INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 5, No. 4, p. 183-194, 2014
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Assessing of canadian water sustainability ındex (CWSI) in ahwaz county located in south west of Iran

Jalal Attari[1], Seyed Ali Mojahedi[2], Amirpouya Sarraf[3]

[1] *Department of Water and Environmental Engineering, Shahid Beheshti University, Tehran, Iran*

[2] *Water Engineering Department, University of Tehran, Tehran, Iran*

[3] *Department of Civil Engineering, Roudehen Branch, Islamic Azad University, Roudehen, Iran*

Article published on October 21, 2014

Key words: Water Resources Sustainability index, CWSI, Ahwaz County, Iran.

Abstract

Sustainability of water resources is vital especially for developing countries such as Iran which are located in the Middle East and North Africa (MENA) region where water is scarce. To balance the high demand of water for economic growth and at the same time preserve the environment for present and future generations, sustainability of water resources should be considered by monitoring and data mining. For this purpose, several quantified indices have been proposed and applied worldwide recently. In this paper, the Canadian Water Sustainability Index (CWSI) proposed by PRI, has been trailed for the case of Ahwaz County, a community located in South West of Iran fed by Karun River. Required data for the composite CWSI score which is the average of five major theme-based components (i.e. resource, ecosystem health, infrastructure, human health capacity) was collected according to the PRI evaluation method. In addition to the standardized CWSI, the final index was also calculated considering weight estimation for the five components by pair-wise comparison, using Expert Choice version 2000. Results showed that application of this index as a policy tool, with some modifications in weights, was satisfactory for the educational case study and could be replicated for other communities in Iran.

***Corresponding Author:** Amirpouya Sarraf ✉ amirpooya@hotmail.com

Introduction

Water Sustainability is vital for preservation of this resource in the world. This is more prominent for developing countries and especially for those located at the Middle East and North Africa (MENA) Region, where water is scarce (World Bank, 2007).

With increasing the population, arising of life standard level and full scaled development, especially in urban areas, water demand is increased for all (various) consumption sectors. The water is one of the main factors that the development is not possible without it. Water resources must be developed and managed in a sustainable manner to ensure the social, economic and environmental development of the present and future generations are not jeopardized. Iran is one of these countries which suffers from limited renewable water supply while intends to develop its economy which highly demands water resources. To balance these two contradictory factors and at the same time preserve the environment for present and future generations, sustainability of water resources should be considered by monitoring and data mining.

The Brundtland Commission's report "Our Common Future" (WCED, 1987) promotes the all encompassing concept of sustainable development. To quote: "Humanity has the ability to make development sustainable to ensure that it meets the needs of present without compromising the opportunities of future generation to meet their own needs".

Loucks (2011) has mentioned that recently strong emphasis has been placed on the adaptive capacity of water resource systems, which refers to measures that reduce the vulnerability of systems to actual or expected future changes. Vulnerability is the magnitude of an adverse impact on a system. Thus, the objective is to look for policies that reduce the adverse impacts of actual and expected events, and to the extent possible, meet the water requirements for humans and the environment, now and in the future. To accomplish this goal, it is necessary to have performance measures or indexes that allow the evaluation and comparison of water resources systems under different scenarios. The objective of this paper is to present a water resources sustainability index that makes it possible to evaluate and compare alternative management policies for water resources systems.

Sustainability indicators and composite index are increasingly recognized as a useful tool for policy making and public communication in conveying information. They simplify, quantify, analyze and communicate otherwise complex and complicated information. There are currently several initiatives working on the frame works for sustainable development in different fields such as environment (Singh *et al.,* 2008).

Mays (2007) defines water resources sustainability as : "the ability to use water in sufficient quantity and quality from the local and global scale to meet the needs of humans and environmental ecosystem for the present and future to sustain life, and to protect humans from the damages brought about by natural and human-caused disasters that affect sustaining life." Whichever definition is used, there is a need for measurement or quantification of water impacts on the environment for present and future generations so that plans for sustainable water resources management can be carried out accordingly.

Loucks and Van Beek (2005) defined sustainable water resources systems as "water resources systems designed and managed to fully contribute to the objectives of society, now and in the future, while maintaining their ecological, environmental and hydrological integrity." Most definition of sustainable water resources is so broad that they defy any measurement or quantity definition.

