A DYNAMIC SIMULATION MODEL TO ANALYSE N2O EMISSIONS FROM BIOMETHANE PRODUCTION SYSTEMS

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Biomethane production in Germany as a source of renewable energy is based mainly on maize. For purposes of a more diverse agricultural landscape alternative crops are investigated. Besides a high dry matter production also the greenhouse gas (GHG) balance should be considered. In intensive and highly productive cropping systems the largest GHG source are N_2O emissions.

N_2O emissions originate from nitrification and denitrification in the soil. Soil water content and temperature of the soil, NH_4 concentration, NO_3 concentration, carbon turnover rate, soil pH are factors affecting these processes. Most of these factors vary during the growing season on a small time scale and are connected to other processes within the system of soil – plant – atmosphere. To evaluate the reasons for differences in N_2O emissions between different cropping systems, N fertilisation levels and years a dynamic simulation model was developed to include both the dynamics of influencing factors and the processes of nitrification and denitrification. The main objective was to build up the model in such a way that the influences on nitrification and denitrification reproduce measured data as accurate as possible.

Materials and Methods

In the seasons 2006/07 and 2007/08 a field trial was conducted at two sites in northern Germany. The data for this project include a maize monoculture at the more sandy site and maize monoculture as well as a crop rotation of wheat (for whole crop silage use), Italian ryegrass and maize at the more loamy site. All crops were tested in an unfertilised treatment and two treatments with different levels of mineral N fertilisation. In the selected treatments leaf area index (LAI), crop height and N in the aboveground biomass were measured at regular intervals throughout the growing season. Soil water content was measured by TDR probes and soil mineral nitrogen (SMN) in the different soil layers was measured before winter, at the beginning of spring growth and after harvest (Wienforth 2011). On average once a week N_2O fluxes from the soil were measured (Senbayram 2009). The soil water content as a factor influencing both nitirification and denitrification was simulated in a dynamic layered model based on a solution of the water content based formulation of the Richards equation. LAI and crop height as input variables for the Penman-Monteith equation for evapotranspiration were interpolated linearly between the measurement dates. Rooting depth and root distribution were estimated based on temperature sum since sowing and provide together with evapotranspiration a measure of water uptake by the crop. The amount of NH_4 as substrate for nitrification was derived from a coupled C and N mineralisation module based on four C pools. NO_3 is then transported by vertical water movement and taken up by the growing canopy. NO_3 also is the substrate for denitrification. Soil temperature was calculated by a simple heat conductance model depending on the soil water content (Fig.1).

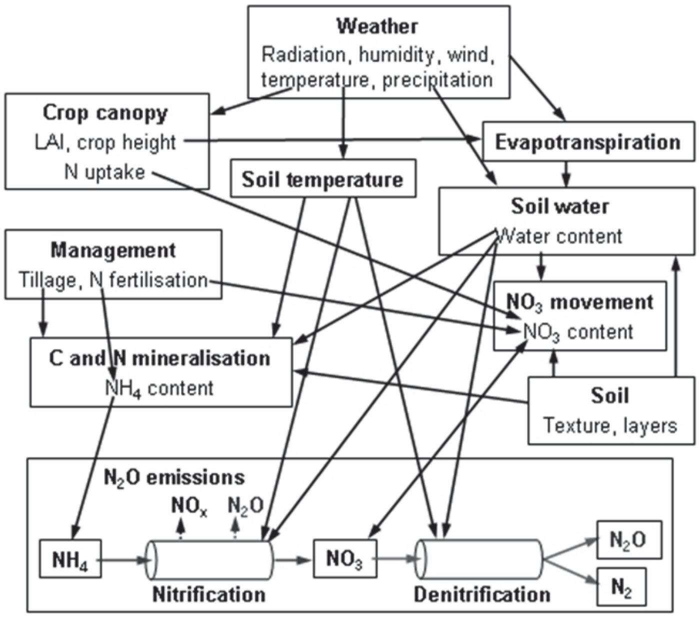

Figure 1: Simplified scheme of the coupled dynamic soil-plant-atmosphere model with processes and variables influencing N_2O emissions by nitrification and denitrification

Results and Discussion

The soil textures as parameters for the soil water dynamics were adjusted according to soil analyses and measured water contents. Due to the large soil heterogeneity at both sites there were large variations in the measured data between the four replications of each treatment. By dynamic modelling we were able to simulate soil water contents in the important layer of 0-30 cm depth quite accurately (RMSE = 0.031 cm^3/cm^3). The turnover rate for the pool of soil organic matter was adjusted for each fertilisation level separately while all other mineralisation parameters were taken from literature. With this parameterisation the model was able to simulate SMN in 0-30 cm well (RMSE = 21.6 kg N/ha). It should be noted that the model also provides plausible data for times without SMN measurements (main mineralization period in spring, fertilisation dates).

Conclusions

The presented model combines frequently available measured data (LAI, crop height, N uptake of the crop) and dynamic process oriented approaches (soil water dynamics, NO_3 dynamics, mineralization, nitrification and denitrification). This combination appears to be a good method to simulate the influencing factors for N_2O emissions from cropping systems as accurately as possible and to provide a tool to analyse the effect of different crop rotations and management measures on N_2O emissions.

Wienforth B 2011. Dissertation, Christian-Albrechts-Universität, Kiel, Germany.

Senbayram M 2009. Dissertation, Christian-Albrechts-Universität, Kiel, Germany.