A Real-Time Decision Support System for Optimal Water Allocation Scenarios in Agriculture and Environmental Management

Parisa Abbasali Zadeh Rezaei[1], Amirreza Meydani[2], Hamidreza Khodaei[3] , Massoud Tajrishy[1] , Delphis F. Levia[2]

[1]Department of Civil Engineering, Sharif University of Technology, Tehran, Iran, [2]Department of Geography & Spatial Sciences, University of Delaware, Newark, DE, USA, [3]Department of Water Engineering, Faculty of Civil & Environmental Engineering, Tarbiat Modares University, Tehran, Iran

1. Introduction

Motivation: Water scarcity in dry regions, especially where agriculture plays a significant role in the economy, poses serious challenges for managing water resources. Agriculture consumes a substantial portion of available water and places significant pressure on meeting the Environmental Water Supply (EWS) required to sustain ecosystems. Over time, this can harm the environment and negatively impact other water users. With climate change, population growth, and increasing food demand, finding ways to balance water use between agriculture and ecosystems is more critical than ever.

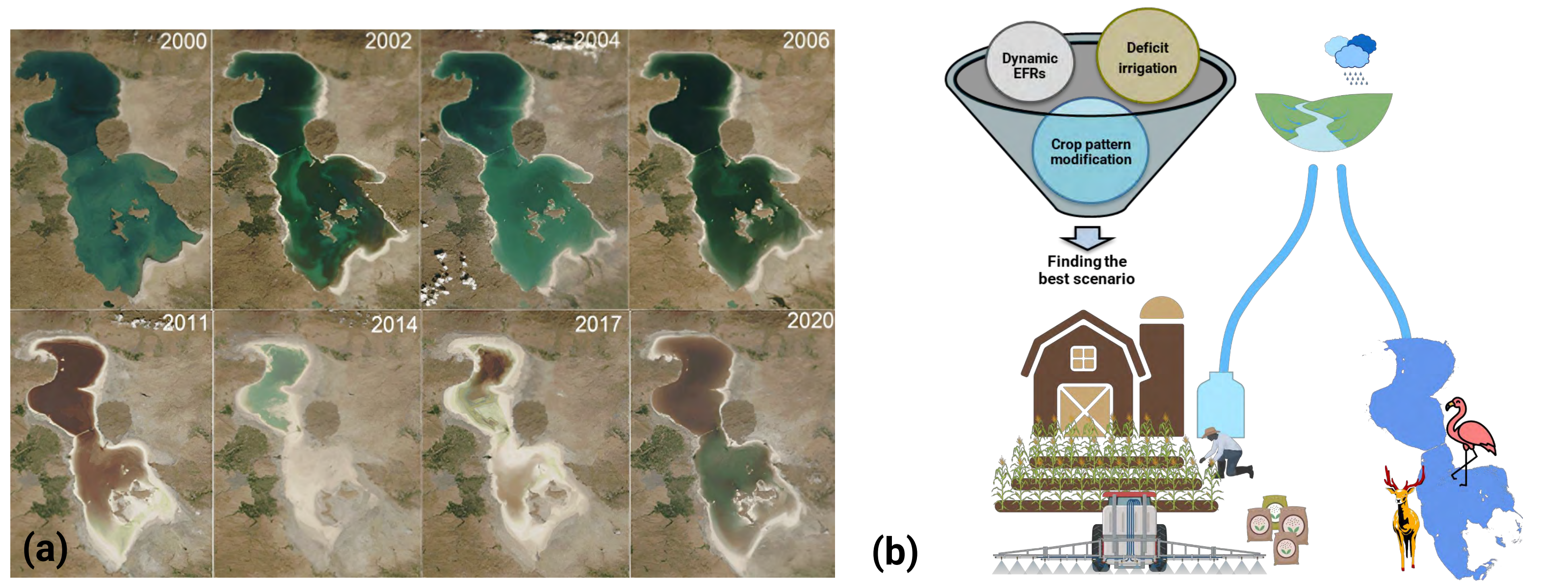


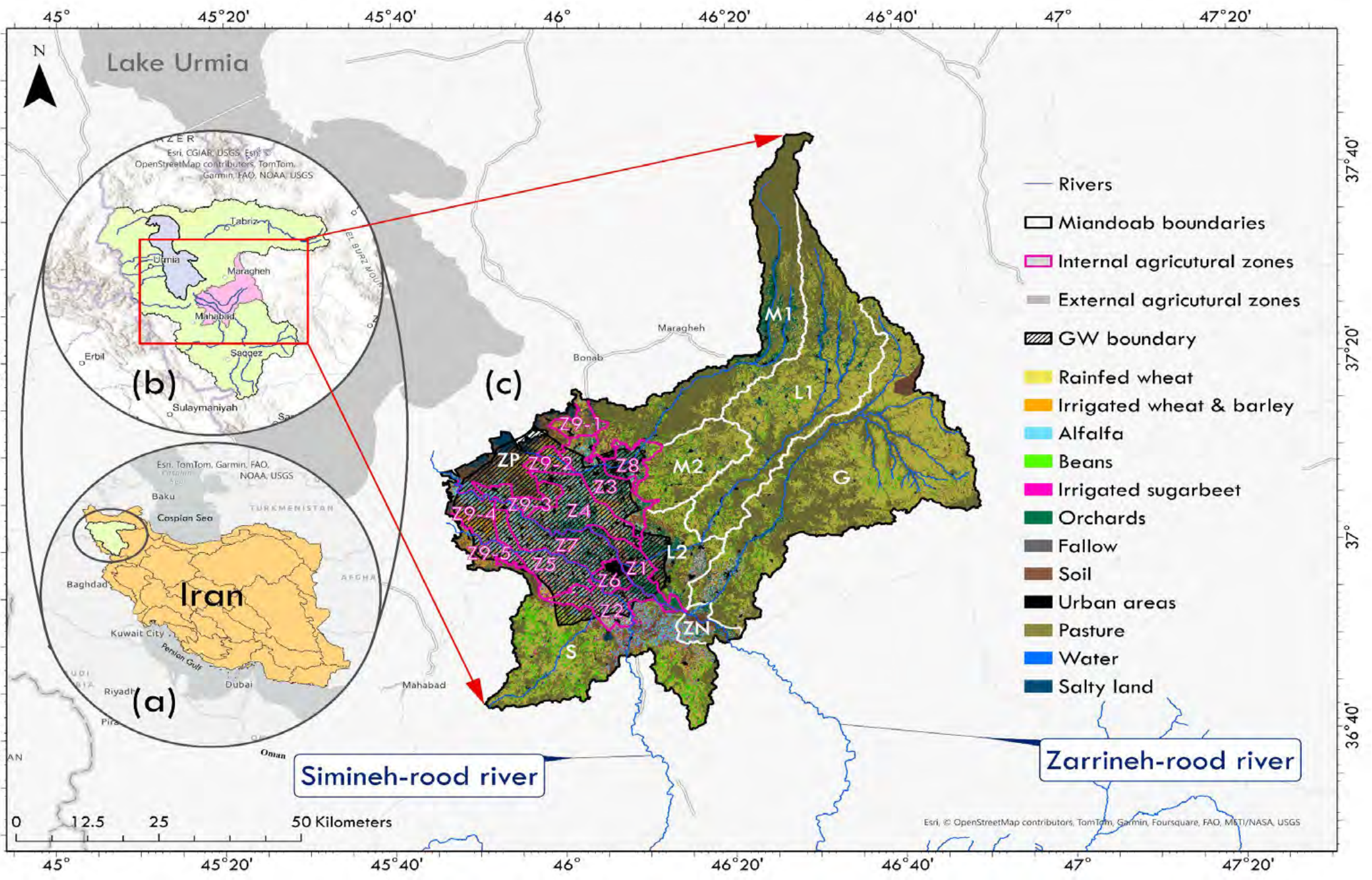
Fig 1. (a) Desiccation of Lake Urmia as an example of agricultural water consumption pressure on the ecosystem over the period 2000–2020 [1], **(b)** balancing agricultural water use and EWS through efficient, real-time water management scenarios (EFRs: Environmental Flow Requirements).