"Sustainable water use" has been defined by Theodore Heintz HJr (2004) as "the use of water that supports the ability of human society to endure and flourish into the indefinite future without undermining the integrity of the hydrological cycle or the ecological systems the depend on it." The following sustainability requirements were presented:

1. A basic water requirement will be guaranteed to all humans to maintain human health.
2. A basic water requirement will be guaranteed to restore and maintain the health of ecosystems.
3. Water quality will be maintained to meet certain minimum standards that will vary depending on location and how the water is to be used.
4. Human actions will not impair the long-term renewability of freshwater stocks and flows.
5. Data on water resources availability, use, and quality will be collected and made accessible to all parties.
6. Institutional mechanisms will be set up to prevent and resolve conflict over water.
7. Water plans and decision making will be democratic, ensuring representation of all affected parties and fostering direct participation of affected interests.

Loucks and Gladwell (1997) presented that guidelines for the development and management of sustainable water resources systems can be defined with respect to:

a. The design, management and operation of physical infrastructure
b. The quality of environment or health of ecosystems
c. Economics and finance
d. Institutions and society
e. Human health and welfare
f. Planning and technology

Considering what was said, sustainability indices provide ways we can measure relative level of sustainability. They can be defined in a number of ways. One way is to express relative levels of sustainability as separate or weighted combinations of reliability, resilience and vulnerability measures of various criteria that contribute to human welfare. These criteria can be economic, environmental, ecological and social. To do this one must first indentify the overall set of criteria and then for each one decide which range of values are satisfactory and which ranges are not. These decisions are subjective. They are generally based on human judgment or social goals, not scientific theory.

An Overview of water Sustainability Indices

Water sustainability indices include several components and indicators concerning to water multi-disciplinary characteristics, such as; water resources, economic and financial, environmental, infrastructures and etc. that depending on various conditions may be changed, added or deleted. Sustainability indicators and composite index are increasingly recognized as a useful tool for policy making and public communication in conveying information. They simplify, quantify, analyze and communicate otherwise complex and complicated information. There are currently several initiatives working on the frameworks for sustainable development in different fields.

From the perspective of sustainability, we need to go beyond quantity and quality. Sustainability literally refers to the maintenance or sustenance of something. It refers to the goal of attaining or maintaining the quality of all life in the long term. Sustainability represents an optimal end state; however this is neither fixed nor constant but is rather time - and space-relevant. Sustainable development therefore offers the direction needed to deliver on selected sustainability goals. It is the process through which specific targets are set, actions planned and strategies implemented in order to deliver on current needs. Various assessment tools may be used in order to be able to determine whether sustainability goals are being achieved generally falling under the headings of simulation, criteria and indices.

Kumambala *et al.*, (2008) developed a framework of water sustainability indicators at basin scale that could assist in decision making for multipurpose water resources development in Malawi. In this study they have demonstrated that through the integration of knowledge from hydrology, human health and environment, Water Sustainability Index (WSI) for policy and decision making can be developed. The WSI can advance the assessment of development of multipurpose water projects by utilizing a multidisciplinary and integrated process. Integrated process of sustainability indicators can influence project development by helping to identify viable design alternatives that are environmentally and socially acceptable, and provide opportunities to meet varying demands within the basin.

Carvalho *et al.,* (2008) adopted a system approach to develop a composite index for the Sustainability Index for Integrated Urban Water Management (SIUWM) that be used to assess the potential of a town or city to be sustainable. This index is composed of 5 components which disaggregate into 20 indicators and ultimately into 64 variables. This index was applied for two Southern African urban centers, Smith and Lant (2004) to test the applicability and validity of the index and to compare their sustainability index scores.

Carden *et al.,* (2007) adopted a structured framework for defining the system and identifying the indicators for the "sustainability index" model. This model has some steps for developing a meaningful water sustainability index, included: developing a theoretical framework, indicators selection, data processing and application and interpretation. The starting point is to specify the overall purpose and here the purpose is to assess the water resources sustainability for multipurpose water resources development. This model is shown in Fig. (1):

