SimDen – A simple empirical model for quantification of N_2O emission and denitrification.

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Introduction

How much N is lost by denitrification? This question we often get from farmers, environmental authorities or others, but in spite of many years of energetic attempts it is still difficult to give an unambiguous answer to the question. However, with the simple empirical model SimDen, which is based on a combination of average results from the literature, several years of experience and a portion of common sense, it is possible to give a rough estimate of the average annual denitrification in Danish agricultural soils (Vinther & Hansen, 2004). The Danish soils are however relatively low in clay, with contents lower than 25%. Therefore, an extended version – SimDen-Clay – is presented here, which gives average estimates of the annual N_2O emission and denitrification in soil with clay contents from 0 to 100 % using only actual clay content and amount of fertiliser as input parameters.

Model description

The denitrification is a microbial process by which nitrate is reduced to nitrous oxide (N_2O) and/or to atmospheric nitrogen (N_2), which means that the denitrification can be calculated as (N_2O-emission) x (N_2/N_2O-ratio) forming the principle of SimDen. Moreover, due to the significant effect of soil moisture, i.e. water filled pore space (WFPS), on the denitrification, and the effect of clay content on hydraulic conductivity, it is possible to establish a relationship between clay content and the denitrification.

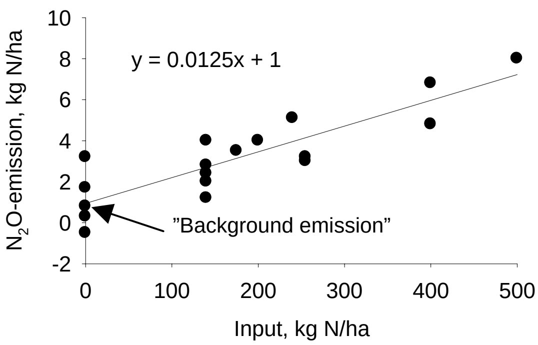

Fig. 1. Relation between input of N and

The N_2O-emission is derived from the relationship between input of fertiliser-N and emission factors (Fig. 1), as used in the IPCC-methodology (IPCC, 1997). However, the IPCC emission factor at 1.25% was modified according to Kasimir-Klemedtsson & Klemedtsson (2002) suggesting 0.8% of applied N for inorganic fertiliser and 2.5% for animal manure/slurry. N_2/N_2O-ratios were derived from literature values; for example Weier et al. (1993) as shown in Fig. 2. Thus, the denitrification in SimDen is calculated as

(Background N_2O-emission + (N-input x N_2O-emission factor)) x N_2/N_2O-ratio

Several studies have shown that the factor of major importance for the denitrification is WFPS, and that the denitrification is insignificant at WFPS < 60% (Fig. 3). In sandy soils with clay contents lower than 10% the WFPS at field capacity is lower than 60% (Fig. 4), and since these soils also have a high hydraulic conductivity (Fig. 5), the consequence is that these soils rarely will reach the threshold level for denitrification. At increasing clay content the WFPS at field capacity increases at the same time as the hydraulic conductivity decreases, resulting in an increasing potential for denitrification.

It was then assumed that the background N_2O emission as well as the N_2/N_2O-ratios as a function of clay content could be described with a Michaelis-Menten equation (Fig. 6). The background N_2O emission was fitted with this equation to give an average emission at about 1 kg N ha^{-1} year^{-1} (Fig. 1). Similarly, the N_2/N_2O ratios were fitted resulting in an average N_2/N_2O ratio at about 4, which corresponds to the mean value of the about 500 N_2/N_2O-ratios found in the literature.

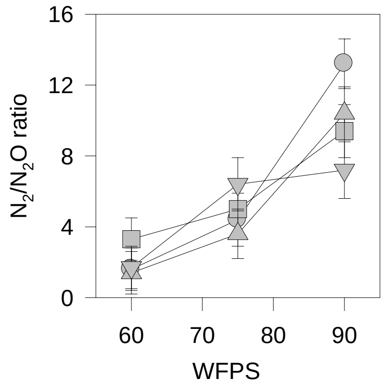

Fig. 2. Relations between water filled pore space (WFPS) and N_2/N_2O ratio in four different soils (from Weier *et al*., 1993).

