



Analyzing the Impact of E and L Indices on Water Sustainability and Security in the Samian Watershed¹

Fariba Esfandyari Darabad ^{1*}, Behrouz Nezafat Takle ²

¹ Professor of Geomorphology, Department of Natural Geography, Faculty of Social Sciences, University of Mohaghegh Ardabili, Ardabil, Iran.

² Phd student of geomorphology, Faculty of Social Sciences, University of Mohaghegh Ardabili, Ardabil, Iran.

Received Date: 02 January 2025

Accepted Date: 02 February 2025

Abstract

Background and Objective: Water and water governance have attracted much attention as a political concern in recent years. In response to the growing understanding of the water crisis, the literature on water governance has been rapidly increasing over the past two decades. The aim of the present study is to analyze the impact of E and L Indices on water sustainability and security in the Samian Watershed.

Methodology: In this study, environmental indicators and the life index were used to estimate the water security index. The environmental criterion focuses on environmental pressure, vegetation cover, and the percentage of protected areas in the watershed. The parameters of the life standard are related to the quality of human life and evaluate the standard of living and the human development index in the watershed. The pressure parameter is determined by the change in per capita income during the study period. In other words, the water security index uses normalization to assess the sustainability of the watershed.

Results and findings: The results of the standardization of the environmental index showed that the highest score was related to sub-basin 7 with a value of one and the lowest was related to sub-basins 5, 10, 14 and 27. Based on the results of the standardization of the human development index, it was shown that the highest level of human development was related to sub-basins 1, 4, 5, 11, 15, 17, 24 and 27. The lowest level of human development was related to sub-basins 12, 13, 18, 19, 21, 22 and 25. Finally, it is recommended to test and use other methods of estimating the Water Security Index (WSI) in future studies.

Keywords: Evaluation, Life Index, Environmental Index, WSI, Samian.

¹ This article is extracted from the elite research project titled "Assessment and Prioritization of Water Security Index (WSI) in Qarasu Sub-basins" conducted at the University of Mohaghegh Ardabili, Ardabil, Iran. Employer: University of Mohaghegh Ardabili Project, Supervisor: Fariba Esfandiari Darabad, Elite Soldier: Behrouz Nezafat Takleh.

* **Corresponding Author Email** Esfandyari@uma.ac.ir

Cite this article: Esfandyari Darabad, F. and Behrouz Nezafat Takle, B. (2026). Analyzing the Impact of E and L Indices on Water Sustainability and Security in the Samian Watershed. *Journal of Sustainable Urban & Regional Development Studies (JSURDS)*, 6(4), 15-30.

Extended Abstract

Introduction:

Water security is strongly influenced by many factors, including increasing urbanization, economic development, changes in living standards, increasing water pollution, overexploitation of groundwater resources, and climate change. Water security is potentially always at risk from population growth and climate change (Wang et al., 2012). In developed societies, the term water security is defined in terms of environmental sustainability and national security (Dalino, 2010, Patrick, 2011). One of the primary indicators of water security is the provision of sufficient water for humans. Water security is achieved when everyone has access to safe and affordable water sufficient to meet basic needs such as drinking and washing (Rijsberman, 2006). Water security from the World Bank's perspective is the only institution that has quantified water security, which is the annual provision of one cubic meter of drinking and sanitary water for an individual, the provision of 100 cubic meters of sanitary water for individual hygiene, and the provision of 1,000 cubic meters of water for agricultural, industrial, and environmental production. Therefore, from the perspective of this institution, the provision of 1,101 cubic meters per year per person means ensuring water security (Alan, 2001). In the United Nations report, water security is defined as "Water security is the capacity of a society to secure sustainable access to sufficient quantities of water of acceptable quality in order to protect livelihoods, human well-being, and social and economic development. Water security also means ensuring protection against water crises, water pollution, and the preservation of ecosystems in conditions of peace and political stability" (Patrick, 2011).

Methodology:

Water Security Index (WSI)

In order to better assess the health of a watershed, these methods should include quantitative and qualitative criteria that determine the level of sustainability of the watershed. The majority of the information that determines the scores of these sub-criteria is measurable in nature. However, there are sub-criteria that are qualitative and are measured based on the opinions of experts and people involved in the watershed. These qualitative sub-criteria are converted into a numerical scale so that they can be used with quantitative criteria and the final numerical values can be used to calculate the index (Cataño et al., 2009).

