Biocompounds

www.bic.reapress.com

Biocompd. Vol. 2, No. 3 (2025) 178–185.

Paper Type: Original Article

WEAP Software: A Tool for Integrated Water Resources Management

Aydin Matin[1,*], **Leila Ooshaksaraie[2]**, **Fatemeh Shariati[2]**

[1] Department of Engineering and Environmental Sciences, To.C., Islamic Azad University, Tonekabon, Iran; aidin.matin.eng@gmail.com.

[2] Department of Environment, La.C., Islamic Azad University, Lahijan, Iran; ooshaksaraei@gmail.com; shariat_20@yahoo.com.

Citation:

Received: 27 December 2024 *Revised: 03 April 2025* *Accepted: 23 June 2025*	Matin, A., Ooshaksaraie, L., & Shariati, F. (2025). WEAP software: A tool for integrated water resources management. *Biocompounds, 2*(3), 178-185.

Abstract

The escalating global water scarcity crisis, coupled with significant challenges in managing freshwater resources, has led to the characterization of the current era as one of "wars over water resources." In various countries worldwide, particularly in developing nations, water-related issues encompass water shortages, pollution, the spread of epidemic diseases, habitat degradation, and species extinction. These problems further exacerbate food insecurity, poverty, and hunger. In arid and semi-arid regions, such as Iran, water shortages are particularly acute, underscoring the critical importance of comprehensive attention to all aspects of water resources. Integrated Water Resources Management (IWRM) emerges as an effective approach to address these challenges. As a systematic process for monitoring and allocating water resources to meet social, economic, and environmental objectives in pursuit of sustainable development, IWRM compensates for deficiencies, enhances storage capacity, minimizes adverse impacts from fragmented resource use, and promotes efficient and optimal water management. Today, modeling techniques and advanced software tools greatly assist specialists in implementing IWRM more precisely and effectively. One such tool is the Water Evaluation and Planning System (WEAP) software, developed by the Stockholm Environment Institute (SEI). This paper emphasizes the necessity of robust water resources management while introducing the WEAP modeling platform. It highlights the software's features, capabilities, approach, performance, and structure to familiarize specialists and users with its potential. WEAP offers a broad spectrum of managerial approaches with a holistic and integrated perspective on large-scale water resources and systems, leading to its widespread adoption in research and operational projects across many countries.

Keywords: Integrated management, Water resources, Systematic approach, Water evaluation and planning system software.

1 | Introduction

The allocation of limited water resources, environmental quality, and policies for sustainable water use are issues of growing global concern. Traditional source oriented simulation models, while widely used, are often inadequate for addressing these complexities. Over the past decade, an integrated approach to water development has gained prominence, necessitating the consideration of water supply schemes within the broader context of demand management, water quality, and ecosystem conservation [1]. Fragmented and non-integrated use of water resources leads to problems such as water shortages during droughts due to insufficient surface water, disruptions in agricultural and horticultural productivity, environmental degradation, groundwater depletion, and saltwater intrusion in coastal areas. In multi purpose systems, water

Corresponding Author: aidin.matin.eng@gmail.com

https://doi.org/10.48313/bic.vi.44

demands are met from both surface and groundwater sources. Treated wastewater represents an additional valuable resource in Integrated Water Resources Management (IWRM), particularly in arid and water-scarce countries like Iran. Advantages of reclaimed wastewater include lower costs, absence of sedimentation and evaporation issues, reduced quality concerns, and fewer environmental, social, and cultural challenges. Achieving effective management requires nothing less than proper IWRM. Manual monitoring and implementation by experts and managers alone are time consuming and challenging, involving numerous calculations and measurements. However, modeling tools have significantly simplified these processes for users. Selecting an appropriate model and software is crucial for optimal management outcomes. The Water Evaluation and Planning System (WEAP) serves as a powerful tool for this purpose, widely adopted in water scarce regions, including Arab and African countries, where it has yielded positive results.