Goal: The goal of this study is to develop a Decision Support System (DSS) that optimizes daily water allocation in the Miandoab Plain (MP). This real-time DSS will empower stakeholders to make informed decisions and balance competing demands by maximizing farmers' profits while ensuring sufficient water is allocated to meet EWS requirements.

2. Methods

1. Study Area

Fig 2. (a) Location of the Lake Urmia Basin (LUB) in Iran; **(b)** the Miandoab Plain (MP) situated within the LUB; and **(c)** the 21 simulated agricultural zones of the MP represented in the hydrological model.



2. Innovations

This study introduces a DSS that operates on a daily basis to tackle the challenges of water allocation in complex systems. It focuses on promoting sustainable agricultural practices within the framework of Integrated Water Resources Management (IWRM). The DSS integrates cutting-edge multi-objective optimization techniques, such as MOEA/D, with physically-based hydrological modeling to improve water use efficiency. By integrating machine learning with physical models, the system links water inflow predictions to optimized water allocation.

3. Workflows

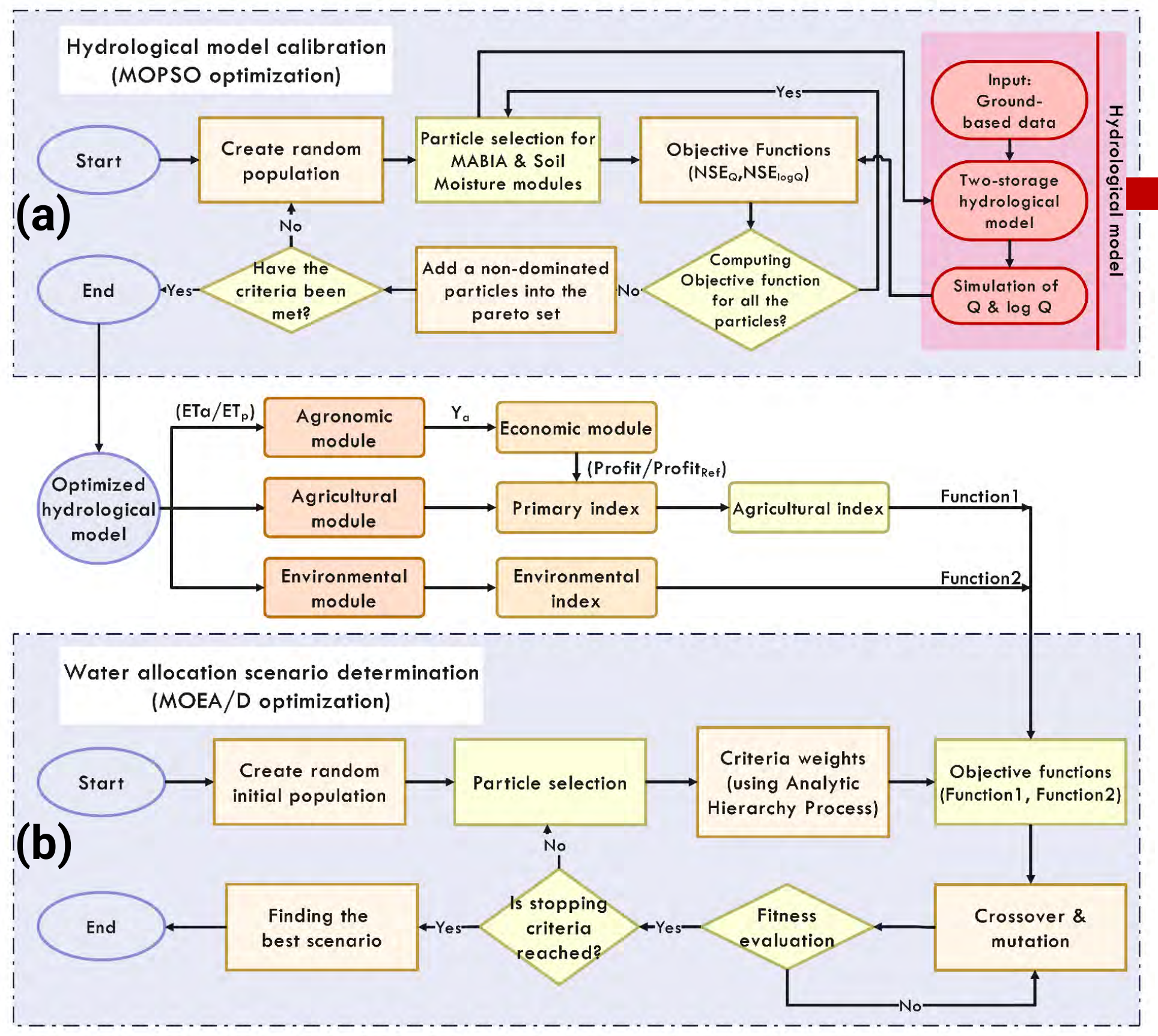


Fig 3. (a) Flowchart illustrating the hydrological model calibration using MOPSO, **(b)** water allocation scenario optimization using MOEA/D, and the interaction between (a) and (b).