Equation 1: $WSI=(H+E+L+P)/4$

Since the criteria, scores are normalized between zero and one, the final index score will also be between zero and one. In order to facilitate the estimation of the level of parameters by users, the quantitative and qualitative parameters were divided into five scores (0, 0.25, 0.50, 0.75 and 1), allowing users to choose the best possible score for each parameter.

To calculate the WSI, basic and available parameters for all watersheds such as the Human Development Index, Biochemical Oxygen Demand over a five-day period BOD5 and EPI are used (Kalizia et al., 2008).

Since watershed management at the local and regional level is more effective in watersheds up to 2500 km², this limit has been suggested for using WSI in assessing watershed sustainability (Scoulier, 1995). However, if the watershed is large, the watershed can be divided into sub-basins to calculate the WSI and the overall score is obtained by summing the WSI scores in the sub-basins (Chavez, 2011).

Since water resources management is a dynamic and comprehensive process, a dynamic approach to the response of the pressure situation for these four criteria is expressed in a

single scheme (Chavez and Alipaz, 2006). The advantage of using the pressure-response approach lies in the fact that it focuses on cause-effect relationships and thus provides a more comprehensive assessment of the watershed than an indicator that only examines the current situation, and helps stakeholders, managers and decision-makers to identify and understand the relationships between parameters (Catano et al., 2011). Since water resources management is a dynamic and comprehensive process, the dynamic pressure-response approach is expressed in a plan for these four criteria (Chavez and Alipaz, 2006). This approach is often used in environmental reporting because it is a simple and useful tool for formalizing environmental problems (Firdas et al., 2014).

Results and Discussion:

The results and analysis of the Water Security Index (WSI) based on the Qarasu-Samian watershed in Ardabil province are presented in Table (5). The results show that in terms of area, sub-basin 8 at Hir station has the largest area among the studied sub-basins with an area of 1.348 km². Also, sub-basin 26 at Shamsabad station has the smallest area among the Qarasu sub-basins with an area of 3.43 km². Vegetation cover is one of the most important effective variables in the water security index. Therefore, studying the vegetation cover of the region in terms of its impact on other environmental components such as geomorphological, hydrological processes and even wildlife is of considerable importance. In the present study, the vegetation cover index (NDVI) was used to assess the overall vegetation cover of the Qarasu-Samian sub-basins. The vegetation cover index image for the year 1402 was taken. Landsat 9 satellite data was also used to prepare a vegetation cover map after making the relevant corrections. The range of this index is between -1 for the minimum level and +1 for the maximum level of photosynthetic activity. The NDVI index is defined as follows. Equation (4)

Land use changes are among the most fundamental changes in the land surface that have significant effects on the environment and natural processes. The land use map for the year 2023 was calculated for the Samian watershed. As can be seen in Figure (3), the land use of the Samian watershed has significant changes at the watershed level. Accordingly, the land use of the Samian watershed was classified into 6 classes: agricultural land, forest, pastures, water area, barren areas and residential areas. According to Figure (3), it was determined that the most common land use in the Samian watershed was agricultural land use. In the second and third categories, forest and pasture land uses accounted for the highest percentage of land use in the Samian watershed. Also, based on the shape, the highest concentration of residential areas is in the center of Ardabil province. In the present study, rangeland and forest land uses were used to evaluate the environmental index for the Water Security Index (WSI). The results of the environmental index evaluation in the studied sub-basins showed that the highest amount of rangeland is in sub-basin 17 with a value of 19.33 percent, and the lowest amount of rangeland is in sub-basins 11 and 14 with a value of 0.04 and 0.07 percent, respectively. In terms of forest areas, the highest percentage of forest lands is related to sub-basin 7 with a value of 60.92 percent, which indicates that sub-basin 7 has rich forest vegetation cover in the Qarasu watershed, and the lowest percentage of forest lands is related to sub-basins 5, 11, and 14 with a value of 0.01, which indicates that the related sub-basins are very poor in terms of forest cover (Table 5).