1.1 | Motivations for Water Resources Management

In today's world, demand for water resources is steadily increasing. Historically, water was inexpensive and abundant, with wastewater discharged into natural systems without significant costs or penalties. Rising expenses for supply, use, and wastewater disposal now serve as incentives for adopting technologies that promote greater environmental sustainability, helping to mitigate damages to a considerable extent [2].

1.2 | Necessity of Integrated Water Resources Management

Iran is an arid country with precipitation far below the global average. According to the Falkenmark Water Stress Indicator, countries experience water stress when annual per capita renewable water resources fall below 1,700 m^3, chronic scarcity below 1,000 m^3, and absolute scarcity below 500 m^3. Recent data indicate that Iran's national per capita renewable water has declined to approximately 1,500–1,700 m^3/year, with projections suggesting further drops toward absolute scarcity levels in coming years. In major cities like Tehran, local stressors exacerbate the crisis, highlighting severe water shortages. IWRM becomes essential when different sectors require specific water qualities and generate wastewaters with varying chemical compositions and environmental impacts. This dictates sector specific disposal methods, achievable only through efficient, pre-planned management. It is the primary means to prevent waste from traditional practices, reduce environmental degradation, avoid overexploitation, protect natural recharge regimes, and prevent diversion or blockage of recharge pathways [2]. Stakeholder participation including relevant organizations and public involvement is critical and indeed mandatory for success [2].

1.2.1 | Importance of modern tools, such as software, in integrated water resources management

Current water management structures in developing countries like Iran often stem from isolated organizational policies, leading to conflicts and inefficiencies [2]. In contrast, modern IWRM encompasses cultural, environmental, economic, social, potential assessment, and risk considerations all interconnected. This comprehensive advantage is embedded in contemporary software tools like WEAP. The greatest benefit of such tools is fostering unified performance among organizations and users, preventing implementation errors, averting environmental issues, and mitigating subsequent human challenges. This unity arises from standardized judgment and assumption processes in modeling software, now commonplace worldwide with frequent updates reflecting their indispensable role. Beyond improved study and project timelines, these tools offer substantial cost savings.

2 | Introduction to the Water Evaluation and Planning System Software and Its Applications

The WEAP model was developed in the early 1990s by the Stockholm Environment Institute (SEI). It has evolved through versions, including an early DOS-based WEAP99 and the current Windows-based platform (commonly referred to as WEAP21). WEAP is a comprehensive, advanced software tool for simulating water resource systems, with widespread applications in watershed management. As an analytical tool, it evaluates all aspects of water management and alternative strategies, modeling multi purpose and competing demands within integrated water systems [3]. WEAP has been applied in diverse research and operational projects globally. Examples include assessing the causes of volume reduction in the Aral Sea [4] and analyzing the impacts of storage reservoirs on water resources in Kenya's Kitui region [5]. In the Lake Naivasha basin, Kenya, WEAP provided a holistic framework to identify current and future challenges [6]. In South Africa's Olifants basin, it was used for comprehensive supply-demand assessments, including demand management scenarios [7]. In Iran, WEAP has supported studies in basins such as Karkheh and Izeh, evaluating water resource development impacts on future agricultural, domestic, and industrial demands [8]. Another application in the Garmsar plain assessed irrigation networks, recommending optimal cultivated areas and management strategies [9], [3].

2.1 | Objectives of Water Evaluation and Planning System

The WEAP is designed as a practical tool for integrated water resources planning, providing comprehensive assessments of demand, supply, and quality [7].

