand Watershed, Iran. *Science of the Total Environment*, 698: 134319. https://doi.org/10.1016/j.scitotenv.2019.134319.

Kiani-Harchegani, M. & Sadeghi, S.H., 2020b. Soil quality analysis of the Shazand watershed ecosystem. *Iranian Journal of Soil and Water Research*, 50 (800784): 1843-1854.

https://dx.doi.org/10.22059/ijswr.2019.272372.668083.

Kiani-Harchegani, M., Sadeghi, S.H., Singh, V.P., Asadi, H. & Abedi, M., 2019. Effect of rainfall intensity and slope on sediment particle size distribution during erosion using partial eta squared. *Catena*, 176: 65-72. https://doi.org/10.1016/j.catena.2019.01.006.

Koirala, S., Fang, Y., Dahal, N.M., Zhang, C., Pandey, B. & Shrestha, S., 2020. Application of Water Poverty Index (WPI) in Spatial Analysis of Water Stress in Koshi River Basin, Nepal. *Sustainability*, 12(2): 727. https://doi.org/10.3390/su12020727.

Kojiri, T., 2008. Importance and necessity of integrated river basin management. *Physics and Chemistry of the Earth, Parts A/B/C*, 33(5): 278-283. https://doi.org/10.1016/j.pce.2008.02.001.

Kumar, V., Parihar, R.D., Sharma, A., Bakshi, P., Singh Sidhu, G.P., Bali, A.S., Karaouzas, I., Bhardwaj, R., Thukral, A.K., Gyasi-Agyei, Y. & Rodrigo-Comino, J., 2019. Global evaluation of heavy metal content in surface water bodies: A meta-analysis using heavy metal pollution indices and multivariate statistical analyses. *Chemosphere,* 236: 124364. https://doi.org/10.1016/j.chemosphere.2019.124364

Lawrence, P.R., Meigh, J. & Sullivan, C., 2002. The water poverty index: an international comparison. Keele, Staffordshire, UK: Department of Economics, Keele University.

Manandhar, S., Pandey, V.P. & Kazama, F., 2012. Application of water poverty index (WPI) in Nepalese context: A case study of Kali Gandaki River Basin (KGRB). *Water Resources Management*, 26(1): 89-107. https://doi.org/10.1007/s11269-011-9907-x.

Minea, G., Ioana-Toroimac, G., Moro, G., 2019. The dominant runoff processes on grassland versus bare soil hillslopes in a temperate environment - An experimental study. *Journal of Hydrology and Hydromechanics,* 67: 8. https://doi.org/10.2478/johh-2019-0018

Minea, G. & Moroşanu, G., 2014. Research of water balance at hydrological micro-scale in the Aldeni experimental basin (Romania). Forum geografic XIII: 185–192. https://doi.org/10.5775/fg.2067-4635.2014.104.d.

Ministry of Energy, 2005. Guide lines and criteria for classification and coding watersheds and study areas in Iran. Publication no. 282-A.178 p.

Mlote, S.D., Sullivan, C. & Meigh, J., 2002. October. Water poverty index: a tool for integrated water management. *3rd WaterNet/Warfsa Symposium 'Water Demand Management for Sustainable Development'*, Dar es Salaam, 30-31 October 2002.

Mohammad Jani, I. & Yazdanian, N., 2014. The analysis of water crisis conjecture in Iran and the exigent measures for its management. *Trend (Trend of Economic Research*, 21 (65-66): 117-144.

Mugagga, F. & Nabaasa, B.B., 2016. The centrality of water resources to the realization of Sustainable Development Goals (SDG). A review of potentials and constraints on the African continent. *International Soil and Water Conservation Research*, 4(3): 215-223. https://doi.org/10.1016/j.iswcr.2016.05.004.

Muoghalu J.I., 2009. Desertification and vegetation monitoring. Environmental monitoring – Vol. II - Desertification and Vegetation Monitoring ©Encyclopedia of Life Support Systems (EOLSS) 2009. (Editor(s): Hilary I. Inyang, John L. Daniels)

OhIsson, L., 2000. Water conflicts and social resource scarcity. *Physics and Chemistry of the Earth, Part B: Hydrology, Oceans and Atmosphere*, 25(3): 213-220. https://doi.org/10.1016/S1464-1909(00)00006-X.

Pandey, V.P., Babel, M.S., Shrestha, S. & Kazama, F. 2011. A framework to assess adaptive capacity of the water resources system in Nepalese river basins. *Ecological Indicators*, 11(2): 480-488. https://doi.org/10.1016/j.ecolind.2010.07.003.

Pardoe, J., Conway, D., Namaganda, E., Vincent, K., Dougill, A.J. & Kashaigili, J.J., 2018. Climate change and the water–energy–food nexus: insights from policy and practice in Tanzania. *Climate Policy*, 18(7): 863-877. https://doi.org/10.1080/14693062.2017.1386082.

Peel, M.C., Finlayson, B.L. & McMahon, T.A., 2007. Updated world map of the Köppen-Geiger climate classification. *Hydrology and Earth System Sciences*, 11(5): 1633–1644. https://doi.org/10.5194/hess-11-1633-2007.

Rijsberman, F.R., 2006. Water scarcity: fact or fiction? *Agricultural Water Management*, 80(1-3): 5-22. https://doi.org/10.1016/j.agwat.2005.07.001.