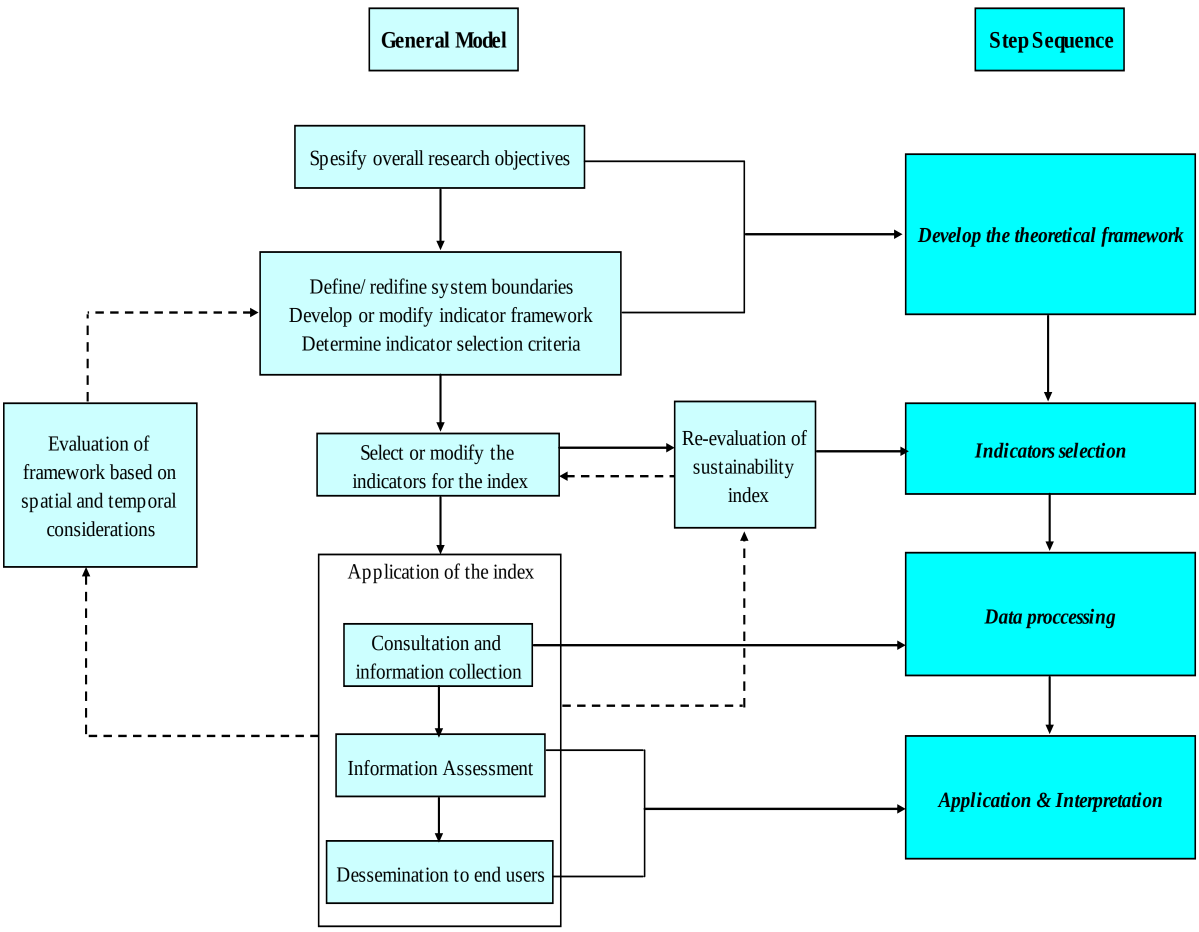

Fig. 1. The Flowchart for Determination of Water Sustainability Index.

Another remarkable point in determination of sustainability index is the scale selection for index, for example, a river basin area or a residential area or a community? Depending on the scale, type and number of data is variable.

After specifying the index framework, its components and indicators, required data were collected, normalized, standardized and analyzed. Because of combination and comparing the indices, the indicator value range must be the same.

Falkenmark (1988) focuses on the role water plays in sustainable development. She identifies various conditions for sustainability. Soil permeability and water retention capacity have to be secured to allow rainfall to infiltrate and be used in the production of biomass on a large enough scale for self-sufficiency.

The Canadian Water Sustainability Index (CWSI) is one of water sustainability index that has been developed by the Policy Research Initiative (PRI) for evaluating the well-being of Canadian communities with respect to freshwater resources. This index integrates a range of water-related data and information into of 15 indicators, classified in 5 major theme-based components that are: resources, ecosystem health, infrastructure and human health capacity. The CWSI which is the arithmetic average of scores of the indicators provides a holistic profile of a community's key water issues, allowing for comparison and analysis.

