Evaluating gross primary productivity, soil moisture and evapotranspiration derived from multiple Noah-MP dynamic vegetation schemes and satellite observations across land cover types in the Mediterranean region

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Abstract here!

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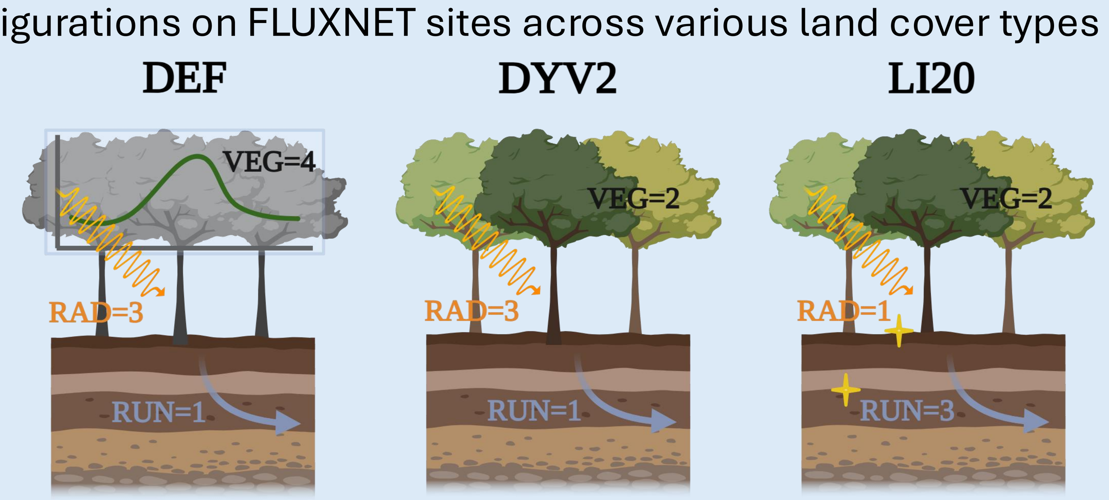
Introduction