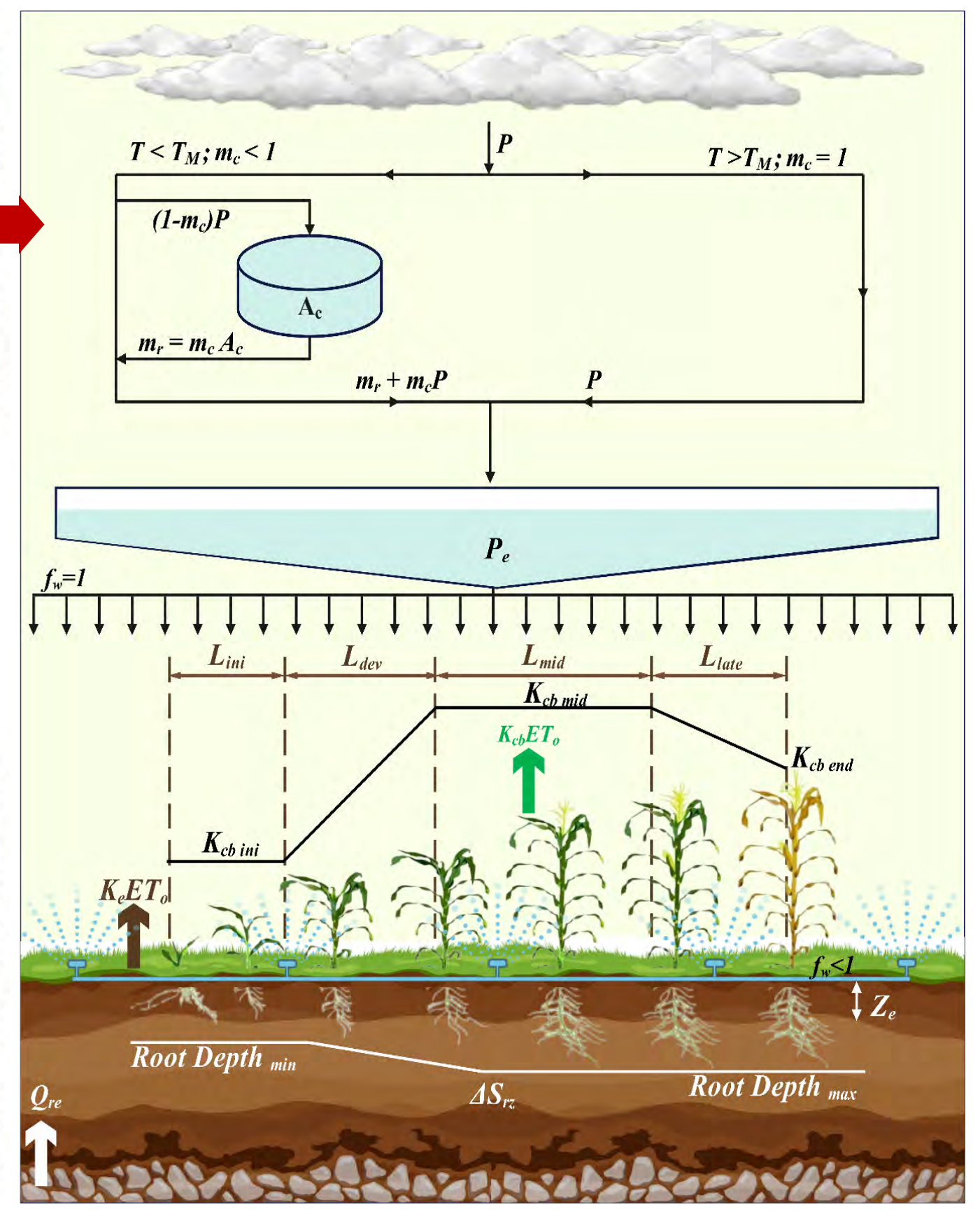


Fig 4. Schematic diagram of the hydrological model implemented in WEAP, including the Soil Moisture module (SM) for rainfall-runoff simulation and the MABIA module for agronomic simulations.