In this index, the system model for the SIUWM was adapted from the life cycle assessment (LCA) approach used by Lundin and Morrison (2002) for the development of environmental sustainability indicators for urban water systems.

The SIUWM was ultimately designed in a similar manner to the well-recognized Environmental Sustainability Index (ESI) developed by the Yale Centre for Environmental Law and Policy. The ESI provides a powerful tool for analytically assessing environmental sustainability and as such is a strong policy-guiding instrument. The scale of implementation between the ESI and SIUWM however differs considerably. The ESI targets national-level policy whilst the SIUWM aims to improve management of water at sector level, thereby requiring a different approach to indicator development and selection. Nevertheless, there is a commonality of purpose in the two indices with respect to informing on progress towards sustainability, aligning with existing policy and highlighting gaps in legislation.

In order to account for the dimensions of sustainability, the SIUWM was designed using the similar five broad components of the ESI:

1. Social/cultural: social fairness and equitable resource distribution.
2. Economic: economically sound principles, economic growth and cost returns.
3. Environmental: environmental protection and preservation of ecological systems.
4. Political: support and international stewardship.
5. Institutional/technological: capacity and progress

64 selected variables that were aggregated into 20 indicators as shown in Table 3. The indicators are both qualitative and quantitative over widely differing ranges. Some sort of standardization was therefore required to place them within comparable scales. This was achieved by expressing each indicator on a scale from 0-5 where the values were based on pre-established reference points or standards, like WHO guidelines. The score for each indicator is then determined from the sum of the variable values multiplied by their respective weightings, expressed as a percentage by multiplying by 100. The scores for the five components– and ultimately the SIUWM – are determined in a similar manner and based on Equation (1). Results of the SIUWM application demonstrate that the index could highlight areas for

improvement and ultimately guide appropriate action and policy-making towards better service delivery and improved resource management. The Canadian Water Sustainability Index (CWSI) has been developed by the Policy Research Initiative (PRI) for evaluating the well-being of Canadian communities with respect to fresh water resources. This index integrates a range of water-related data and information into a series of 15 indicators, classified in five major theme-based components (i.e. resource, ecosystem health, infrastructure, human health capacity). The CWSI which is the arithmetic average of scores of the indicators provides a holistic profile of a community's key water issues, allowing for comparison and analysis (PRI, 2007). As mentioned above the main purpose of this research is to assess the water resources sustainability and well being in the Ahwaz County located in South West of Iran fed by Karun River. In the absence of any local index, the Canadian Water Sustainability Index (CWSI) has been used.

Material and methods

In the absence of any local index, the CWSI has been trialed for the Ahwaz County in Iran. Most of the water and wastewater data for calculation CWSI indicators in this community were collected form the local (AWWC, 2006) and national sources (NWWEC, 2006), while the demographic information were acquired from the latest census carried out (SCI, 2006). In this study, the standard CWSI score which is the simple average of five major theme-based components was first calculated according to the PRI evaluation method. Furthermore, the index was also calculated considering weight adjustments. For this purpose, importances of five components relative to each other were first estimated on the basis of an internal data analysis and weights were further calculated by pair-wise comparison, using Expert Choice version 2000. In this regard, arithmetic weights were considered for the components. On this basis the final CWSI of the five components were calculated according to the following formula:

$$CWSI = \frac{\sum_{i=1}^{N} w_i \times X_i}{\sum_{i=1}^{N} w_i} \qquad (1)$$

Where: X_i refers to component i of the index for a particular community

W_i is the weight applied to that component. Finally the standardized CWSI score was compared with the weighted average.

Study Area

Ahwaz City is the center of Khuzestan province, located in South West of Iran (Fig. 2). Ahwaz County (City of Ahwaz and subsidiary cities) has a population of 1,166,287 people (NWWEC, 2006). Karun River, the most important river of Iran, passes through this county which is located about 12 meters above the sea level (Fig. 2). This river is the main source of supplying drinking water to the citizens and abstraction from the ground water resources is negligible. Total length of the water supply network is 2349 km which covers 278,000 connections (AWWC, 2006).

