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Multiyear high-resolution carbon exchange over European croplands from the integration of observed crop yields into CarbonTracker Europe

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Carbon exchange over croplands plays an important role in the European carbon cycle over daily-to-seasonal time scales. Not only do crops occupy one fourth of the European land area, but their photosynthesis and respiration are large and affect CO_2 mole fractions at nearly every atmospheric CO_2 monitoring site. A better description of this crop carbon exchange in our CarbonTracker Europe data assimilation system – which currently treats crops as unmanaged grasslands – could strongly improve its ability to constrain terrestrial carbon fluxes. Available long-term observations of crop yield, harvest, and cultivated area allow such improvements, when combined with the new crop-modeling framework we present. This framework can model the carbon fluxes of 10 major European crops at high spatial and temporal resolution, on a 12x12 km grid and 3-hourly time-step. The development of this framework is threefold: firstly, we optimize crop growth using the process-based WOrld FOod STudies (WOFOST) agricultural crop growth model. Simulated yields are downscaled to match regional crop yield observations from the Statistical Office of the European Union (EUROSTAT) by estimating a yearly regional parameter for each crop species: the yield gap factor. This step allows us to better represent crop phenology, to reproduce the observed multiannual European crop yields, and to construct realistic time series of the crop carbon fluxes (gross primary production, GPP, and autotrophic respiration, R_{aut}) on a fine spatial and temporal resolution. Secondly, we combine these GPP and R_{aut} fluxes with a simple soil respiration model to obtain the total ecosystem respiration (TER) and net ecosystem exchange (NEE). And thirdly, we represent the horizontal transport of carbon that follows crop harvest and its back-respiration into the atmosphere during harvest consumption. We distribute this carbon using observations of the density of human and ruminant populations from EUROSTAT. We assess the model's ability to represent the seasonal GPP, TER and NEE fluxes using observations at 6 European FluxNet winter wheat and grain maize sites and compare it with the fluxes of the current terrestrial carbon cycle model of CarbonTracker Europe: the Simple Biosphere - Carnegie-Ames-Stanford Approach (SiBCASA) model. We find that the new model framework provides a detailed, realistic, and strongly observation-driven estimate of carbon exchange over European croplands. Its products will be made available to the scientific community through the ICOS Carbon Portal, and serve as a new cropland component in CarbonTracker Europe flux estimates.