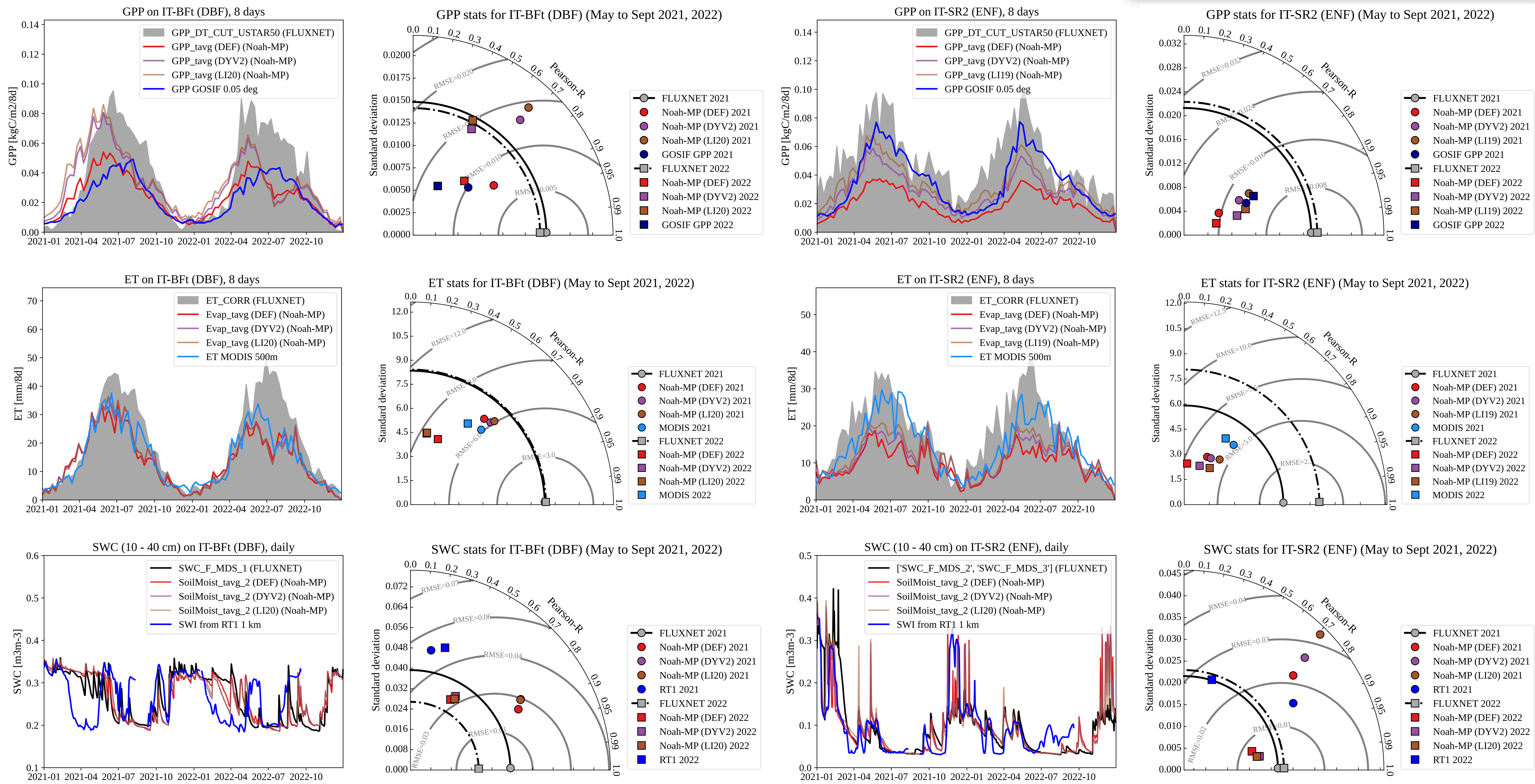
- Accurate representation of vegetation processes in land surface models is crucial, as it directly affects the simulation of energy and soil water balances (Arsenault et al., 2018; Kumar et al., 2019).
- The **Noah-MP** land surface model offers multiple parameterization options for both vegetation dynamics and biogeochemical processes (Niu et al., 2011).
- To effectively assimilate satellite observations and update vegetation states, it is essential to first compare and evaluate different vegetation schemes to identify the most suitable one for ecosystem modeling (Li et al., 2019, 2020; De Lannoy et al., 2022).

Methods

- In-situ observations of **GPP (Gross Primary Production)**, **ET (Evapotranspiration)**, and **SWC (Soil Water Content)** were collected from two FLUXNET/ICOS sites in Italy—**IT-BFt** (Dfa climate) and **IT-SR2** (Cfa climate)—covering two consecutive years: 2021 climatologically normal and 2022 characterized by significant precipitation deficit and summer drought.
- Vegetation is characterized by a **landcover class following IGPB-Modis classification (20 classes)**: IT-BFt (Carpinus betulus, Quercus robur and mixed understory), is classified as Deciduous Broadleaf Forest (DBF), IT-SR2 (Pinus pinea L.) is classifiend as Needleleaf Evergreen Forest (ENF).
- **Model simulations were performed using the Noah-MP land surface model** within the **NASA LIS framework**, on a 0.005 deg grid and by forcing the model with MERRA2 reanalysis data.
- Three vegetation scheme configurations have been tested:
  - **DEF:** default Noah-MP with prescribed vegetation
  - **DYV2:** default configuration with dynamic vegetation enabled
  - **LI20:** recommended dynamic vegetation configuration from Li et al. (2020), optimized based on a global sensitivity analysis of different configurations on FLUXNET sites across various land cover types



- We compared **Noah-MP simulations** with satellite products: **GPP** from GOSIF (8-day, ~5 km), **ET** from MODIS (8-day, ~500 m), **soil water content** from Sentinel-1 RT1 (1 km). We focused on the **summer months (May–Sept) and used RMSE**, **standard deviation**, and **correlation (R)** to assess performance. We also assessed how **soil moisture and ET** are coupled in each model setup by using **triple collocation** (Lei et al., 2018), comparing: FLUXNET data, model outputs and satellite observations.