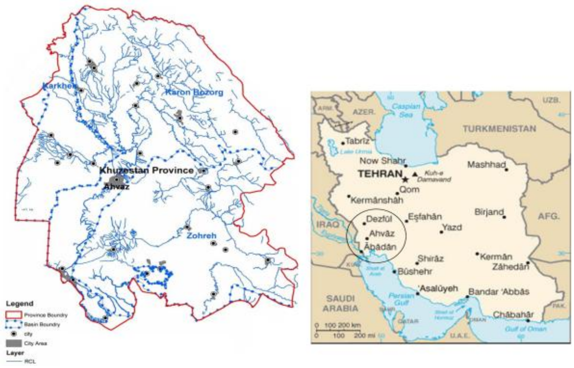

Fig. 2. Location of Ahwaz County in Khuzestan Province – Iran.

The flow rate of Karun river, measured at Ahwaz station, are 90 m^3/s in low water seasons, 2500 m^3/s high water season and about 5000 m^3/s in maximum floods. This River suffers from discharge of pollution loads from industrial, agricultural, agro-industrial and domestic sources. Increasing water withdrawal from and wastewater discharge to the river has endangered the aquatic life of this important ecosystem. Furthermore, the drinking and in-stream water quality standards have been violated in many instances (Karamouz *et al.,* 2008).

Result and discussion

The indicators of CWSI for Ahwaz County were calculated according to the mentioned methodology. Results for estimation of each of the 15 sub-components, grouped in the 5 thematic components, are summarized below.

1. Resource*:* This component, evaluated at the river basin scale, scores the natural endowment of freshwater and comprises three indicators of Availability, Supply and Demand as follows:

1. a. Availability: This indicator assesses the annual amount of renewable fresh water available which is 21.8 BCM for the population of 1,166, 287 persons for Ahwaz County. Considering the Falkenmark water stress indicator as a bench mark, the score for this component would be $R_a = 100$.

1. b. Supply: This indicator considers the seasonal variability of the supply only as the ground water resources depletion does not occur in Ahwaz. Using discharge time series of the Karun River at Ahwaz location, run-offs exceeded 5% and 95% of the year are 244 (m^3/s) and 1715 (m^3/s) respectively. By dividing the last tow fig.s, the score for this component would be $R_s = 0$.

1. c. Demand: This indicator assesses the current level demand of water on the basis of water license allocations. In Ahwaz County, the total amount of water consumed for municipal, irrigation and industrial use were 1.3 BCM in 2006. This amount in relation to the total amount of renewable freshwater (21.8 BCM), scores $R_d = 94$.

2. Ecosystem Health: This component examines the health of the river basin's aquatic system with three indicators of Stress, Quality and Fish as mentioned below:

2. a. Stress: This indicator is intended to reflect the pressures imposed on ecosystem by pollution as well as excessive water use. In Ahwaz County, 20.5 BCM of water is removed from the ecosystem which leads to score of $E_s = 85$.

2. b. Water Quality: This indicator assesses the quality of water with respect to protection of aquatic life. For this purpose CWSI relies on the Water Quality index (WQI). This tool was also employed for the case of Ahwaz County which provided a result of $E_{wq}=85$.

Water quality is an important factor for preservation of human life and aquatic ecosystem. Even if water may be available in adequate quantities, its un-suitable quality limits the uses that can be made of it. Although the natural ecosystem is in harmony with natural water quality, any significant changes to water quality will usually be disruptive to the ecosystem.

Quality of surface water is affected by the environment, climate condition, and seasonal variation, and land-use, natural and man-made pollution of watershed. Considering growth of water use for different consumptions (e.g. domestic, agricultural, and industrial) and discharge of wastewaters in rivers, several water quality parameters are usually monitored along rivers in different periods. However, there is a need to combine results of such measurements in the form of composite indices which are understandable to political decision makers, non-technical water mangers and general public (Simoes *et al.,* 2008).

A number of indexes have been developed to summarize water quality data in an easily expressible and easily understood format (Sanchez *et al.,* 2007). A water quality index provides a convenient means of summarizing complex water quality data and facilitating its communication to a general audience.

Furthermore, it provides a platform for comparison of the water quality among different sites with an ultimate view of classification of water quality in rivers.

National Sanitation Foundation of the USA developed the Water Quality

Water Quality Index (CCMEWQI).This simple tool has been devised as an alternative for traditional reports on water quality trends which typically consisted of variable-by-variable, water-body-by-water-body statistical summaries (CCME, 2001).

