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Incorporating grassland management in a global vegetation model

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Grassland is a widespread vegetation type, covering nearly one-fifth of the world's land surface (24 million km2), and playing a significant role in the global carbon (C) cycle. Most of grasslands in Europe are cultivated to feed animals, either directly by grazing or indirectly by grass harvest (cutting). A better understanding of the C fluxes from grassland ecosystems in response to climate and management requires not only field experiments but also the aid of simulation models. ORCHIDEE process-based ecosystem model designed for large-scale applications treats grasslands as being unmanaged, where C / water fluxes are only subject to atmospheric CO_2 and climate changes. Our study describes how management of grasslands is included in the ORCHIDEE, and how management affects modeled grassland-atmosphere CO_2 fluxes. The new model, ORCHIDEE-GM (Grassland Management) is capable with a management module inspired from a grassland model (PaSim, version 5.0), of accounting for two grassland management practices (cutting and grazing). The evaluation of the results of ORCHIDEE-GM compared with those of ORCHIDEE at 11 European sites equipped with eddy covariance and biometric measurements, show that ORCHIDEE-GM can capture realistically the cut-induced seasonal variation in biometric variables (LAI: Leaf Area Index; AGB: Aboveground Biomass) and in CO_2 fluxes (GPP: Gross Primary Productivity; TER: Total Ecosystem Respiration; and NEE: Net Ecosystem Exchange). But improvements at grazing sites are only marginal in ORCHIDEE-GM, which relates to the difficulty in accounting for continuous grazing disturbance and its induced complex animal-vegetation interactions. Both NEE and GPP on monthly to annual timescales can be better simulated in ORCHIDEE-GM than in ORCHIDEE without management. At some sites, the model-observation misfit in ORCHIDEE-GM is found to be more related to ill-constrained parameter values than to model structure. Additionally, ORCHIDEE-GM is able to simulate forage yield, herbage consumption, animal products (e.g. milk), animal respiration and animal CH4 emissions. These new variables combined with organic C fertilizer applied on the field could provide a more complete view of grasslands C fluxes for applications of the model on a grid. The 11 site simulations of this study show that European grasslands generally are C sinks (positive NBP). At grazed grasslands, both C export in the form of milk production and CH4 emissions by animals only consist a minor part of net primary production (NPP), and this means that NBP mainly depends on NPP. On the contrary, the cut sites accumulate less C in soils because a large part of NPP has been exported as forage production. Furthermore, theoretically potential of productivity and livestock density in European grassland can be predicted by ORCHIDEE-GM, based on the strategy modeling of the optimal livestock density and management change.