According to the results of the water security index, after standardizing the environmental indicators and the human development index, these results were obtained, which can be seen in Table (5). The results of the environmental index standardization showed that the highest score was related to sub-basin 7 with a value of one, and the lowest score was related to sub-basins 5, 10, 14, and 27. Based on the results of the standardization of the Human Development Index, it was shown that the highest level of human development is related to

sub-domains 1, 4, 5, 11, 15, 17, 24 and 27. The lowest level of human development is related to sub-domains 12, 13, 18, 19, 21, 22 and 25 (Table 6).

Conclusion:

In the present study, the impact of hydrological index on water security index (WSI) in the sub-basins of Qarasu watershed was evaluated. The results showed that the highest amount of pasture land is in sub-basin 17 with a value of 19.33 percent, and the lowest amount of pasture land is in sub-basins 11 and 14 with a value of 0.04 and 0.07 percent, respectively. In terms of forest areas, the highest amount of forest land is in sub-basin 7 with a value of 60.92 percent, which indicates that sub-basin 7 has rich forest vegetation in the Qarasu watershed, and the lowest percentage of forest land is in sub-basins 5, 11 and 14 with a value of 0.01, which indicates that the related sub-basins are very poor in terms of forest cover.

Declarations

Funding

This research was conducted with the support of the University of Mohaghegh Ardabili.

Authors' Contribution

Authors contributed equally to the conceptualization and writing of the article. All of the authors approved the content of the manuscript and agreed on all aspects of the work declaration of competing interest none.

Conflict of Interest

The authors declare no conflict of interest.

Acknowledgments

We are grateful to all the scientific consultants of this paper.

References

- Adb. (2020). Asian Water Development Outlook, Strengthening Water Security in Asia and the Pacific.
- Alami Heydaranlou, Z., Rezaei, H., Khalili, K. (2023). Evaluation of Water Security Status from the Perspective of Water Resources and Consumption: A Case Study of the Western Sub-basin of Urmia Lake. *Journal of Soil and Water Science*, 1, 145-159.
- Allan, A. (2001). Water Security Policies and Global Systems for Water-Scarce Regions, World Bank.
- Alwathafa, Y, Kawya ,A, AlAreeqe, N, AlAreeqd, A, Al-qatnie, K. (2023), Urban Water Security Index assessment For Ibb City, Yemen: Comprehensive Vision, *Water Conservation & Management (Wcm)* 7(1) 28-35
- Baharshahi, M., Khazimeh Nejad, H., Niknia, N., Khashaei Siouki, A. (2021). Assessment and Ranking of Water Security in Study Areas of South Khorasan Using Grey Analysis. *Journal of Water and Sustainable Development*, 3, 11-22.
- Calizaya A. Chaves H. Bengtsson L. Berndtsson R. and Hjorth P. (2008). Application of the Watershed Sustainability Index to the Lake Poopo Watershed, Bolivia. Unesco/Phi Intern Conf on Water and Global Change. 28 June. Montevideo, Uruguay.

