Evaluation of mitigation practices to attenuate N2O emission and increase soil C stock: a multi-model assessment in five croplands worldwide

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Introduction

Understanding the impacts of the agronomic practices on greenhouse gas (GHG) emissions and soil carbon (C) storage is a key aspect to counteract climate change, mitigate emissions and develop adaptation strategies. Modelling an uncertain future provides stakeholders with a range of potential outcomes to better lead decision making, facilitating the construction and analysis of future scenarios. Notwithstanding mitigation strategies to attenuate GHG emission as nitrous oxide (N_2O) and increase soil C stock are well known, their inclusion in process-based models is still limited (Brilli et al., 2017), as well as an exhaustive evaluation based on a variety of model outputs (e.g. crop productivity).

The objective of this work is to evaluate the response and uncertainties of predictions from an ensemble of crop models, which were run with a set of management options recognized for GHG mitigation and soil C sequestration, i.e., nitrogen (N) fertilisation regimes, irrigation amount and the handling of crop residues. This work was carried out in the framework of the FACCE-JPI project CN-MIP (C and N Models Inter-comparison and Improvement to assess management options for GHG mitigation in agrosystems worldwide; Ehrhardt et al., 2018, Sándor et al., 2018).

Material and Methods

We based this assessment on a set of 13, fully-calibrated process-based crop models (APSIM 7.6, Agro-C 1.0, CERES-EGC, DailyDayCent, DAYCENT [v4.5.2013, v4.5.2010, v4.5.2006], DNDC CAN, DSSAT GHG, EPIC 0810, FASSET v2.5, INFOCROP v2.1 and STICS v.831), managed by an equal number of modelling teams worldwide. Calibration was performed against N_2O emissions and biomass production data at five long-term crop rotations including wheat, soybean, canola, maize, triticale, rice and oat) located in India, France, Australia, Canada and Brazil (Ehrhardt et al., 2018).

Mitigation options were identified for each site based of the current practices of local farmers. They include: i) crop-specific N fertilisation regimes ranging from the maximum to the minimum applied dosages, ii) irrigation amounts from +50% to -50% of the baseline values, and iii) management of crop residues, exported or recycled to the field. With each model included in the ensemble, these options were assessed over a gradient of intensities using the parameter settings obtained with the site-specific calibration. The median of the multi-model ensemble was taken as an indicator of the central tendency of the model outputs, while the variability among models was assumed as an uncertainty measure.

Results and Discussions

Results highlight that a reduction of fertilizer N input is accompanied by a more than proportional reduction of N_2O emissions compared to a decline in biomass production: A fertilization at 20% of the maximum N dose for each crop and in each site is expected to reduce N_2O emissions of about 25% (0.3 kg N_2O-N ha^{-1} y^{-1}), with a reduction of 6% of the aboveground biomass (AGB; 0.6 t DM ha^{-1} y^{-1}). Furthermore, the effect of N dose reduction decreases by 25% and 30% nitrate leaching and ammonia emission, respectively.

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High irrigation volumes (up to +50% from the baseline) combined with high N rates increase N_2O emissions by about 3% with respect to the baseline irrigation, accompanied by a 3% increase in AGB. Reducing both irrigation to -50% from the baseline and N to the lowest doses causes a reduction down to 60% in N_2O emissions compared to the high N input and +50% of irrigation, with 18% reduction in AGB. A significant effect on N_2O emissions and soil C stock was observed with crop residues management. Multi-model uncertainty varied with the output and generally increased with low N doses and high irrigation volumes.

Conclusions

This work demonstrates the capability of multi-modelling assessment to quantify the impact of mitigation options on N_2O emissions, crop production and soil C stocks, providing an estimate of the uncertainties associated with the ensemble modelling.

Keywords: multi-modelling, greenhouse gas emission, soil carbon stock, management practices, cropland.

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