Accounting for vegetation dynamics in hydrological modelling of Mediterranean mountain catchments using TSEB-derived evapotranspiration

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Mountainous areas play a crucial role as reservoirs of biodiversity and providers of ecosystem services such as water supply. However, they are highly vulnerable to environmental change, particularly global warming, which threatens their hydrological dynamics and the provision of services. Designing adaptation and mitigation strategies, therefore, requires reliable information on water balance dynamics to support decision-making. In Mediterranean climates, vegetation strongly regulates hydrological processes by controlling evapotranspiration, interception, and water redistribution. Changes in vegetation phenology or distribution can therefore significantly affect the hydrological cycle. However, many hydrological models still rely on simplified or static vegetation representations and estimate evapotranspiration (ET) mainly from climatic variables, making it difficult to adequately represent vegetation dynamics [1].

This study investigates the integration of satellite-derived ET and vegetation dynamics into the distributed physically based hydrological model WiMMed (Watershed Integrated Model in Mediterranean regions) [2]. The analysis focuses on a mountain catchment located in the Parque Natural de Cardeña y Montoro (southern Spain), within the Guadalquivir River Basin. The basin is characterized by typical Mediterranean vegetation, including oak woodland, mixed forest, and olive groves, and benefits from long-term monitoring and high-quality meteorological and environmental data. Vegetation heterogeneity and dynamics were explicitly represented by integrating Landsat-derived daily ET estimates obtained with the Two-Source Energy Balance (TSEB) model [3] together with satellite-based fractional vegetation cover (FC) within the modelling framework. Hydrological simulations were performed for the period 2000–2025. Model performance and hydrological responses were compared with a conventional modelling approach based on a crop-modified Hargreaves formulation and a static vegetation representation.

Results show that vegetation representation strongly influences simulated water flux partitioning. Higher fractional cover (FC) reduces the amount of water reaching the soil, which can then infiltrate, evaporate, percolate, or generate excess runoff. Static vegetation scenarios tend to overestimate interception losses in these semiarid systems, whereas simulations that include dynamic vegetation reduce interception and substantially alter the balance between infiltration and runoff, particularly during wet years. Incorporating remotely sensed evapotranspiration also improves the spatial representation of water balance components and better captures seasonal and interannual variability among land covers. Our results show that representing vegetation dynamics is key to capturing water–vegetation interactions in Mediterranean catchments and provides a basis for evaluating future hydro-ecological responses to climate and land-use change.

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