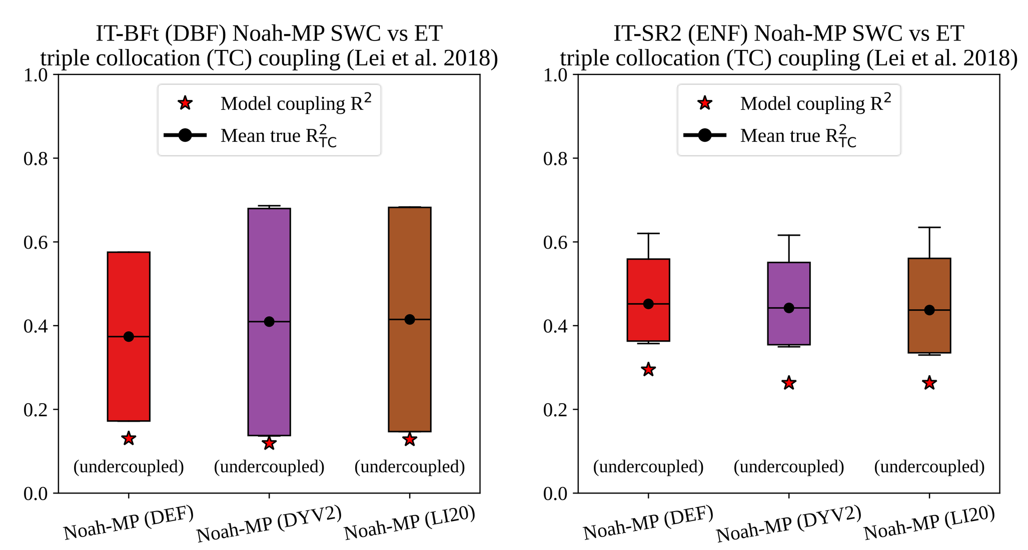


Results

- The prescribed vegetation scheme (Noah-MP DEF) consistently underestimates gross primary production (GPP) compared to the dynamic vegetation configurations (DYV2 and LI20) across both sites and years. At IT-BFt (deciduous broadleaf forest, DBF), the dynamic schemes demonstrate improved performance in 2021, a non-drought year, whereas performance declines in 2022. At IT-SR2 (evergreen needleleaf forest, ENF), the three configurations show comparable performance for both GPP and evapotranspiration (ET), with no clear patterns emerging for soil water content (SWC).
- In 2022, simulations at IT-BFt appear highly impacted by low soil moisture levels, while in situ data suggest limited vegetation stress, likely due to water uptake from deeper soil layers or groundwater sources—a characteristic feature of Mediterranean ecosystems.
- Across all schemes, evapotranspiration (ET) appears undercoupled to soil moisture variations, indicating that ET responds less sensitively to changes in soil moisture than expected. Although a strong decrease in ET under low soil moisture conditions was observed at IT-BFt in 2022, this apparent contradiction can be partly attributed to the use of shallow soil moisture observations (10–40 cm) to assess coupling, which may not fully capture deeper root zone processes critical for plant water uptake. Additionally, the parameterization of the Ball–Berry stomatal resistance formulation may contribute to this behavior, potentially limiting the modeled sensitivity of stomatal conductance—and hence ET—to soil moisture variability.

$$R^2[\mathrm{SM_{True}},\ \mathrm{ET_{True}}]_{i,l} \equiv \frac{\mathrm{Cov}[\mathrm{SM_{True}},\ \mathrm{ET_{True}}]_{i,l}^2}{\mathrm{Var}[\mathrm{SM_{True}}]_j\ \mathrm{Var}[\mathrm{ET_{True}}]_l}$$

$$= \frac{\mathrm{Cov}[\mathrm{SM}_i,\ \mathrm{ET}_l]^2\ \mathrm{Cov}[\mathrm{SM}_j,\ \mathrm{SM}_k]\ \mathrm{Cov}[\mathrm{ET}_m,\ \mathrm{ET}_n]}{\mathrm{Cov}[\mathrm{SM}_i,\ \mathrm{SM}_j]\ \mathrm{Cov}[\mathrm{SM}_i,\ \mathrm{SM}_k]\ \mathrm{Cov}[\mathrm{ET}_l,\ \mathrm{ET}_m]\ \mathrm{Cov}[\mathrm{ET}_l,\ \mathrm{ET}_n]}$$



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