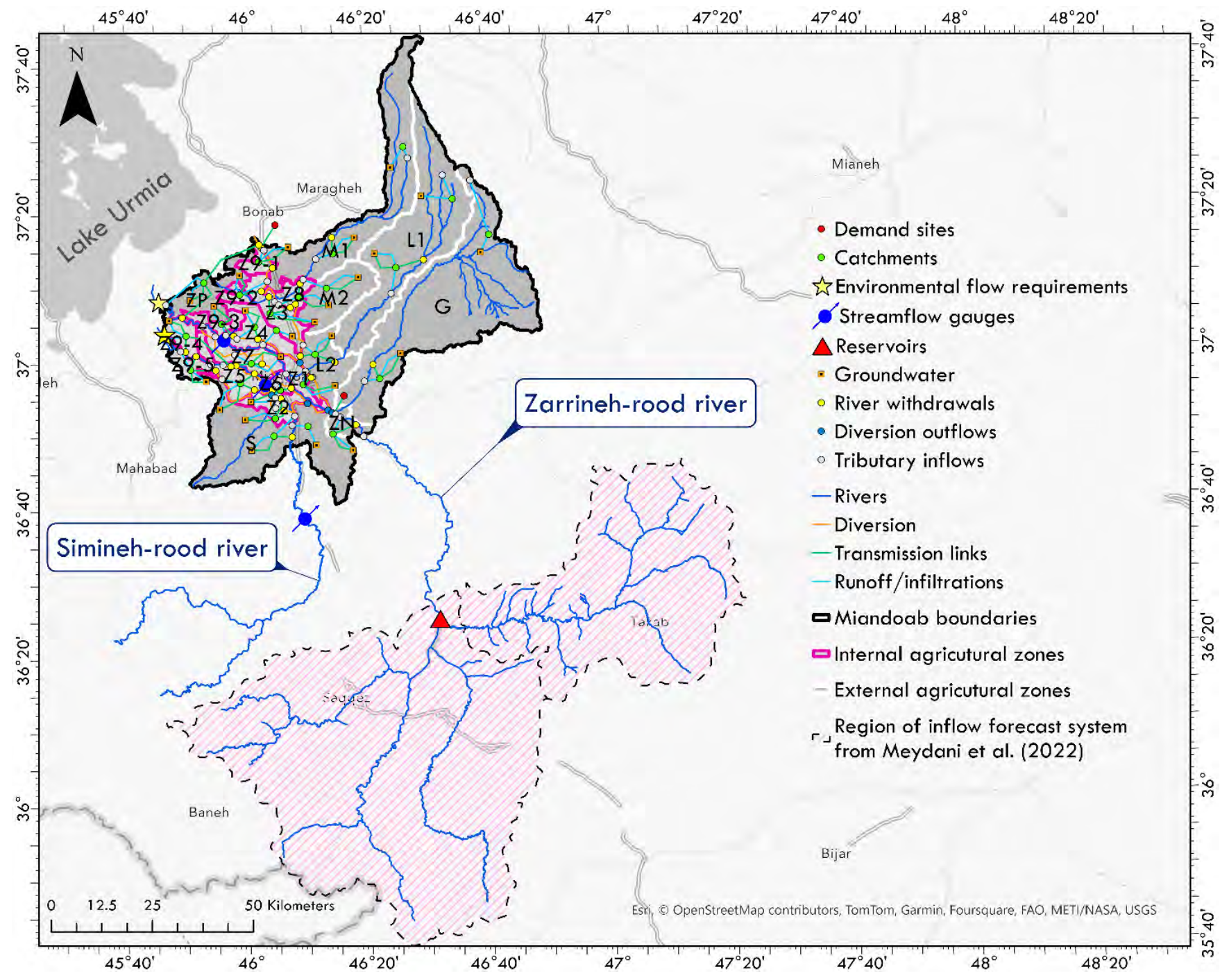
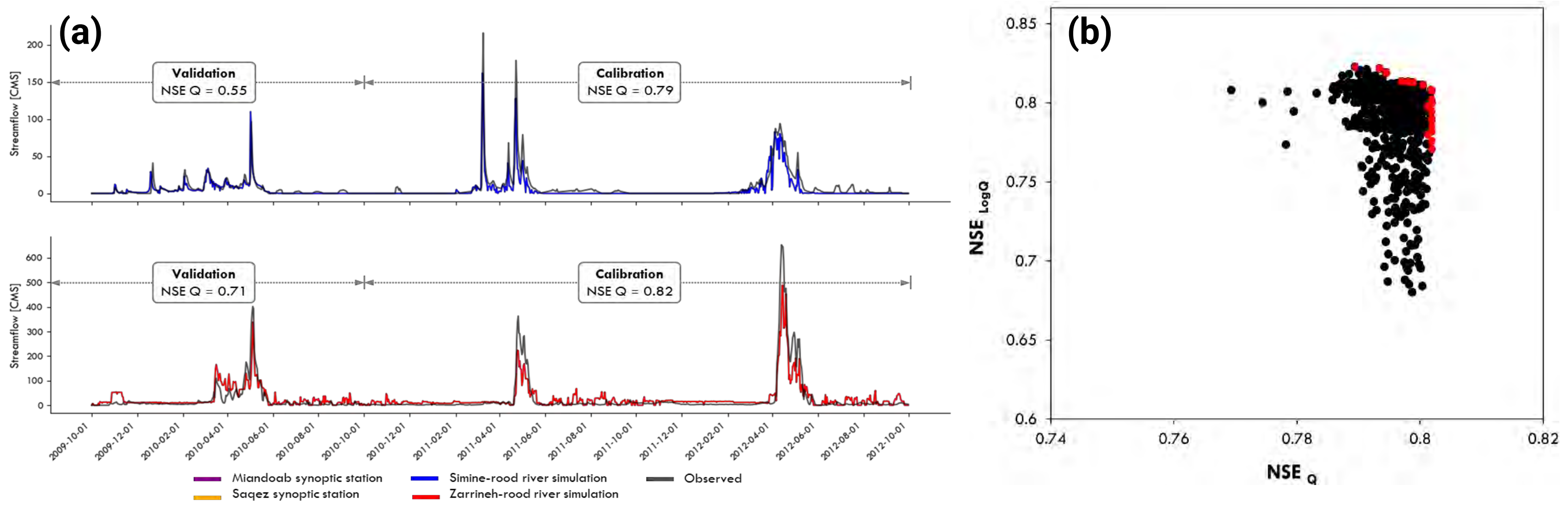


Fig 5. WEAP spatial elements as model components in the study area.

Table 1. Different water allocation scenarios

Scenario	Description
SC1-X	Dynamic Peak Environmental Supply (Supply environmental flow at different months)
SC2-X	Deficit Irrigation
SC3-1	Crop Pattern Change