The CCME Index incorporates three elements: Scope (F1) - the number of variables not meeting water quality objectives; Frequency (F2) - the number of times these objectives are not met; and Amplitude (F3) - the amount by which the objectives are not met. The CCME WQI is then calculated as:

$$\text{CCME WQI} = 100 - \frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732} \qquad (2)$$

The index produces a number between 0 (worst water quality) and 100 (best water quality). These numbers are divided into 5 descriptive categories to simplify presentation. The CCME WQI allows the index user to select the objective set on which to compare measured water quality. This is a design feature that increases the versatility of the index considerably but allows for misuse (CCME, 2001).

In the absence of any local index, the NSF WQI as well as CCME WQI has been trailed for Karun River System in Iran. Most of the existing data for calculation of these indices were collected form the Khuzestan Water and Power Authority (KWPA) and Iran Water Resources Management Company (IWRMC). A list of water quality parameters for calculation of CCME WQI for Karun River is given in Table 2. The Objectives, mentioned in this Table, were adopted from Falkenmark (1988).These indices were calculated using existing data and their variations have been analyzed and compared in 9 stations, located along the river, for different periods.

For calculation of the CCME WQI, a spread sheet in EXCEL developed by (CCME, 2001) was employed.

2. c. Fish: This indicator reflects the health of native fish species that are economically and culturally important for the community. These fish population trends are not considered to have much influence in Ahwaz County and therefore collection of limited data for estimation of this indicator was not considered.

In the Karun River, BOD, DO, Na, Cl parameters were found to be in an acceptable range, with respect to water quality criteria. The high value of Focal Coliform is an indication of un-treated wastewater discharge to this river. Furthermore, the TDS value is also considerably higher than the water quality criteria. This is attributed mostly to drainage of agricultural return flow and is to an extent stemmed from salinity of parts of the upper watershed.

Fig. 2 depicts temporal variation of the CCME water quality index for 9 stations located along the Karun River system. The temporal trend lines of this index are found to be generally similar, despite their locations. Some minor discrepancies are attributed to missing data. Each line shows a rapid decline in the 2nd half of the study period which is classified as "Marginal" and "Poor". This is because of inclusion of heavy metal and Focal Coliform parameters data which has decreased the value of the index. Typically, the Water Quality Index decreased towards the downstream end of the Karun River. The lowest values were observed at Stations 2, 7 and 8 because of some local wastewater discharge and agricultural return flows. The Index at these stations is considered to be in "poor" category according to CCME classification. Further to decline of WQI in 2006-2007, a more rigor policy for the Karun River protection was enforced by the Department of Environment of Iran.

3. Infrastructure: This component assesses the state of water and wastewater infrastructure by combination of its ability to meet future demand, its condition and the level of treatment it provides as follows:

3. a. Demand: This indicator assesses the capacity of the water infrastructure to meet future demand due to population growth. The Water distribution network of the Ahwaz county currently covers the entire community but this would not be enough for a population growth of about 1.28% in this area and therefore $I_d = 8$.

3. b. Condition: This indicator reflects the condition of water and wastewater infrastructure by considering the system losses. Unfortunately, the un-accounted for water in Ahwaz network is more than the limiting value of 25% and therefore $I_c = 0$.

3. c. Treatment: This indicator focuses on the level of wastewater treatment. In Ahwaz County, 85% of populations are connected to the municipal sewers but only 28% receive secondary treatment in which insoluble matter and biological impurities and therefore $I_t = 18.6$.

4. Human Health: This component considers three issues of Access, Reliability and Impact of water supply which are directly related on the health and well being of the community.

4. a. Access: This indicator measures the amount of potable water which is available to each person. In the Ahwaz County, about 230L/cap/day is available which is larger than the bench mark value of 150L/cap/day and therefore $H_a = 100$.

4. b. Reliability: This indicator reflects reliability of a community's water supply in terms of services disruptions days per person. This fig. for the City of Ahwaz is estimated to be 0.35 day per person which rewards a high score of $H_r = 100$.

4. c. Impact: This indicator assesses the number of registered water borne incidences per 1000 people. Such an official data was not available for the Ahwaz County at the time to the authors.

