Ability of the upgraded CNMM-DNDC model to simulate soil erosion, productivity and C/N losses

The upgraded CNMM-DNDC model coupled the biogeochemical processes with soil erosion, which was able to predict the crucial variables relevant to biogeochemical processes, including the productivity, greenhouse gases, contaminated gases and NO_3^- loss and the variables related to soil erosion, including the losses of sediment and particulate C, N and P. Figure 7 showed the simulated annual crop grain yield or forest biomass, C sink intensity, emissions of CH_4, N_2O, NO and NH_3, NO_3^- losses through leaching and runoff and losses of sediment and particulate C, N and P among different land uses from 2004 to 2014 in the Jieliu catchment.

The sediment yield and particulate C, N, and P losses of different land use types from 2004 to 2014, which were resulted from the newly added modules of soil erosion, were illustrated in Fig. 7a. For the RF crop system, the upgraded model simulations resulted in no losses of sediment and particulate C, N, and P because of the year-round flooding. Although the simulated average sediment yield of SU was approximately 60% higher than that of SP, the particulate C, N, and P losses of SU and SP were very closer (92.4 versus 78.2 kg C ha^{-1} yr^{-1}, 8.6 versus 7.6 kg N ha^{-1} $yr^{-1}$and 1.2 versus 1.1 kg P ha^{-1} yr^{-1}, respectively). With regard to FL, the upgraded model resulted in the lowest sediment yield and particulate C, N, and P losses among all the land use types.

The simulated annual grain yields of the SU, SP and RF crop systems from 2004 to 2014 averaged 10.6 t dm ha^{-1} yr^{-1} with the range of 9.6−11.4 t dm ha^{-1} yr^{-1}, while the annual accumulated biomasses of the forests from 2004 to 2014 were predicted to range from 6.1 to 10.8 t dm ha$^{−1}$ yr$^{−1}$ with the average of 7.4 t dm ha$^{−1}$ yr$^{−1}$ (Fig. 7b). With regard to the C sink simulation, the FL yielded to the maximum C sink of 3372.7 kg C ha$^{−1}$ yr$^{−1}$ on average with the range of 2877.9−4193.6 kg C ha$^{−1}$ yr$^{−1}$ (Fig. 7c). Meanwhile, the crop systems of SU and SP also acted as C sinks, whose C sink intensities were lower than that of the FL. Compared to the C sink intensity of the SP (averaged 316.3 kg C ha$^{−1}$ yr$^{−1}$ within the range of 230.1−416.6 kg C ha$^{−1}$ yr$^{−1}$), the SU yielded to the larger C sink intensity on the average of 800.7 kg C ha$^{−1}$ yr$^{−1}$ (within the range of 288.4−986.2 kg C ha$^{−1}$ yr$^{−1}$). However, the C sink intensity of RF ranged from −196.1 to −44.6 kg C ha$^{−1}$ yr$^{−1}$, with an average of −97.6 kg C ha$^{−1}$ yr$^{−1}$, which acted as C source (Fig. 7c).

The FL and SU acted as the weak CH_4 sinks, which averaged −1.1 kg C ha$^{−1}$ yr$^{−1}$ (ranged from −1.8 to −0.3 kg C ha$^{−1}$ yr$^{−1}$) and −1.7 kg C ha$^{−1}$ yr$^{−1}$ (ranged from −1.9 to −1.6 kg C ha$^{−1}$ yr$^{−1}$), respectively (Fig. 7d). However, the average annual CH_4 emissions of SP and RF reached 233.2 kg C ha$^{−1}$ yr$^{−1}$ (within the range of 180.6−269.8 kg C ha$^{−1}$ yr$^{−1}$) and 474.6 kg C ha$^{−1}$ yr$^{−1}$ (within the range of 359.2−556.9 kg C ha$^{−1}$ yr$^{−1}$), respectively. In addition, the annual N_2O emissions of FL were extremely low, which averaged 0.1 kg N ha$^{−1}$ yr$^{−1}$ within the range of 0.1−0.2 kg N ha$^{−1}$ yr$^{−1}$, while that of RF yielded to 1.2 kg N ha$^{−1}$ yr$^{−1}$ (ranged from 1.0 to 1.7 kg N ha$^{−1}$ yr$^{−1}$) as Fig. 7e shown. The simulated average annual N_2O emissions of SU and SP were very closer, which averaged to 2.9 kg N ha$^{−1}$ yr$^{−1}$ (within the range of 1.5−4.1 kg N ha$^{−1}$ yr$^{−1}$) and 3.0 kg N ha$^{−1}$ yr$^{−1}$ (within the range of 1.6−5.0 kg N ha$^{−1}$ yr$^{−1}$), respectively. Compared to the annual NO emissions of SU and SP, which averaged 1.4 kg N ha^{-1} yr^{-1} (within 0.6−2.2 kg N ha^{-1} yr^{-1}) and 0.5 kg N ha^{-1} yr^{-1} (within 0.2−0.8 kg N ha^{-1} yr^{-1}), the model simulations yielded to slightly lower NO emissions from RF and FL (Fig. 7f). With regard to NH_3 emissions, the model simulations for the SU, SP and RF crop systems resulted in average annual NH_3 emissions of 90.8 (within 59.7−134.9 kg N ha^{-1} yr^{-1}), 29.7 (within 14.4−48.6 kg N ha^{-1} yr^{-1}) and 66.4 (within 54.7−93.1 kg N ha^{-1} yr^{-1}) kg N ha^{-1} yr^{-1}, respectively. Moreover, the annual NH_3 emissions of FL were very slight, which ranged from 4.9 to 7.3 kg N ha^{-1} yr^{-1}on the average of 6.1 kg N ha^{-1} yr^{-1} (Fig. 7g). Compared with the slight NO_3^- runoff loss (within 0.1−2.3 kg N ha^{-1} yr^{-1} among all the land uses), the simulated annual NO_3^- leaching out of the depth of 0–60 cm soil profile averaged 54.5, 24.2, 29.7 and 9.0 kg N ha^{-1} yr^{-1}, with the range of 5.9−112.7, 8.9−54.0, 21.0−37.6 and 3.8−13.8 kg N ha^{-1} yr^{-1}, respectively (Fig. 7h).