2.2 | Capabilities and Strengths of Water Evaluation and Planning System

WEAP integrates consumption patterns, water quality, and ecosystem preservation into water planning tools. Its core strength lies in its integrated simulation approach and policy orientation. It simultaneously addresses demand-side factors (consumption patterns, equipment efficiency, reuse, costs, and allocation) and supply side elements (surface flows, groundwater, reservoirs, and transfers). WEAP serves as a virtual laboratory for testing diverse water development and management strategies [1]. The software is comprehensive, transparent, and user-friendly, assisting rather than replacing skilled planners. As a database, it organizes resource and demand data. As a forecasting tool, it simulates demands, supplies, flows, storage, production, treatment, and pollution loads. As a policy analysis tool, it evaluates a wide range of options, incorporating multiple competing uses [1]. WEAP simulates the effects of development projects, such as inter-basin transfers, on existing resources. It interfaces with MODFLOW for groundwater simulations, assessing impacts on aquifers. An economic submodule enables cost-benefit analyses. As an object-oriented, programmable model, WEAP supports integrated management while forecasting demands, resources, flows, storage, pollution dispersion, and yields [7]. WEAP operates on basic water balance principles, applicable to urban, agricultural, single basin, or multi-basin river systems. It simulates a broad array of natural and engineered components, including runoff, baseflow, groundwater recharge, demands, storage, water rights and priorities, reservoir operations, hydropower generation, pollution tracking, water quality, vulnerability assessments, and ecosystem requirements. Simulations are typically monthly, with inputs such as reservoir level-volume-height relationships, sectoral demands, inflow time series, evaporation rates, and seepage. In summary, WEAP enables:

I. Analysis of surface and groundwater balance components at study and basin scales.

II. Evaluation of quantitative and qualitative changes due to withdrawals across the basin.

III. Determination of sectoral shares from basin resources.

IV. Integration with remote sensing tools.

V. Calibration to current basin conditions.

VI. Graphical display of policy impacts on sensitive variables.

VII. Social impact analysis of projects.

VIII. Flexibility to modify components based on basin specific conditions [7].

2.3 | Water Evaluation and Planning System Approach

WEAP relies on fundamental water balance equations and applies to urban/agricultural systems, independent basins, or complex transboundary rivers. It covers issues including sectoral demand analysis, water conservation, water rights and allocation priorities, surface/groundwater interactions, reservoir operations, hydropower, pollution tracking, ecosystem needs, vulnerability assessments, and cost benefit analysis. Data structures and detail levels are easily customizable to fit specific analyses and highlight data limitations [1]. Scenarios build on a reference (current accounts) scenario, which provides calibration and an overview of actual demands, pollution loads, resources, and supplies. Key assumptions define policies, costs, and influencing factors. Scenarios test alternative assumptions or policies on future availability and use, evaluated by water volume, costs/benefits, environmental compatibility, and sensitivity to uncertainties [1]. The analyst defines the system through supply components (rivers, streams, groundwater, reservoirs, treatment plants), withdrawals, transmissions, wastewater treatment, ecosystem demands, water needs, and pollution generation.

2.4 | Simulatable Elements in Water Evaluation and Planning System

The key elements that can be simulated in WEAP include [7]:

I. Rivers
II. Diversions
III. Reservoirs
IV. Groundwater resources
V. Demand sites
VI. Catchments
VII. Runoff and infiltration
VIII. Transmission links
IX. Wastewater treatment plants
X. Return flows from demand sites
XI. Run of river hydropower plants
XII. Required instream flows
XIII. Flow gauges (for comparing simulated and observed flows)

2.4.1 | Water quality simulation

WEAP offers notable water quality simulation capabilities, including modeling of Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), conservative pollutants, and first order decay pollutants. Additionally, environmental requirements (e.g., minimum DO levels downstream of dams) can be incorporated as model constraints. These are considered alongside downstream demands and minimum flow requirements.

2.4.2 | Economic simulation

WEAP integrates economic calculations into its algorithms. Users can define costs for all operations and water transfers, enabling subsequent economic analyses. Various functions allow incorporation of factors such as inflation into quantitative and qualitative simulations.

2.5 | Data Requirements for Simulation

Data required for WEAP simulations fall into four main categories:

I. Demand site data

II. Hydrological data

III. Supply data (rivers, reservoirs, etc.)

IV. Water quality data [7].

2.5.1 | Data entry methods

WEAP supports flexible data entry in various formats, including monthly or annual time series. When data are insufficient, it provides interpolation methods, forecasting tools, and mathematical operations. These are managed through the Expression Builder, which includes modeling, mathematical, and logical functions [7].