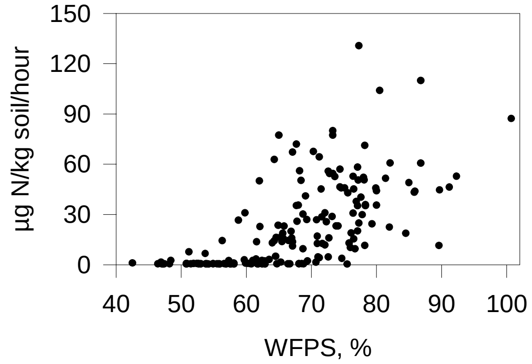

Fig. 3. Relations between water filled pore space (WFPS) and denitrification activity.

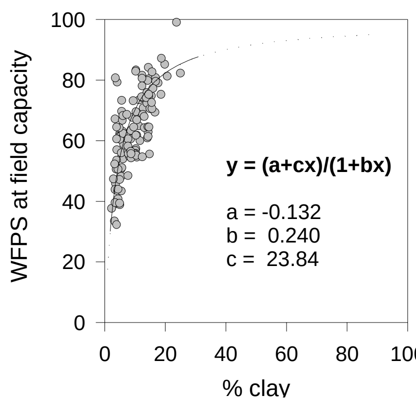

Fig. 4. Relationship between clay content and WFPS at field capacity.

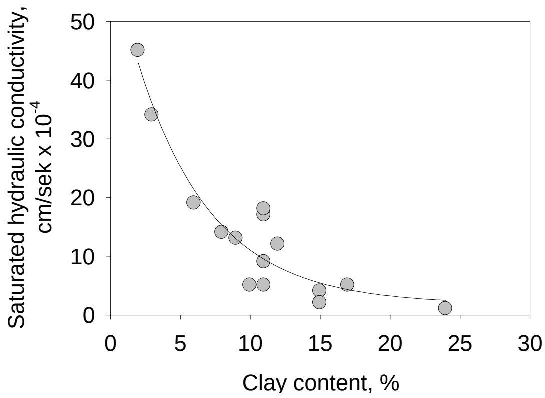

Fig. 5. Relationship between clay content and saturated hydraulic conductivity.

SimDen is described in further details in (Vinther & Hansen, 2004) and can be downloaded at www.agrsci.dk/simden

Results

SimDen was compared with a number of field measurements in Danish soils (Fig. 7).

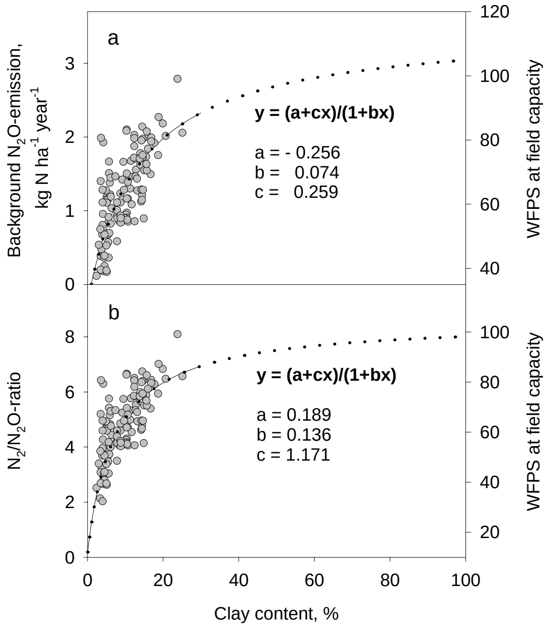

Fig. 6. Fitted relationships between background N_2O emission (a) and N_2/N_2O-ratios (b) as function of clay content. Dots are measured values of WFPS at field capacity as function of clay content.

