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# Environmental assessment of biofuel chains based on ecosystem modelling, including land-use change effects

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The potential greenhouse gas (GHG) savings resulting from the displacement of fossil energy sources by bioenergy mostly hinges on the uncertainty on the magnitude of nitrous oxide ($N_2O$) emissions from arable soils occuring during feedstock production. These emissions are broadly related to fertilizer nitrogen input rates, but largely controlled by soil and climate factors which makes their estimation highly uncertain.

Here, we set out to improve estimates of $N_2O$ emissions from bioenergy feedstocks by using ecosystem models and measurements and modeling of atmospheric $N_2O$ in the greater Paris (France) area. Ground fluxes were measured in two locations to assess the effect of soil type and management, crop type (including ligno-cellulosics such as triticale, switchgrass and miscanthus), and climate on $N_2O$ emission rates and dynamics. High-resolution maps of $N_2O$ emissions were generated over the Ile-de-France region (around Paris) with two ecosystem models using geographical databases on soils, weather data, land-use and crop management. The models were tested against ground flux measurements and the emission maps were fed into the atmospheric chemistry-transport model CHIMERE. The maps were tested by comparing the CHIMERE simulations with time series of N2O concentrations measured at various heights above the ground in two locations in 2007.

The emissions of $N_2O$, as integrated over the region, were used in a life-cycle assessment of representative biofuel pathways: bioethanol from wheat and sugar-beet ($1^{st}$ generation), and miscanthus ($2^{nd}$ generation chain); bio-diesel from oilseed rape. Effects related to direct and indirect land-use changes (in particular on soil carbon stocks) were also included in the assessment based on various land-use scenarios and literature references. The potential deployment of miscanthus was simulated by assuming it would be grown on the current sugar-beet growing area in Ile-de-France, or by converting land currently under permanent fallow.

Compared to the standard methodology currently used in LCA, based on fixed emissions for $N_2O$, the use of model-derived estimates leads to a 10 to 40% reduction in the overall life-cycle GHG emissions of biofuels. This emphasizes the importance of regional factors in the relationship between agricultural inputs and emissions (altogether with biomass yields) in the outcome of LCAs. When excluding indirect land-use change effects (iLUC), 1st generation pathways enabled GHG savings ranging from 50 to 73% compared to fossile-derived equivalents, while this figure reached 88% for 2nd generation bioethanol from miscanthus. Including iLUC reduced the savings to less than 5% for bio-diesel from rapeseed, 10 to 45% for 1st generation bioethanol and to 60% for miscanthus. These figures apply to the year 2007 and should be extended to a larger number of years, but the magnitude of N2O emissions was similar between 2007, 2008 and 2009 over the Ile de France region.