2.6 | Scenario Definition

WEAP provides the capability to define and implement multiple management scenarios simultaneously, allowing users to view and compare results side by side. For example, one scenario might assume a population growth rate of 2%, while another uses 2.5%, enabling direct comparison of outcomes after model execution [7]. The process begins by selecting a reference year (representing current conditions), into which required data are entered. This reference year does not necessarily need to be the most accurate historical estimate but should be one with reliable, high precision data available. Following the reference year, a multi year simulation period is defined, facilitating the necessary forecasting and generation of desired results [3].

2.7 | Water Evaluation and Planning System Interface and Visual Design

Figs. 1–3 present various views of the WEAP software interface and sections, designed with user-friendliness and accessibility in mind [10–14].

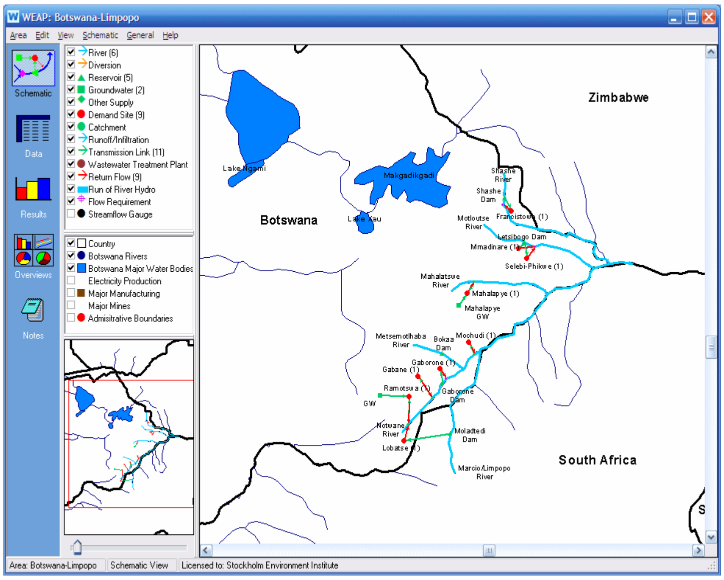

Fig. 1. View of the main internal environment and dashboard of the WEAP.

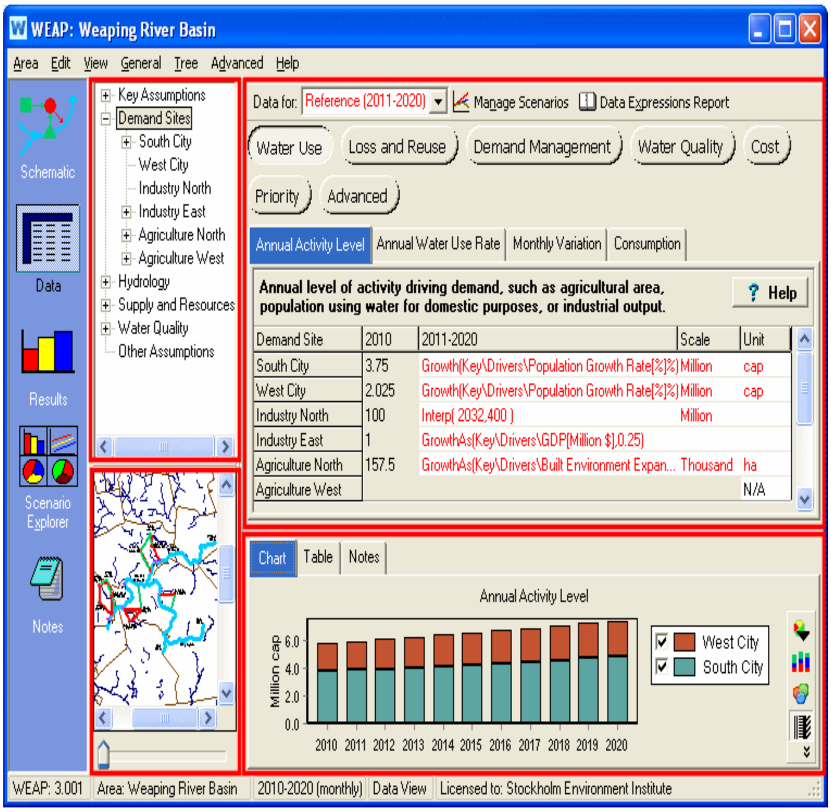

Fig. 2. Data view for entry and storage of information in the WEAP software.

