Simulation of Greenhouse Gas Emissions after Land Application of Cattle Manure

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ABSTRACT
Land application of cattle manure is a cost effective source of nutrients and organic matter for crop production. However, emissions of greenhouse gases after land application contribute to air pollution impacting public health and welfare. Knowledge of gas transport mechanisms in manure-amended soils is an important part of predicting gaseous emissions from land application practices. A predictive empirical model was developed based on detailed numerical simulations of wetting and drying processes in manure using HYDRUS-1D. Similar to the principle of soil respiration, the fundamental model parameters, calculated based on field measurements of gaseous emissions after surface application of four different manure sources (i.e. dairy manure, beef manure, dairy compost, and beef compost). Soil / manure moisture contents were monitored during the course of measurements using dielectric sensors. The developed model provides improved means for estimation of greenhouse gas emissions from land-applied manure, based on the physical and thermal soil and manure properties.

THEORETICAL CONSIDERATIONS
Soil and Cattle Manure Hydraulic Parameters:
The soil-hydraulic function of van Genuchten (1980) using the statistical pore-size distribution model of Mualem (1976) was implemented to obtain a predictive equation for the unsaturated hydraulic conductivity function in terms of soil and manure water retention parameters. The van Genuchten’s water retention parameters and hydraulic conductivities used in the simulations are listed in the table below.

<table>
<thead>
<tr>
<th>Medium</th>
<th>( \Theta_s )</th>
<th>( \Theta_r )</th>
<th>( \alpha )</th>
<th>( n )</th>
<th>( m )</th>
<th>( K_s )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cattle manure</td>
<td>0.087</td>
<td>0.895</td>
<td>0.027</td>
<td>1.391</td>
<td>0.281</td>
<td>190</td>
</tr>
<tr>
<td>Millville silt loam</td>
<td>0.097</td>
<td>0.428</td>
<td>0.012</td>
<td>1.916</td>
<td>0.479</td>
<td>65.73</td>
</tr>
</tbody>
</table>

\( \Theta_s \) is residual water content; \( \Theta_r \) is saturated water content; \( \alpha \), \( n \), and \( m \) are shape parameters related to the pore-size distribution; and \( K_s \) is saturated hydraulic conductivity

EXPERIMENTAL SETUP
Manure surface application (2.5 cm) plots were set up at Greenville Research Farm (central coordinates: 41° 45’ 58.5” N 111° 46’ 41.9” W) in North Logan, UT during Aug. and Sept. 2013 to quantify gaseous emissions. The soil / manure moisture content sensors were inserted into the surface to a depth of 5 cm. A multiplexed automated chamber system was employed for evaluation of manure management practices. The figure below shows a closed dynamic chamber measuring gas buildup to estimate emissions from soil surface-applied manure.

RESULTS AND DISCUSSION
Figure (a) shows a good agreement between measured and modeled \( CO_2 \) fluxes for surface application of cattle manure on Millville silt loam. The coefficient of determination \( R^2 \) was 0.84 as illustrated in Figure (b). The large deviations between the measured and modeled \( CO_2 \) fluxes were observed at the beginning of drying stage when the water content was rapidly changing as shown in Figure (c). The measurements are presented in hourly values to investigate variations in gas emissions related to changes in temperature. Figure (c) shows the comparison of the predicted and measured daily water contents approximately at 5 cm depth. Figure (d) shows the predicted \( CO_2 \) concentrations in the profile during the course of experiment.

In this study, we presented a model development to investigate gas (i.e. \( CO_2 \)) emissions from land application of cattle manure using HYDRUS-1D. The accuracy of the model is limited by the assumption that the gas production by microorganisms is identical in all materials. The concept of model development can be further used for investigation of other gaseous compounds and greenhouse gases emitted from manure.

REFERENCES

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