5. Capacity: This component measures the capacity of the community to manage their water resources in terms of Financial Capacity, Education and Training as mentioned below:

5. a. Financial: This indicator examines the financial capacity of a community to manage water resources in relation to the communities with the highest surplus and debt in the country. Unfortunately, all of the water and wastewater companies in Iran face deficits now days as they are not functioning on a full cost recovery basis. Therefore, the companies with the maximum (-12.45$) and minimum amount of loss (-2.23$) per capita in the country were selected for the sake of this comparison. In the Ahwaz County, the amount of surplus in relation to the expenditures is -8.61$ per capita which leads to a score of $C_f = 38$.

5. b. Education: This indicator considers the level of education in the community to address local water issues. In Iran, 45% (the maximum) and 18% (the minimum) of the population, aged between 20 to 64, have at least high school education. This fig. for the Ahwaz County is 34% and therefore $C_E = 58$.

5. c. Training: This indicator specifically addresses the level of training that water and wastewater treatment plant operators have received. In the Ahwaz water and wastewater company, roughly about 60% of the operators have had no training, 25% had other trainings and 10% have industrial certified trainings. This leads to a score of $C_o = 27.5$.

The results of estimation of the indicators as well as an average of their sub-components are summarized in Table 1. The final CWSI index was first evaluated according to standardized method and then by consideration of weights using Equation 1. Comparison of these results did not show a significant effect once weights were adjusted for this county. Therefore, application of the standardized index is more appropriate especially for intra-community comparison purposes.

Table 1. Results of final CWSI for Ahwaz County.

No.	Component	Indicator	Code	Score	Component Score (W_i)	Component Weight (X_i)	Component ($W_i \times X_i$)
1	Resource	Availability Supply Demand	R_a R_s R_d	100 0 94	64.7	0.329	21.3
2	Ecosystem Health	Stress Quality Fish	E_s E_{wq} E_f	85 50 NA	67.5	0.199	13.4
3	Infrastructure	Demand Condition Treatment	I_d I_c I_t	8 0 18.6	8.9	0.179	2
4	Human Health	Access Reliability Impact	H_a H_r H_i	100 99 NA	99.5	0.17	16.9
5	Capacity	Financial Education Training	C_f C_e C_o	38 58 27.5	41.2	0.122	5
Final CWSI Score				Average = 56.36		Weighted Average = 58.6	

Conclusion

1. Definition and using of index is an appropriate and simple tool in measurement and monitoring of sustainability in water resources. In which could observe sustainability orientation and the results of developing and executive policies on water resources by knowing the index rate and comparing with its temporal and spatial condition in the past and present and concerning it, will done the correction and orientation of the appropriate policies in the future.

2. The assignment of goal has main role in definition of water sustainability index, which according its goal, components and indicators defines. According to aforementioned and previous studies, in the most cases, economical, social, environmental, political and institutional components are the main components of water sustainability index that could have different indicators depending on conditions, case study and other effective factors. An integrated and general index has the skill of using in different regions and conditions, could consider various rational weights regards to sensitivity of different components and indicators, and thus, covered the components and indicators heterogeneity. The indices should be quantitative to facilitate understanding and sensitivity transfer. However, the quality components must be quantities that result in restriction of indicators selections. It is necessary the index values classified to identify different degrees of sustainability.

3. As a conclusion, measuring, calculation and monitoring of water resources sustainability index is very important concerning frequently drought, climate change and degradation of water resources quantity and quality, especially in MENA region. The trend of water resources sustainability variation has identified according to this Index and comparing its value in past and present condition. According to this, it is possible to have a logical planning for water resources management in future and promote its sustainability. In addition, design a monitoring plan and data collection for indicators without information. Besides, most the studies conducted so far to evaluate sustainability considered surface water resources. It is necessary to consider ground water resources in stability index measurement according to its critical role especially in MENA region.

In this paper, the Canadian Water Sustainability Index (CWSI) was used for the case of Ahwaz County located in the South western part of Iran. Results showed that:

4. In the absence of any local water sustainability index, the first attempt to apply CWSI index for the case study in Iran was found satisfactory, despite economical and ethical differences.

5. The final standardized CWSI score, calculated for Ahwaz, were found to be in the range of the fig.s calculated for the six communities in Canada.

6. The final CWSI score for Ahwaz County has most benefited form the large amount of resources component while the poor infrastructure component has dramatically lowered the average score. To improve this, wastewater treatment plants with large investments are currently under construction.