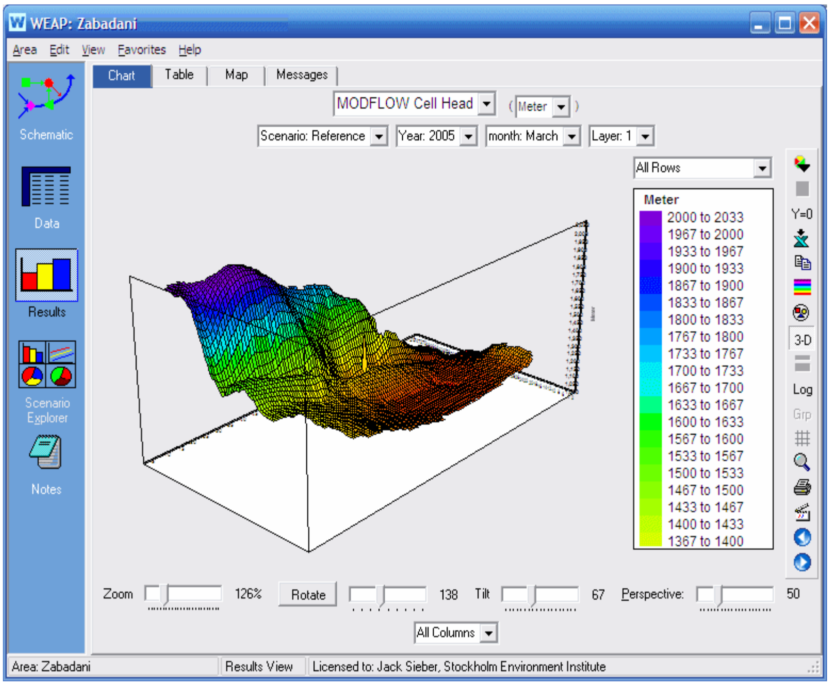

Fig. 3. Presentation of results as 2D and 3D graphs.

3 | Discussion

Water resource systems are managed using various models, broadly categorized into simulation and optimization approaches. Optimization models effectively achieve system objectives but face significant limitations in large scale applications, including prolonged computation times and occasional failure to converge on feasible solutions [15], [16]. Simulation models, therefore, provide a practical alternative for operational planning in complex systems [15]. As described, WEAP exemplifies a widely adopted simulation tool. Another prominent model with similar functionality is MODSIM, developed in the mid-1980s at Colorado State University and finalized. MODSIM offers extensive graphical capabilities, including integration with Geographic Information Systems (GIS), and supports programming in languages such as C and Visual Basic [17].

Although MODSIM has a longer history of application, WEAP encompasses these features while providing a more user-friendly interface and greater accessibility, as noted in comparative studies (e.g., enhanced GUI convenience in K-WEAP variants) [from search results]. Recent analyses indicate that both models produce comparable water balance results, with WEAP often preferred for ease of model construction and data processing. A key difference in allocation lies in priority handling: in WEAP, equal priorities result in uniform percentage satisfaction across demands, whereas differing priorities mirror MODSIM's numeric scaling [17–22]. Overall, WEAP demonstrates superior performance in holistic IWRM due to its comprehensive scenario based framework. In multi reservoir systems, optimization models may yield better operational outcomes. However, simulation and optimization approaches show no statistically significant differences in many cases, justifying the use of simulation tools like WEAP for efficiency and practicality. The integrated features of WEAP have driven its increasing adoption for complex basin planning. Despite its strengths, limitations exist in detailed hydropower modeling (e.g., constraints on turbine flow, head variations, and priority-driven releases), often requiring linkage with external tools like Excel for advanced calculations [23]; WEAP documentation.

