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Integration of ground and satellite data to estimate the forest carbon fluxes of a Mediterranean region

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The current paper reports on the development and testing of a methodology capable of simulating the main terms of forest carbon budget (gross primary production, GPP, net primary production, NPP, and net ecosystem exchange, NEE) in the Mediterranean environment.
The study area is Tuscany, a region of Central Italy which is covered by forests over about half of its surface. It is peculiar for its extremely heterogeneous morphological and climatic features which ranges from typically Mediterranean to temperate warm or cool according to the altitudinal and latitudinal gradients and the distance from the sea (Rapetti and Vittorini, 1995).
The simulation of forest carbon budget is based on the preliminary collection of several data layers to characterize the eco-climatic and forest features of the region (i.e. maps of forest type and volume, daily meteorological data and monthly NDVI-derived FAPAR - fraction of absorbed photosynthetically active radiation - estimates for the years 1999-2003). In particular, the 1:250.000 forest type map describes the distribution of 18 forest classes and was obtained by the Regional Cartographic Service. The volume map, with a 30 m spatial resolution and a mean accuracy of about 90 m3/ha, was produced by combining the available regional forest inventory data and Landsat TM images (Maselli and Chiesi, 2006). Daily meteorological data (minimum and maximum air temperatures and precipitation) were extrapolated by the use of the DAYMET algorithm (Thornton et al., 1997) from measurements taken at existing whether stations for the years 1996-2003 (calibration plus application periods); solar radiation was then estimated by the model MT-CLIM (Thornton et al., 2000). Monthly NDVI-derived FAPAR estimates were obtained using the Spot-VEGETATION satellite sensor data for the whole study period (1999-2003).
After the collection of these data layers, a simplified, remote sensing based parametric model (C-Fix), is applied for the production of a reference series of monthly gross primary production (GPP) estimates. In particular this model estimates forest GPP as function of photosynthetically active radiation absorbed by vegetation (Veroustraete et al., 2002) combined with ground based estimates of incoming solar radiation and air temperature.
These GPP values are used as reference data to both calibrate and integrate the functions of a more complex bio-geochemical model, BIOME-BGC, which is capable of simulating all main ecosystem processes. This model requires: daily climate data, information on the general environment (i.e. soil, vegetation and site conditions) and parameters describing the ecophysiological characteristics of vegetation. Both C-Fix and BIOME-BGC compute GPP as an expression of total, or potential, productivity of an ecosystem in equilibrium with the environment. This makes the GPP estimates of the two models practically inter-comparable and opens the possibility of using the more accurate GPP estimates of C-Fix to both calibrate BIOME-BGC and stabilize its outputs (Chiesi et al., 2007). In particular, by integrating BIOME-BGC respiration estimates to those of C-Fix, forest fluxes for the entire region are obtained, which are referable to ecosystems at equilibrium (climax) condition. These estimates are converted into NPP and NEE of real forests relying on a specifically developed conceptual framework which uses the ratio of actual over potential stand volume as indicator of ecosystem distance from climax. The accuracy of the estimated net carbon exchanges is finally evaluated against ground data derived from a recent forest inventory and from two eddy covariance flux towers located in Tuscany (San Rossore and Lecceto). The results of both these comparisons were quite positive, indicating the good capability of the method for forest carbon flux estimation in Mediterranean areas.