3. Results and Discussion



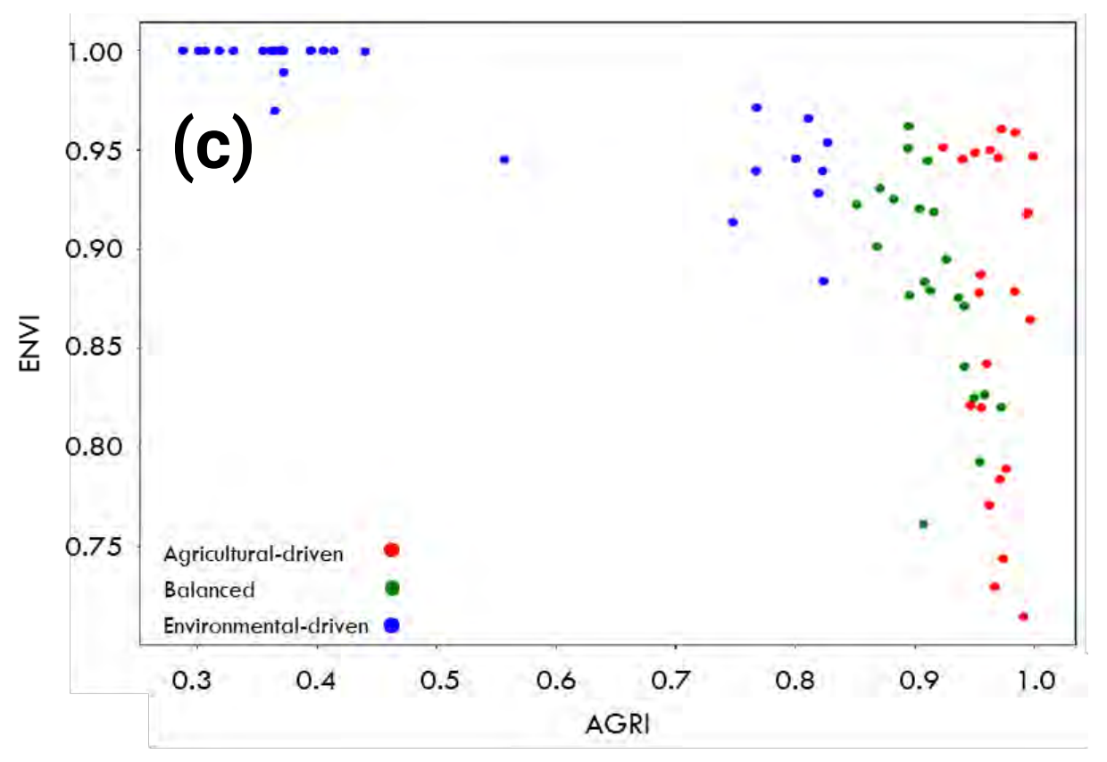


Fig 6. (a) Calibration and validation of the hydrological model using optimal parameters at two hydrometric gauge stations. **(b)** The Pareto plot of the hydrological model after 2,580 runs with different calibration parameter values. Each point represents a set of calibration parameter values for a single run, with red points indicating the Pareto front of non-dominated simulations. **(c)** Pareto diagram of the three water allocation criteria resulting from MOEA/D.

