MODEL BASED ANALYSIS OF FACTORS GOVERNING N2O EMISSION FROM BIOENERGY CROPPING SYSTEMS

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There is growing concern that greenhouse gas (GHG) emissions from cropping systems for biomethane production might mitigate intended GHG emission savings. Biomethane as the major bioenergy source in Germany is based on intensive and highly productive cropping systems, mainly dominated by maize, while alternative crops are investigated. N_2O emission is the major GHG source in all intensive cropping systems because of high fertilizer N inputs. The influence of different cropping systems on N_2O emissions in interaction with temporal and spatial variations in weather and soil properties is still largely unknown. The aim of the presented study was to adapt a process oriented model approach for the analysis of factors governing N_2O emissions under different environmental and management conditions.

Materials and Methods

A dynamic simulation model was developed as a combination and adaptation of existing approaches. It calculates N_2O emissions from nitrification and denitrification in soil. Nitrification is calculated by first order kinetics with the influence of water content and soil temperature (Zhou et al. 2010, Hansen et al. 1990). Denitrification is calculated by Michaelis-Menten kinetics with influence of soil water, soil temperature, and C mineralisation rate (Zhou et al. 2010, Del Grosso et al. 2000, Hansen et al. 1990). The boundary conditions (nitrate concentration, water content in soil) for these processes are calculated with already existing modules for crop growth, water balance and mineralisation. A field trial was conducted at two sites in Northern Germany (Wienforth 2011). N_2O fluxes were measured with closed-chamber technique on average once a week, March 2007 – April 2009 (Senbayram 2009). Cumulative N_2O emissions were calculated by linear interpolation between measured daily fluxes. The present work is based on data of a maize monoculture at a sandy site and a crop rotation of silage maize, wheat (for whole crop silage use) and Italian ryegrass (catch crop) at a loamy site. We evaluated an unfertilised treatment (N1) and two levels of mineral N fertilization with 120 kg N ha^{-1} for maize and wheat and 160 kg N ha^{-1} for grass (N2) and 360 kg N ha^{-1} for maize and wheat and 160 kg N ha^{-1} for grass (N4).

Table 1: Measured and simulated annual N_2O emissions and emission factors for the period 1.4.2007- 15.3.2009

Crop rotation	Mineral Fertilizer [kg N ha^{-1} a^{-1}]	N_2O emission measured [kg N ha^{-1} a^{-1}]	N_2O emission simulated [kg N ha^{-1} a^{-1}]	Emission factor measured [% Fertilizer]	Emission factor simulated [% Fertilizer]
Maize – Wheat – Grass (loamy site)	0	1.0	1.6		
	200	4.3	3.2	2.1	1.6
	440	6.7	5.9	1.5	1.3
Maize – Maize (sandy site)	0	0.8	0.5		
	120	0.8	0.7	0.7	0.6
	360	3.3	1.7	0.9	0.5

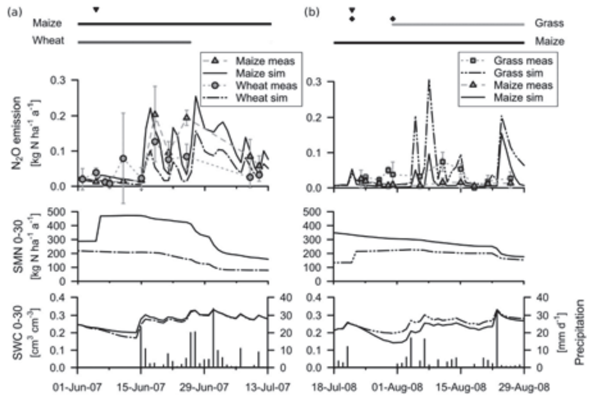

Figure 1: Daily measured (meas) and simulated (sim) N_2O emissions of the N4 treatment. Corresponding simulated SMN in 0-30 cm soil depth, SWC in 0-30 cm soil depth and daily precipitation at the loamy site for (a) Maize and Wheat 1.6. – 13.7.2007, (b) Ryegrass and Maize 18.7. – 29.8.2008. Triangles: fertilization dates, rhombs: tillage dates, horizontal lines: growing periods of maize, wheat or grass. Error bars for standard error of the mean of each treatment (n=3).

Results and Discussion

As a prerequisite for the simulation of nitrification and denitrification the boundary conditions were described as close to measured data as possible using dynamic modules and linear interpolation of measured data (plant N uptake). Then two parameters were fitted to N_2O emission data, all other parameters were taken from literature. The model reproduced the annual variation between crop rotation and fertilizer levels of the parameterization data set (Table 1). The simulated time course of daily N_2O fluxes is generally plausible (Figure 1). Fertilization events result in increasing soil mineral nitrogen (SMN). Higher SMN in soil results in higher N_2O fluxes in maize in comparison to wheat, under conditions of similar soil water content (SWC) in both crops (Figure 1a). On the other hand higher SWC under grass results in higher N_2O fluxes, even when SMN is lower than in maize (Figure 1b). During dry periods there are generally no N_2O fluxes (early June 2007). N_2O emissions start with increasing SWC after the dry period (Figure 1a). The model was not able to simulate increasing N_2O fluxes after tillage events properly (Figure 1b). Precipitation events mostly resulted in N_2O emission peaks. Sometimes simulated N_2O emission peaks were not captured by the measurement scheme but seem plausible to have happened (e.g. end of August 2008).

Conclusions

The model calculated reasonable annual N_2O emissions after site specific calibration. The variation due to differences in weather, fertilization, location and crop rotation was reproduced. In some cases the dynamics of simulated data is more plausible than linear interpolation of measured data. Accuracy of the results clearly depended on adaptation of boundary conditions to measured data.

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