EGU26-17207, updated on 10 Apr 2026
https://doi.org/10.5194/egusphere-egu26-17207
EGU General Assembly 2026

Assessing the Ag-MAR potential in a rice-dominated alluvial plain in Northern Italy by combining MODFLOW-6 and QGIS-SWAP-Paddy

Petra Baják[1], Giulio Gilardi[2], Daniele Pedretti[1], Arianna Facchi[2], Marco Masetti[1], Lorenzo Sangalli[1], Alessandro Sorichetta[1], Darya Tkachenko[2], and Michael Valtorta[1]

[1]Università degli Studi di Milano (UNIMI), Department of Earth Sciences 'Ardito Desio', Milan, Italy
[2]Università degli Studi di Milano (UNIMI), Department of Agricultural and Environmental Sciences – Production, Landscape, Agroenergy (DiSAA), Milan, Italy

Agricultural Managed Aquifer Recharge (Ag-MAR) has emerged as a sustainable water management technique that utilizes farmland, particularly during fallow periods , to intentionally flood fields and replenish underground aquifers, thereby storing water for future use. Quantifying the benefits of Ag-MAR and evaluating its cost-effectiveness remains challenging due to strong nonlinear interactions between surface–subsurface processes, which generally requi re numerical modeling approaches that are still poorly established for Ag-MAR systems.

This study presents the initial development of a numerical modeling framework to evaluate the effectiveness of different Ag-MAR practices in the Lomellina area (1,250 km^2) in Northern Italy, Europe's largest rice-producing district. In this region, excess surface water is typically available during the winter months (November–February). Although winter flooding of rice fields has been promoted in recent years by the EU Rural Development Programme (CAP) for agronomic and environmental purposes, its hydrological benefits remain largely unquantified. Ag-MAR in the region may occur through deliberate field flooding or infiltration from irrigation canals, yet the relative importance of these pathways and their long-term impacts on groundwater resources are still unknown.

The proposed framework couples (a) recharge rates calculated using QGIS-SWAP-Paddy, a semi-distributed version of the SWAP model (https://www.swap.alterra.nl/), implementing also the irrigation/drainage network, and (b) groundwater flow rates calculated using the MODFLOW-6 model (https://www.usgs.gov/ software/modflow-6-usgs-modular-hydrologic-model). QGIS-SWAP-Paddy provides transient net percolation rates from agricultural fields and the irrigation canal network, accounting for land-use, soil variability, and irrigation practices throughout the year. MODFLOW-6 uses QGIS-SWAP-

Paddy's percolation rates to simulate seasonal and interannual groundwater dynamics across the domain, including interactions with major rivers (Po, Ticino, and Sesia) and minor surface water bodies.

Due to the characteristics of the hydrogeological system, namely, the flooding of vast rice-growing areas and the presence of very shallow groundwater levels, recharge in QGIS-SWAP-Paddy depends on groundwater levels, while the groundwater level simulated by MODFLOW-6 depends on percolation rates estimated in QGIS-SWAP-Paddy.

Currently, the two models have been calibrated independently. QGIS-SWAP-Paddy has been calibrated using irrigation discharge data and a reference groundwater level map, interpolated using geostatistical methods, as the lower boundary condition. Conversely, the groundwater flow model, using the recharge rates produced by the QGIS-SWAP-Paddy model as input, was calibrated against observed groundwater levels in various wells from 2018–2020, successfully reproducing observed seasonal fluctuations.

The next step is to develop a code that allows the two models to be explicitly coupled monthly to improve the estimation of both percolation rates and the groundwater balance. If necessary, the calibration and validation of the integrated model will therefore be repeated, considering the irrigation discharges delivered to the district and the groundwater levels observed during the period 2018–2020. Once this step has been completed, the model will be ready to simulate Ag-MAR scenarios.

This study was carried out in the context of the PROMEDRICE project (https://promedrice.org/; PRIMA-Section2–2022) funded, for the Italian partners, by MUR (Italian Ministry of University and Research).