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| **Monitoring forest attributes, C-fluxes, and C-stock in the Italian forests through a process-based model (3D-CMCC-FEM)** |
| **Introduction/Aim:** Process-based Forest models (PBFM) are relevant tools for investigating climate change effects and alternative management strategies. However, they can also be considered a valuable and complementary tool for monitoring forest conditions and their dynamics over short- to long-periods when ancillary data are poor and continuous measurements are costly and time-demanding over large areas. Thanks to the implementation of key ecophysiological processes, PBFMs account for the impact of climate and local competition for resources on tree growth. This study aims to evaluate the PBFM named ‘3D-CMCC-FEM’ (Three-Dimensional - Coupled Model Carbon Cycle - Forest Ecosystem Module) on the capacity to simulate Italian forests' structural variables, C-fluxes and C-stocks and, thus, its monitoring capacity. The model simulations for the period 2005-2020 were tested for a subset of field plots as part of the third Italian National Forest Inventory (Inventario Nazionale delle Foreste e dei Serbatoi di Carbonio – INFC 2015) measured between 2017 and 2020 for a total of 1615 plots and nine different species along a wide environmental gradient.  **Methods:** The 3D-CMCC-FEM model was forced by daily climate data at 2.2 km spatial resolution and a national soil database at 250 m resolution and initialized with the plot-level structural information derived from the second Italian NFI for 2005. The model was used to predict the most common structural variables, such as diameter at breast height (DBH), tree height (H), basal area (BA), growing stock volume (GSV), carbon stocks (CS), tree density, and current annual volume increment (CAI), and validated against field observations from the third Italian NFI (2017-2020). In addition, we compared the gross primary productivity (GPP) against well-known RS datasets for the whole simulated period (2005-2020).  **Results:** Overall, the model was well-suited to reproducing the main stocks and structural variables with R2 ranging between 0.71 (CS) and 0.46 (H) and RMSE% between 30% (DBH and H) and 40% (BA, GSV, and CS). The four most represented species (Q. cerris, F. sylvatica, C. sativa, and P. nigra), corresponding overall to 84% of the whole simulated plots, with the best results in terms both of RMSE% and R2 for the DBH, CS and GSV. In contrast, the modeled GPP showed higher variability than the RS-based data, obtaining an overall RMSE% of 54% and 49% against the MODIS and GOSIF datasets, respectively. Overall, the best agreement was found against the GOSIF dataset, and the best-simulated species were C. sativa and F. sylvatica (33% and 34%, respectively).  **Conclusion:** The outputs from the 3D-CMCC-FEM model have shown consistent reliability, establishing it as a valuable tool for monitoring forests across large spatial scales up to daily temporal resolution. This approach performs similarly to RS-based approaches while offering increasingly continuous temporal data. Furthermore, it can be used to track GSV and CS changes between NFI surveys at local and national scales. Thus, it establishes a forest monitoring system to meet governmental interests in updated GHG emissions inventories and private entities in carbon offset investments. |