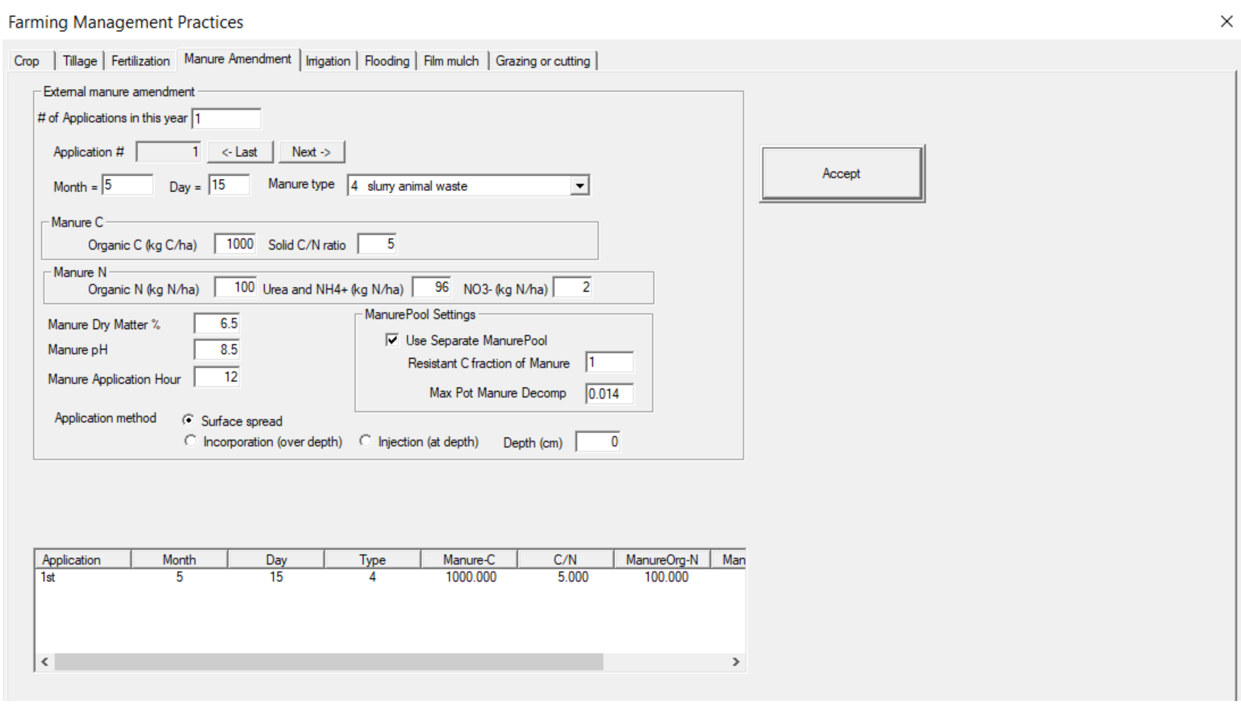
DNDC 9.6.0 November 24

Inclusion of a Separate Manure C Pool for handling of biosolids and sterilized C additions:

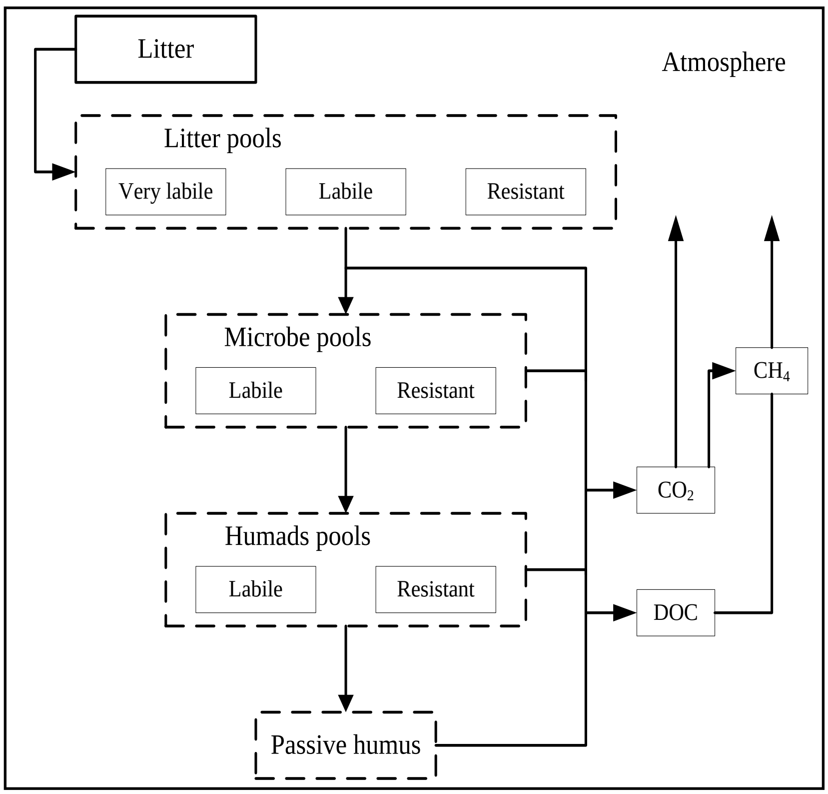
A separate manure pool was developed to allow for improved user parameterization of C amendments that weren't well characterized under the default C amendment framework. This new addition allows the user to have more control over the decomposition rate of these C amendments before they are cycled into the microbial and litter C soil pools. The user should be able to define the rate of decomposition of these additions.