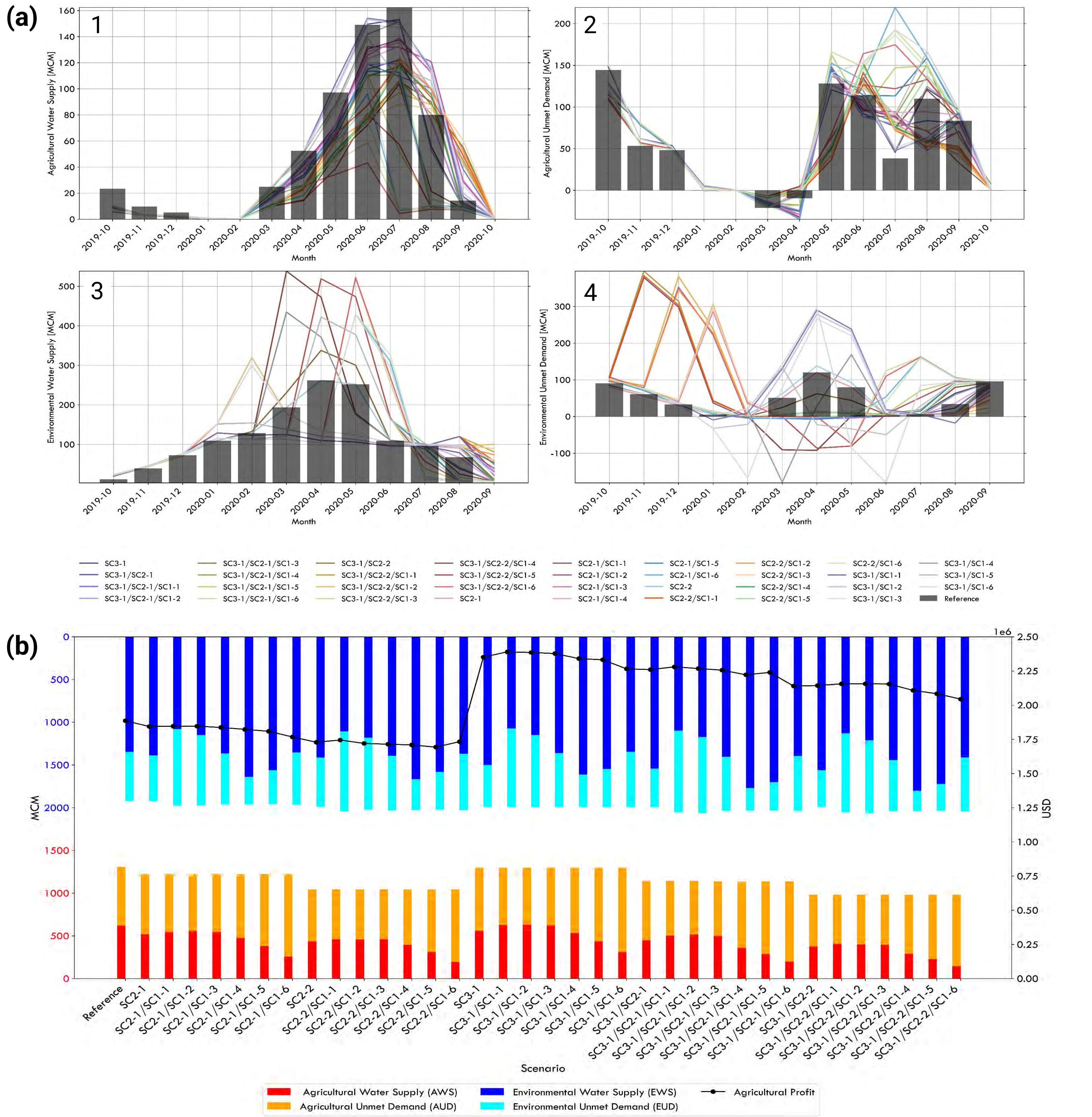


Fig 7. (a) Comparison of monthly values for (1) Agricultural Water Supply (AWS), (2) Agricultural Unmet Demand (AUD), (3) Environmental Water Supply (EWS), and (4) Environmental Unmet Demand (EUD) under different scenarios, compared to the reference scenario (gray bars). **(b)** Comparison of AWS, AUD, EWS, EUD, and agricultural profit across different scenarios.

4. Conclusion

- Integrating data-driven and physically-based models, along with modules like MABIA and SM, improves the hydrological model's ability to assess irrigation scenarios and optimize water resource management.
- The optimized model calibration using MOPSO achieved high accuracy (NSE ~ 0.8) for daily streamflow simulation.
- Scenario analysis reveals that early water releases from dams in winter, coupled with crop pattern shifts and deficit irrigation, can increase EWS by up to 31%, and boost agricultural profits by 26%.
- The real-time DSS demonstrated strong efficiency in evaluating various water allocation and crop pattern scenarios.

5. Reference

[1] Abadi, A.R.S., Hamzeh, N.H., Shukurov, K., Opp, C., Dumka, U.C., 2022. Long-Term Investigation of Aerosols in the Urmia Lake Region in the Middle East by Ground-Based and Satellite Data in 2000–2021. Remote Sensing 14, 3827. https://doi.org/10.3390/rs14153827.

Note: This research is under review for journal publication.

Contact: Amirreza Meydani, **e-mail:** meydani@udel.edu