- Catano, N, Marchand, M, Staley, S, Wang, Y. (2009). Development and Validation of the Watershed Sustainability Index (Wsi) for the Watershed Cartago, Costa Rica: Comcure Report.
- Chaves, H, M, Alipaz, S, (2007). An Integrated Indicator Based on Basin Hydrology, Environment, Life, and Policy. The Watershed Sustainability Index. *Water Resources Management* 21:883–895
- Chaves, H, M, L, (2011). Integrated Sustainability Analysis of Six Latin-American Help Basins. Second International Symposium on Building Knowledge Bridges for a Sustainable Water Future. November 21-24. Panama, Republic of Panama
- Chaves, H, M, L, Alipaz, S, (2006). An Integrated Indicator Based on Basin Hydrology, Environment, Life, and Policy. The Watershed Sustainability Index. *Water Resources Management* 21:883-895
- Cook, C. and Bakker, K. (2012). Water security, Debating emerging paradigm. *Global Environmental Change*, 22:102_94.(1)
- Dolhinow, R., (2010). A Jumble of Needs: Women's Activitsm and Neoliberalism in the Colonias of the Southwest. University of Minnesota, Minneapolis, MN
- Esfandiari Darabad, F., Mostafizadeh, R., Abyat, A., Naseri, A. (2021). Determination of Meandering Pattern of Qareh Su River Using Bending Coefficient and Central Angle Indices (Area from Anzab Village to Samian Bridge). *Journal of Applied Geographical Sciences Research*, 21(61), 119-131.
- Esfandiari Darabad, F., Nezafat Takleh, B., Mostafizadeh Raouf, R. (2025). Evaluation of the Impact of Hydrological Index on Water Security Index (WSI) in Sub-basins of Qareh Su Watershed. *Quarterly Journal of Sustainable Urban and Regional Development Studies*, 6(1), 315-335. https://www.srds.ir/article_216650.html
- Firdaus, R, Nakagoshi, N, Idris, A. (2014). Sustainability Assessment of Humid Tropical Watershed: A Case of Batang Merao Watershed, Indonesia. *Procedia Environmental Sciences* 20:722-731
- Hazbavi, Z., Babaei, L., Zarei, Sh., Alaei, N., Malkian, R. (2022). Spatial Heterogeneity of Ecological Security in Samian Watershed, Ardabil Province. *Scientific Quarterly of Regional Planning*, 12(48), 77-94.
- Haziri Niri, H., Jami Odolu, M., Nezafat Takleh, B. (2024). Economic Factors Affecting the Enhancement of Human Development Indices in Ardabil Province. *Quarterly Journal of Sustainable Urban and Regional Development Studies*, 5(3), 205-219. https://www.srds.ir/article_212804.html
- Jabbari Qarabaghi, S., Rezaei, H., Bagheri, A. (2021). Application of Indicator-Based Approach in Water Security Assessment of Urmia Lake Basin. *Iranian Journal of Water Resources Research*, 2, 100-113.
- Maleki, N., Shakeri Bostanabad, R., Salehi Kamroodi, M., Seyed Abadi, S. (2021). Assessment of Composite Water Security Index in Iranian Provinces During 2011-2016 Using Multi-Criteria Analysis Methods. *Water and Sustainable Development*, 21-32.
- Miralles, WF, Sanchez, MR, Muñoz, CR, (2022), Assessing Water Security Through a Set of Consistent Metrics and Application to Water Funds in Latin America, *Current Trends in Civil & Structural Engineering*, 2643_6876, DOI: 10.33552/CTCSE.2022.09.000704
- Nkiaka, E. (2022), Exploring the socioeconomic determinants of water security in developing regions. *Water Policy*, 24 (4). pp. 608-625. ISSN 1366-7017
- Olsonoski, A., & Gianoli, A. (2024). Water management for flood control in New Orleans: Key factors contributing to institutional inertia. *Cities*.

- Patrick, R.J., (2011a). Enhancing water security in Saskatchewan, Canada: an opportunity for a water soft path. *Water International* 36 (6), 748-763
- Rijsberman, FR, (2006). Water scarcity fact or fiction? *Agricultural Water Management* 80, 5-22.
- Salami Sarmast, S., Zahraei, Sh. (2021). Assessment of Water Security in Iran at the Provincial Level Using Composite Index. *Water Management and Irrigation*, 3(11), 617-632.
- Salami, H., Taheri Rikandeh, A. (2019). Measuring the Water Security Status in Iranian Provinces. *Economics and Agricultural Development*, 33, 75-94.
- Seo, YP, Jong, SK , Seungho, L, Joo, HL, (2022), Appraisal of Water Security in Asia: The Pentagonal Framework for Efficient Water Resource Management, *Applied Sciences*, 12(16), 8307; <https://doi.org/10.3390/app12168307>
- Wang, X. J., Zhang, J. Y., Shahid, S., ElMahdi, A., He, R. M., Wang, X. G., & Ali, M. (2012). Gini coefficient to assess equity in domestic water supply in the Yellow River Mitigation and Adaptation Strategies for Global Change, 17(1), 65-75.
- Yazdanparast, M., Ghorbani, M., Salajegheh, A., Karachian, R. (2024). Analysis and Evaluation of Water Security Index (WSI) in Nishabur Plain Watershed. *Journal Name*, 1(11), 116-135.
- Zakeri, M. A., Mirnia, Kh., Moradi, H. R. (2021). Evaluation of Water Security Status in the Great Watershed of Central Iranian Plateau. *Watershed Management Research*, 2(35), 71-87.
- Zarrin, A., Dadashi Rudbari. (2023). Examining the Consequences of Climate Change on Water Security in Iran. *Journal of Water and Sustainable Development*, 1, 37-44.