Background on default C decomposition:

DNDC uses first order kinetics to describe C decomposition and characterizes soil C dynamics across a number of conceptual pools. These pools are divided across litter (very labile, labile, resistant), microbial (labile, resistant) and intermediate (humads) and slow (humus) C pools that each have their own base decomposition rates that are adjusted by soil environmental conditions (temperature, moisture, texture and aeration). The decomposition process steps through these pools sequentially (Fig 1) by converting litter to microbial biomass then to humus and humads. The rate of conversion of litter to microbial biomass is limited by the availability of soil N substrates that would be necessary to decompose varying C:N residues (i.e. wider C:N residues would require higher amounts of soil N to supply the microbial biomass formation which is around ~10:1 C:N ratio). By default manure C additions are handled in the soil by discerning the C:N of the incoming manure addition which is used to determine the partitioning of the manure C into the litter pools (vlabile[C:N <=5] , labile [C:N <= 10] and resistant labile pools [C:N <=25) and >25 directly to the humads. Generally this approach works well for typical manure additions (slurries, farmyard compost) it becomes limiting in representing biosolid C additions which may have relatively narrow C:N ratios but have slower rates of decomposition that are influenced by factors outside of just their C:N ratio (i.e. sterilized, alkalized treatments). Thus it was determined that a expanding the C decomposition framework to accommodate for a wider range of organic C amendments would be useful to better characterize C decomposition and the related soil CO2 fluxes.

Figure 1. Describing the general framework for C:N decomposition.



The modified DNDC model integrates a new separate manure C pool (in addition to the existing C pools), that expands the characterization for a wider range of organic C amendment types by allowing user defined control over manure C decomposition dynamics outside of just the C:N characteristics of the amendments. The expanded model framework allows the user to control the allocation of manure and biosolids C along the C decomposition pathways (default stepwise vs. user controlled partitioning into labile and resistant fractions) by defining the maximum potential decomposition rate and proportion of resistant manure C that constitutes a manure/biosolid C addition. This ability of allowing for a user defined portion of manure C (defined as resistant manure C) can help facilitate lower associated CO_2 emissions for slower decomposing biosolid C additions, as the manure C (still regulated by available N and base decomposition rates) can decompose directly into the microbial fraction without having to follow the models default pathways of stepwise manure decomposition through the litter fractions before entering the microbial. This flexibility ensures model simulation of slowly decomposing biosolid additions can be better represented for their decomposition dynamics and CO_2 emissions evolution over seasonal and annual temporal scales. By enabling precise control over manure C pathways, the model enhances its applicability for assessing GHG emissions and optimizing best management practices.

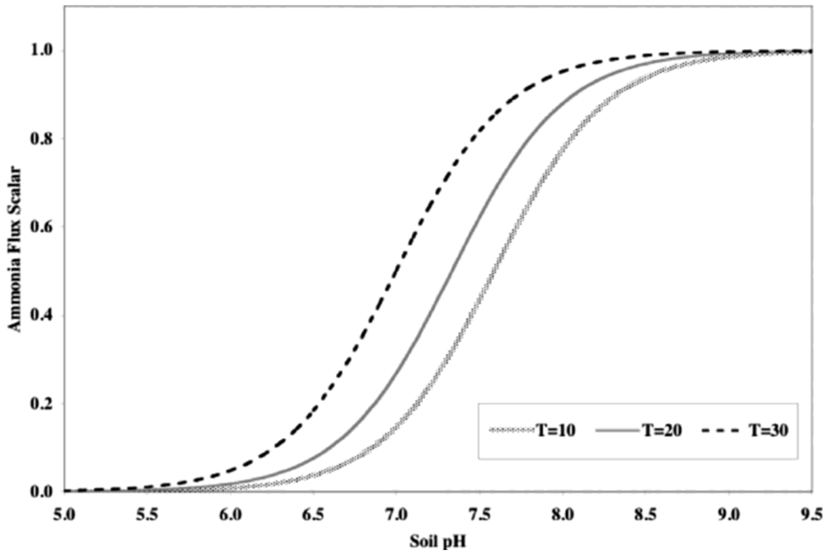
The default temperature effect on decomposition was also updated during these revisions.

RFMT=3.8×10−9·temp[l]^5−8.001×10−7·temp[l]^4+3.8932×10−6·temp[l]^3+9.827301×10−4·temp[l]^2+0.0160017336·temp[l]+0.0910419050

Where temp[l] = soil temperature for that layer oC and RFMT is the temperature effect on C decomposition.