Rodrigo-Comino, J., López-Vicente, M., Kumar, V., Rodríguez-Seijo, A., Valkó, O., Rojas, C., Pourghasemi, H.R., Salvati, L., Bakr, N., Vaudour, E., Brevik, E.C., Radziemska, M., Pulido, M., Di Prima, S., Dondini, M., de Vries, W., Santos, E.S., Mendonça-Santos, M. de L., Yu, Y., Panagos, P., 2020. Soil Science Challenges in a New Era: A Transdisciplinary Overview of Relevant Topics. *Air, Soil and Water Research*, 13: 1178622120977491. https://doi.org/10.1177/1178622120977491.

Salvati, L. & Carlucci, M., 2016. Patterns of Sprawl: The Socioeconomic and Territorial Profile of Dispersed Urban Areas in Italy. *Regional Studies*, 50: 1346–1359. https://doi.org/10.1080/00343404.2015.1009435

Shakya B., 2012. Analysis and mapping water poverty of Indrawati Basin. World Wide Fund for Nature Nepal Report, 70 pp.

Smakhtin, V.U., 2001. Low flow hydrology: a review. *Journal of Hydrology*, 240: 147- 186. https://doi.org/10.1016/S0022-1694(00)00340-1.

Smedema, L.K., 2003. Irrigated agriculture in Iran: a review of the principal sustainability, reform and efficiency issues. 28 pp.

Sullivan, C., 2002. Calculating a water poverty index. *World development*, 30(7): 1195-1210. https://doi.org/10.1016/S0305-750X(02)00035-9.

Sullivan, C.A. & Jemmali, H., 2014. Toward understanding water conflicts in MENA region: a comparative analysis using water poverty index. In: *Economic Research Forum*. Working Paper (Vol. 859), 27 pp.

Sullivan, C.A., Meigh, J.R. & Giacomello, A.M., 2003. The water poverty index: development and application at the community scale. *Natural Resources Forum,* 27 (3): 189-199. Oxford, UK: Blackwell Publishing Ltd.

Sullivan, C.A., Meigh, J. & Lawrence, P., 2006. Application of the Water Poverty Index at Different Scales: A Cautionary Tale. In: Memory of Jeremy Meigh who gave his life's work to the improvement of peoples lives. *Water International*, 31(3): 412-426. https://doi.org/10.1080/02508060608691942.

Sullivan, C., Meigh, J. & Fediw, T., 2002. Derivation and testing of the water poverty index phase 1. Final report, volume 1 – overview, center for ecology & hydrology (CEH). *International Development and the Natural Environment Research Council*, UK.

Taghipour, M. & Sarchoghaei, J.A., 2015. Evaluation of Tourist Attractions in Borujerd County with Emphasis on Development of New Markets by Using Topsis Model. *Science Journal of Business and Management*, 3(5): 175.

Thakur, J.K., Neupane, M. & Mohanan, A.A., 2017. Water poverty in upper Bagmati River basin in Nepal. *Water Science*, 31(1): 93-108. https://doi.org/10.1016/j.wsj.2016.12.001.

UNCED. 1992. United Nations Conference on Environment & Development Rio de Janerio, Brazil, 3 to 14 June 1992 AGENDA 21.

van der Vyver, C., 2013. Water poverty index calculation: additive or multiplicative function?. *Journal of South African Business Research*, 2013. ID 615770, 1-11.

Van Ty, T., Sunada, K., Ichikawa, Y. & Oishi, S., 2010. Evaluation of the state of water resources using Modified Water Poverty Index: A case study in the Srepok River basin, Vietnam–Cambodia. *International Journal of River Basin Management*, 8(3-4): 305-317. https://doi.org/10.1080/15715124.2010.523004.

Vargas-Pineda, O.I., Trujillo-González, J.M., Torres-Mora, M.A., 2020. Supply–Demand of Water Resource of a Basin With High Anthropic Pressure: Case Study Quenane-Quenanito Basin in Colombia. *Air, Soil and Water Research*, 13: 1178622120917725. https://doi.org/10.1177/1178622120917725.

Viviroli, D., Weingartner, R. & Messerli, B., 2003. Assessing the hydrological significance of the world's mountains. *Mountain Research and Development*, 23(1): 32-40. https://doi.org/10.1659/0276-4741(2003)023[0032:ATHSOT]2.0.CO;2.

WCED, S.W.S., 1987. World commission on environment and development. *Our common future*, 17: 1-91.

Weststrate, J., Dijkstra, G., Eshuis, J., Gianoli, A. & Rusca, M., 2019. The Sustainable Development Goal on Water and Sanitation: Learning from the Millennium Development Goals. *Social Indicators Research*, 143(2): 795-810. https://doi.org/10.1007/s11205-018-1965-5.

WHO/UNICEF. 2000. World Health Organization/United Nations Childrens Fund. Joint monitoring programe for water supply and sanitation. Global Water Supply and Sanitation Assessment Report.2000.

Wurtz, M., Angeliaume, A., Herrera, M.T.A., Blot, F., Paegelow, M., & Reyes, V.M., 2019. A spatial application of the water poverty index (WPI) in the State of Chihuahua, Mexico. *Water Policy*, 21(1): 147-161. https://doi.org/10.2166/wp.2018.152.

Yegemova, S., Kumar, R., Abuduwaili, J., Ma, L., Samat, A., Issanova, G., Ge, Y., Kumar, V., Keshavarzi, A. & Rodrigo-Comino, J., 2018. Identifying the key information and land management plans for water conservation under dry weather conditions in the Border areas of the Syr Darya River in Kazakhstan. *Water*, 10(12): 1754. https://doi.org/10.3390/w10121754.