IWRM is not a rigid scientific theory but a flexible set of recommendations derived from practical understanding of water management elements. It requires adaptive approaches tailored to local, national, cultural, social, political, economic, and environmental contexts. In the era of advanced technologies, traditional methods alone are insufficient for managing scarce resources, particularly in arid regions like Iran. Tools such as WEAP with high efficiency, comprehensiveness, and user friendliness, facilitate precise evaluations, informed decision making, macro policy formulation, and infrastructure planning. Recent applications (2023–2025) highlight WEAP's role in climate adaptation, SDG 6.4.2 reporting (sub-basin water stress), habitat trade-offs (e.g., California salmon/steelhead), strategic plans in Chile, and dynamic modeling in Egypt and India. A major strength of WEAP in IWRM is providing a common language for water managers and policymakers, enabling knowledge exchange, agreements on shared resources, and monitoring of management objectives from local to national scales. In conclusion, WEAP represents a robust, accessible tool for sustainable water resources management, particularly in water-scarce contexts. Its continued evolution and integration with complementary models position it as essential for addressing future challenges under climate variability and growing demands.

Reference

[1] Bierkens, M. F. P., van Beek, L. P. H. R., & Wanders, N. (2024). Gisser-Sánchez revisited: A model of optimal groundwater withdrawal under irrigation including surface-groundwater interaction. *Journal of hydrology*, *635*, 131145. https://doi.org/10.1016/j.jhydrol.2024.131145

[2] Asghar, A., Iqbal, J., Amin, A., & Ribbe, L. (2019). Integrated hydrological modeling for assessment of water demand and supply under socio-economic and IPCC climate change scenarios using WEAP in Central Indus Basin. *Journal of water supply: Research and technology aqua*, *68*(2), 136–148. https://doi.org/10.2166/aqua.2019.106

[3] Wang, Y., Wang, W., Jia, R., Li, M., Liu, B., Zhang, K., … ., & Jia, J. (2019). Research on treating algae-polluted reservoir water by the process of pre-oxidation/dissolved air flotation/carbon sand filter. *Water supply*, *19*(3), 823–830. https://doi.org/10.2166/ws.2018.128

[4] Herbertson, P. W., & Tate, E. L. (2001). *Tools for water use and demand management in South Africa*. https://B2n.ir/ux4876

[5] Alfarra, A. (2004). *Modelling water resource management in Lake Naivasha* [Thesis]. https://ftp.itc.nl/pub/naivasha/ITC/Alfarra2004.pdf

[6] Casado, A. L., & López, N. C. (2025). Comparison of synthetic unit hydrograph methods for flood assessment in a dryland, poorly gauged basin (Napostá Grande, Argentina). *AIMS geosciences* , *11*(1), 27-46. https://doi.org/10.3934/geosci.2025003

[7] Zegait, R., Bouznad, I. E., Remini, B., Bengusmia, D., Ajia, F., Guastaldi, E., … ., & Petrone, D. (2024). Comprehensive model for sustainable water resource management in Southern Algeria: Integrating remote sensing and WEAP model. *Modeling earth systems and environment*, *10*(1), 1027–1042. https://doi.org/10.1007/s40808-023-01826-y

[8] Yates, D., Sieber, J., Purkey, D., & Huber-Lee, A. (2005). WEAP21—A demand-, priority-, and preference-driven water planning model: Part 1: Model characteristics. *Water international*, *30*(4), 487–500. https://doi.org/10.1080/02508060508691893

[9] Htoo, T. Z., Htwe, Y. Y., & Kyi, C. C. T. (2024). Assessment on water resource management for sedawgyi dam: A WEAP analysis approach. *The indonesian journal of computer science*, *13*(5), 7067-7083. https://doi.org/10.33022/ijcs.v13i5.4272