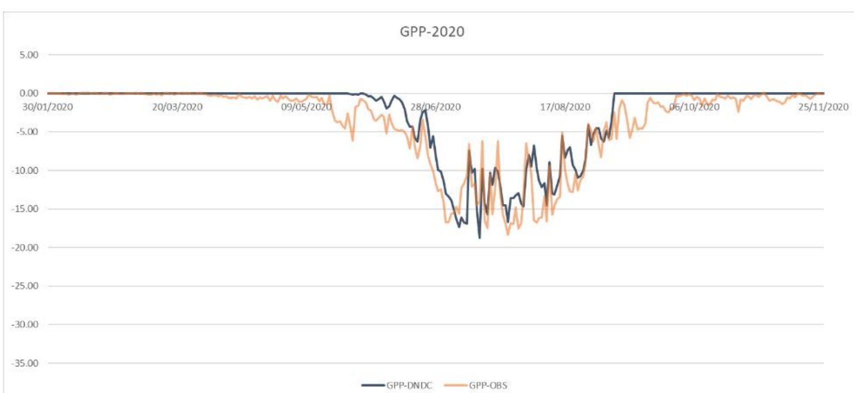
Adjustment to the NH4:NH3 equilibrium and pH sensitivities to NH3 fluxes

After some investigations with acidic soils in Brazil we had revisited the formulations that we'd included in the 2016 Congreves et al., publication that had made some improvements in this function with regards to manure slurries and NH3 fluxes. While this routine worked quite well for soils ~6.5 – 7.5 pH there were some improvements that were found to better characterize the full range of initial soil pH impacts on this equilibrium equation. Using a relationship similar to the one by Potter et al., 2003 we've better tuned the NH4:NH3 equilibrium to better represent these relationships between soil pH, NH3/NH4 in soil solution and temperature. Some improvements to the hourly surface soil temperature calculations for tropical soils and residue cover were also included in this work along with the calculation of pH buffering capacity in offsetting pH shifts due to urea hydrolysis.



Inclusion of Radiation Use Efficiency on crop growth

The model relies on temperature driven plant growth that is adjusted by water, nitrogen and temperature stresses. Comparisons to CO2 respiration and GPP have highlighted some limitations of this approach in the day to day effects of solar radiation input on determining daily growth limitations. We have implemented a generalized RUE stress based on solar radiation input to reduce daily potential growth however it is not crop species specific at this time. Additional work is planned to elaborate this feature to be crop species dependant.



Inversion Tillage with buried carbon:

The model already had buried carbon tillage implementation where crop residues were deposited below the plough depth however it did not represent the inversion of soil layers within the plough depth well. The default tillage methodology mixes all soil layers evenly within the plough depth before applying a temporary aeration factor to influence the enhanced decomposition associated with that specific tillage type. To accommodate a better representation of mouldboard plough we have inverted the soil C layers in the model with this buried tillage implement. Future plans will include the option to specify a custom tillage option that describes the tillage affected depth, the type of mixing of soil layers (inversion with buried residue C, fully mixed, partially mixed, undisturbed) and aeration factor .

New DNDC Outputs

Additional outputs were added to the model. Day_SOILN2O outputs the nitrification and denitrification evolved in a specific soil depth. Also the total soil water (liquid + ice) is also reported in this file.

Future Plans:

Banded Fertilizers:

The models ability to handle banded fertilizers and the influence of discrete soil pH shifts and associated N gas fluxes is not handled well currently. We are working with the University of Manitoba to develop a Quasi 2D approach towards better conceptualizing this common fertilizer application method within the 1D model framework. The conceptualization of N diffusion outwards on the horizontal and vertical planes will be added (expansion of N dimensions), the recalculation of the concentration of N at each of these horizontal/vertical nodes will be determined and then upon exiting of the anerobic balloon code the model will shrink the N pools back to 1D.

Intercropped Rooting development and plant resource demand/competition

A McGill lead initiative is being conducted to work on the improvement of root expansion and development in intercropped situations. This will require representing root development across a quasi 2D plane to allow for the better estimation of root resource uptake by intercropped species.

Improved representation of vertical stratification of microbial denitrification/nitrification activity

With partnership with the University of Guelph we are hoping to better understand the relative contribution of vertical planes towards the denitrification footprint of N2O emissions (especially under winter conditions). The model currently has some simplifications in the way that redox potential is calculated and used to determine the aerobic/anaerobic partitioning. Using measurements from lysimeters these relationships between soil environmental conditions and microbial activity should be better understood and described within the modelling framework.

Bayesian Optimization Approaches

Under a University of Ohio led initiative we are hoping to help develop improved techniques for Bayesian optimization of model parameters for calibration techniques. Previous work with the PEST model had shown some promising results for optimization capabilities however other approaches may have similar benefits with less required overhead in implementation of these optimization techniques.