Within the entire range of measurements (Fig. 7, left) there seem to be a reasonable good agreement between the measured denitrification rates and those calculated with SimDen. The high denitrification rate at 230 kg N ha^{-1} $year^{-1}$ was measured during the third year in a loamy soil (ST6), which had received 100 tons pig slurry ha^{-1} $year^{-1}$ for three years (Maag, 1989). Within the lower range of values, where the major number of results is found (Fig. 7, right), SimDen seems to overestimate the denitrification.

However, different circumstances under which these measurements were made indicate that the measured values may be underestimated: 1) SimDen estimates the denitrification in 0-100 cm, whereas all measurements only include the 0-20 cm soil layer, 2) the measurements in the field were performed with relatively large time intervals, and thus the denitrification flushes following precipitation may not have been caught, 3) few of the results include measurements during the winter time, where it has been found that up to 75% of the annual emission may be measured (Goossens et al., 2001), and finally, 4) all measurements were performed on well-drained soils without depressions in the field with higher soil moisture and potentials for higher denitrification.

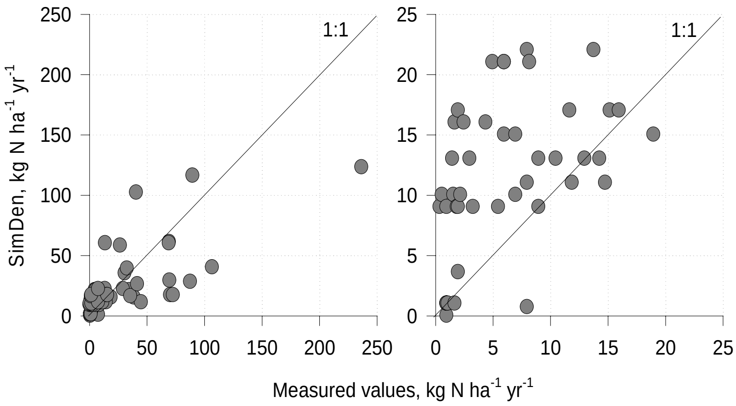

Fig. 7. Measured and SimDen-modelled denitrification rates in the entire range (left) and the lower range of values (right).

Comparisons between the original version of SimDen and SimDen-Clay show a good agreement between the two models (Fig. 8).

Conclusion

Based on knowledge about only clay content and input of fertiliser N is it possible it is possible to give a rough estimate of annual denitrification.

If more detailed information is needed, i.e., regarding temporal variation under certain climatic conditions, dynamic models as for example the soil-plant-atmosphere model Daisy must be used.

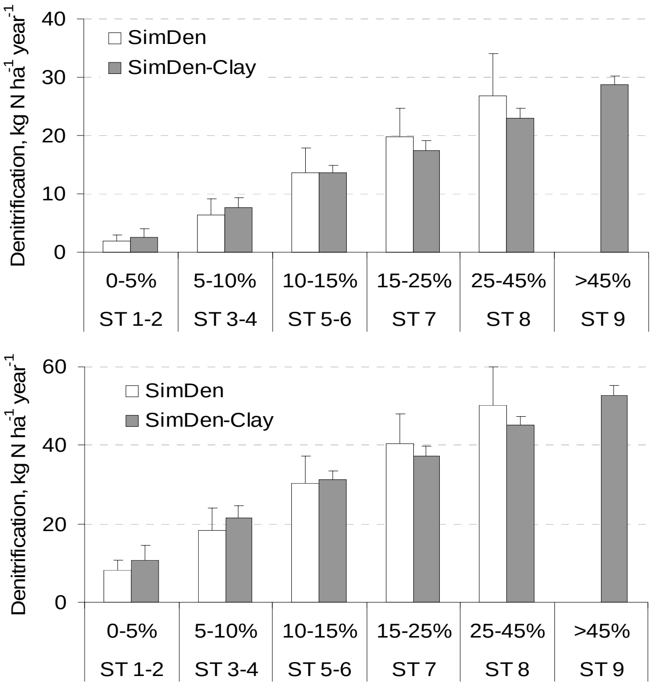

Fig. 8. Comparisons of average annual denitrification estimated by SimDen and SimDen-Clay at the soil types (ST) 1 – 9 with clay contents from <5% to >45%.

References

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