[10] Raskin, P., Hansen, E., Zhu, Z., & Stavisky, D. (1992). Simulation of water supply and demand in the Aral Sea region. *Water international*, *17*(2), 55–67. https://doi.org/10.1080/02508069208686127

[11] Sieber, J. (2008). *Guideline of WEAP software. August 2008 (Water evaluation and planiing system),SEI (Stockholm Environment Institute).* https://www.researchgate.net/publication/377724910

[12] Le Page, M., Fakir, Y., & Aouissi, J. (2020). Modeling for integrated water resources management in the Mediterranean region. In *Water resources in the Mediterranean region* (pp. 157-190). Elsevier. https://doi.org/10.1016/B978-0-12-818086-0.00007-8

[13] Hadri, A., Saidi, M. E. M., El Khalki, E. M., Aachrine, B., Saouabe, T., & Elmaki, A. A. (2022). Integrated water management under climate change through the application of the WEAP model in a Mediterranean arid region. *Journal of water and climate change*, *13*(6), 2414–2442. https://doi.org/10.2166/wcc.2022.039

[14] Kandera, M., Výleta, R., Liová, A., Danáčová, Z., & Lovasová, L. (2021). Testing of water evaluation and planning (WEAP) model for water resources management in the hron river basin. *Acta hydrologica slovaca*, *22*(1), 30–39. https://doi.org/10.31577/ahs-2021-0022.01.0004

[15] Myat, K., & Aye, N. (2017). Proposal of water allocation plans for Mandalay area in Myanmar. *American Academy of science research journal f engineering,o technology, and sciences*, *31*(1), 24–39. https://asrjetsjournal.org/American_Scientific_Journal/article/view/2893

[16] Maßmann, J., Wolfer, J., Huber, M., Schelkes, K., Hennings, V., Droubi, A., & Al-Sibai, M. (2012). WEAP-MODFLOW as a decision support system (DSS) for integrated water resources management: Design of the coupled model and results from a pilot study in Syria. In *Groundwater quality sustainability* (pp. 161-173). CRC Press / Taylor & Francis Group. https://www.scribd.com/document/836708111/226-iah2010-massmann

[17] Hamdi, A. A., Abdulhameed, I. M., & Mawlood, I. A. (2023). Application of WEAP model for managing water resources in Iraq: A review. *IOP conference series: Earth and environmental science* (pp. 012032). IOP Publishing. https://doi.org/10.1088/1755-1315/1222/1/012032

[18] Gohil, K. B., & Jain, R. (2023). Extensive review of water resources management using WEAP and its integrated models. *Journal of indian water works association*, *55*(2), 119–124. https://www.iwwa.info/assets/journal/final/127121691486135.pdf#page=39

[19] Neeti, K., Singh, R., Ahmad, S., & Sakshi Kumar, A. (2024). Challenges and opportunities in integrated water resources management. In *Integrated management of water resources in India: A computational approach: Optimizing for sustainability and planning* (pp. 345-359). Springer, Cham. https://doi.org/10.1007/978-3-031-62079-9_19

[20] Kumar, P., Johnson, B. A., Dasgupta, R., Avtar, R., Chakraborty, S., Kawai, M., & Magcale-Macandog, D. B. (2020). Participatory approach for more robust water resource management: Case study of the Santa Rosa sub-watershed of the Philippines. *Water*, *12*(4), 1172. https://doi.org/10.3390/w12041172

[21] Giupponi, C., & Sgobbi, A. (2013). Decision support systems for water resources management in developing countries: Learning from experiences in Africa. *Water*, *5*(2), 798–818. https://doi.org/10.3390/w5020798

[22] Torabi, A., Yosefvand, F., Shabanlou, S., Rajabi, A., & Yaghoubi, B. (2024). Optimization of integrated operation of surface and groundwater resources using multi-objective grey wolf optimizer (MOGWO) algorithm. *Water resources management*, *38*(6), 2079–2099. https://doi.org/10.1007/s11269-024-03744-9

[23] Voinov, A. A. (2008). *Systems science and modeling for ecological economics*. Academic Press. https://B2n.ir/tq7003