7. Modifications of the CWSI index by weight adjustments, using pair-wise, did not show a significant effect. Therefore, application of the standardized index is more appropriate especially for intra-community comparison purposes.

8. This educational case study can be replicated for other communities in Iran which further facilitates comparison of the indices.

References

AWWC. 2006. Ahwaz Water and Wastewater Company. http://www.aww.co.ir

Canadian Council of Ministers of the Environment (CCME). 2001. Canadian Water Quality guidelines for the protection of aquatic life. CCME Water Quality Index 1.0, User's Manual and Technical Report.

Carden K, Armitage N, Carvalho De, Stoeckigt T. 2007. Development of a "sustainability index" for integrated urban water management in the low-income areas of South Africa, IMESA.

Carvalho De, Carden KJ, Armitage NP. 2008. Application of a sustainability index for integrated urban water management in Southern African cities: Case study comparison–Maputo and Hermanus, (Special WISA 2008 edition), Water SA, **35(2)**.

Falkenmark M. 1988, Sustainable development as seen from a water perspective. In Perspectives of Sustainable Development, Stockholm Studies in Natural Resources Management, **1**, 71 - 84.

Karamouz M, Kerachian R, Akhbari M, Hafez B. 2008. Design of river Water Quality Monitoring Networks: A Case Study, Environ Model Assess, Springer. http://dx.doi.org/10.1007/s10666-008-9172-4

Kumambala PG, Ervine A, Turner S. 2008. Water resources sustainable decision making for Malawi based on basin hydrology, human health and environment, U21 Postgraduate Research Conference Proceedings, Water - how need drives research and research underpins solutions to world-wide problems, University of Birmingham, Birmingham, UK.

KWPA. 2008. Khuzestan Water and Power Authority. http://www.kwpa.ir

Loucks DP, Gladwell JS. 1997. Quantifying trends in system sustainability, Hydrological Sciences-Journal-des Sciences Hydrologiques, **42 (4)**, 513 - 530.

Loucks DP, Van Beek E. 2005. Water resources systems planning and management, United Nations Educational, Scientific and Cultural Organization (UNESCO), Paris.

Loucks DP. 2011. Sustainability Index for Water Resources Planning and Management, Journal of Water Resources Planning and Management © ASCE, September / October, 2011.**137**, 381 - 390. http://dx.doi.org/10.1061/(ASCE)WR.1943-5452.0000134

Lundin M, Morrison G. 2002. A lifecycle assessment based procedure for development of environmental sustainability indicators for urban water systems, Urban Water, **4**, 145 - 152.

Mays LW. 2007. Water resources sustainability, McGraw-hill, WEF Press, New York. http://dx.doi.org/10.1029/2007WR006767

Theodore Heintz HJr. 2004. Applying the concept of sustainability to water resources management, Universities Council on Water resources, Water Resources Update, **127**, 6 - 10.

NWWEC. 2006. National Water and Wastewater Engineering Company of Iran. http://www.nww.co.ir

Policy Research Initiative (PRI). 2007. The Canadian Water Resources Sustainability Index (CWSI). PRI Project Report, Ottawa, 1 - 27.

Sanchez E. 2007. Use of Water Quality Index and Dissolved Oxygen Deficit as Simple Indicators of Watersheds Pollution, Journal of Ecological Indicators, **7**, 315 - 328. http://dx.doi.org/10.1016/j.ecolind.2006.02.005

SCI. 2006. Statistical Center of Iran. http://www.sci.org.ir

Simoes FS. 2008. Water Quality Index as a Simple Indicator of Aquaculture Effects on Aquatic Bodies, Journal of Ecological Indicators, **8**, 476 - 484.

Singh RK, Murty HR, Gupta SK, Dikshit AK. 2008. An overview of sustainability assessment methodologies, Journal of Ecological Indicators, Elsevier, 1 - 24. http://dx.doi.org/10.1016/j.ecolind.2008.05.011

Smith ET, Lant C. 2004. Water resources sustainability: A guide to this issue, Universities Council on Water resources, Water Resources Update, **127**, 1 – 5.

World Commission on Environment and Development (WCED). 1987. Our Common Future (The Brundtland Report), Oxford University Press, Oxford, UK.

World Bank. 2007. Making the most of scarcity: Accountability for better water management results in the Middle East and North Africa, MENA Development Report. 1 - 227.