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Modeling the comparative advantages of two lignocellulosic crops for biofuel production

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Crop yields and nitrous oxide (N2O) emissions during feedstock production are important items in the life-cycle impacts and energy efficiency of second-generation biofuels, which results in uncertainties and scientific debates regarding their climate mitigation potential. Several studies have been conducted to find the most promising crops from this point of view, among which perennial grasses such as miscanthus and switchgrass feature prominently. Since greenhouse gas (GHG) emissions strongly depend on crop management and pedoclimatic conditions, it is important to compare feedstocks under similar conditions to quantify their respective performances and guide crop selection. Beyond field trials representing particular sets of such conditions, agro-ecosystem models offer a prime route to generalize trends over large area relevant to supply a full-scale biofuel production plant. Only few such models are currently available, and they have been little tested or used from this perspective thus far.

Here we set out to test whether one of these models was specific enough to capture differences between miscanthus and switchgrass in France, and to simulate their performance at regional level. The biophysical model CERES EGC was compared to field observations obtained in long-term trials in Estrées-Mons (Northern France), two regions that carried experiments and have quantified yields for both crops. The trials involved different treatments for both crops, in terms of fertilizer input rates and harvesting date. Regional simulations were subsequently run in Southern France using a soil map and near-term future climate data from a meso-scale climate simulation model.

In Estrées-Mons the deviation between simulated and observed biomass yields for miscanthus varies between 1 t dry matter (DM) ha-1 (for the early harvest without fertilization) and 4 t DM ha-1 (late harvest with fertilization). However for switchgrass the simulated yields are overestimated by less than 1 t ha-1 compared to the experiments. The yield of miscanthus remains higher than switchgrass for all treatments. The model tended to over-estimate N2O emissions in spring and autumn, resulting in a 20% over-estimation on an annual basis.

According to the regional averages calculated for the two crops in the French regions under Mediterranean climates (Provence Alpes Côte d'Azur and Occitanie), the yield differences between the two crops ranges from 1.5 to 6 t DM ha-1, with miscanthus outperforming switchgrass overall. Applying a fertlizer input rate of 60 kg N ha-1 increased miscanthus yields by up to 5 t ha-1 and only 3 t ha-1 for switchgrass.

considering the regional scale we note that switchgrass emits up to 60% more N2O when fertilised compared to miscanthus. knowing that miscantus produces more than switchgrass we conclude that probably miscanthus is more intersting for producing biofuels.

The ranking and differences between crops reflected those observed in 3 local trials in these regions. However in both cases some irrigation appeared necessary in years with long drought episodes – evidencing the relevant of using models to select the most appropriate crops and management in the medium-term, accounting for future climate changes.