Steps for Calibration and Validation of DNDC

By

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The Denitrification-Decomposition (DNDC) model is a biogeochemical process model. DNDC was constructed based on four basic concepts, i.e., biogeochemical abundance, field, coupling, and cycling. DNDC consists of six sub-models for soil climate, crop growth, decomposition, nitrification, denitrification, and fermentation. The six interacting sub-models include fundamental factors and reactions, which integrate C and N cycles into a computing system. DNDC has been validated against numerous datasets observed worldwide. During the last several years, DNDC has been independently tested by researchers in many countries and applied for their national C sequestration and N_2O inventory studies. By tracking crop biomass production and decomposition rates, DNDC simulated long-term SOC dynamics. DNDC predicts N_2O and CH_4 emissions by tracking the reaction kinetics of nitrification, denitrification, methanogenisis and methanotrophy and gas transport from soils to atmosphere across climatic zones, soil types, and management regimes. This white paper outlines the steps that were used for calibration and validation of DNDC for modeling rice methane emissions in the US.

Independent field data were utilized to calibrate and then independently validate DNDC. Calibration was performed to set the model input crop parameters for varieties grown in California and MidSouth rice growing regions to ensure that the modeled crop growth had correct effects on the soil climate and carbon (C) and nitrogen (N) dynamics. No internal parameters in DNDC were calibrated leaving the biogeochemical processes embedded in DNDC unchanged. This is critically important for independent validation.

The following steps were followed for DNDC validation:

1. Read original field data collection reports/papers to collect all the input information including

    (1) location (latitude), year (climate data),
    (2) soil properties (texture, bulk density, pH, SOC, field capacity, wilting point, clay fraction, saturation conductivity) for top layer (<10 cm),
    (3) crop: type, planting/harvest dates, residue management, maximum yield, biomass partitions and C/N ratio, thermal degree days to maturity, water requirement, N fixation rate,
    (4) management practices: tillage, fertilization, manure application, irrigation, flooding, plastic file mulching, plant cut/trim, grazing intensity and timing.

When some of the required input information is missing in the original reports, DNDC-default data are used. This is typically the case for some of the soil properties such as field capacity, wilting point, clay fraction, saturation conductivity, and for the crop parameters such as biomass partitions and C/N ratio, thermal degree days to maturity, water requirement, N fixation rate.

2. Review original reports/papers to collect all the measured data potentially useful for model calibration and validation. These data include:

   (1) crop phenology and yield, crop biomass chemical analysis results,
   (2) soil temperature/moisture/pH/Eh/C/N profiles,
   (3) fluxes of CO_2, N_2O, NO, N_2, NH_3, and CH_4 emitted from the soil-plant system.

3. Start DNDC to open the main menu.

4. Click "Site: Input" to initiate input procedure.

5. Click "Climate" to type in information of location name, latitude, simulated years, daily weather file(s), atmospheric N deposition, atmospheric NH_3 concentration, atmospheric CO_2 concentration.

6. Click "Soil" to type in information of soil properties. A group of soil properties (field capacity, wilting point, clay fraction, porosity, saturation conductivity) related to soil texture will be automatically shown up after the soil texture is selected. The default parameters are subject to adjustment by the users based on their knowledge of the field conditions.

7. Click "Cropping" to start the input processes for crop cultivation.

   (1) Click "Crop" to type in information of the crop(s) planted in the very year. A group of crop parameters (biomass partitions and C/N ratio, thermal degree days to maturity, water requirement, N fixation rate) will be automatically shown up after the crop type is selected. The default parameters are subject to adjustment by the users based on their best knowledge.
   (2) Click "Tillage" to type in information of tilling practices applied in the very year.
   (3) Click "Fertilization" to type in information of fertilizer application(s) in the very year.
   (4) Click "Manure amendment" to type in information of organic fertilizer application(s) in the very year.
   (5) Click "Irrigation" to type in information of irrigation application(s) in the very year.
   (6) Click "Flooding" to type in information of flooding application(s) in the very year.

    (7) Click “Plastic” to type in information of plastic file mulch application(s) in the very year.
    (8) Click “Grazing and cutting” to type in information of grazing and plant cutting application(s) in the very year.

8. Click “Save” on the input menu to safe the input information into a file for future use.

9. Click “OK” to come back to the main menu.

10. Click “Site: Run” to execute the simulation.

11. Review modeled crop phenology and yield in comparison with observations. If there are discrepancies, go back to the “Crop” page to modify the crop parameters such as maximum yield, biomass partitions between grain/leaf/stem/root, and C/N ratio in grain/leaf/stem/root, thermal degree days to maturity, water requirement, and N fixation index. The priority of parameters subject to adjustment depends on the nature of the discrepancies. In DNDC, crop biomass/yield is mainly driven by stresses of temperature, water and nitrogen (N). DNDC provides a chart at the main menu to assist quick check for finding the major stress. Clicking “Results\Crop” will lead to the chart on which ideal biomass for grain, leaf+stem and root is compared with the modeled biomass. By comparing the demand of temperature, water or N with modeled crop gain of temperature, water or N, the users can easily identify the major factor(s) affect the crop growth. It is highly encouraged to gain understandings of the crop phenology, biomass structure and physiology that will be helpful to accelerate the adjustment procedure.

12. Review modeled soil temperature/moisture/pH/Eh/C/N profiles in comparison with field observations. If there are discrepancies, go back to the “Soil” page to modify the soil parameters. Soil moisture profile can be adjusted by altering the hydrological parameters such as field capacity, wilting point, porosity, and saturation conductivity. Soil C or N profiles can be adjusted by redefining the initial SOC profile, SOC partitions to litter, humads and humus, or default specific decomposition rates for litter, humads or humus. Understandings of the soil hydrological processes will be helpful to adjust the soil parameters. The default soil hydrological parameters by soil texture class were used for the rice validation analyses.

13. Review modeled gas fluxes on daily or annual basis in comparison with observations. If there are discrepancies, go back to the “Crop” and/or “Soil” page to modify crop or soil parameters. There is no approach to directly adjust gas fluxes. As end products of C or N biogeochemical cycle in agroecosystems, C gases or N gases can be adjusted only

through modifying crop or soil parameters to alter the biogeochemical processes. The success of gas adjustment through modifying crop and/or soil properties is ensured by the biogeochemical processes embedded in the structure of the model. It is highly encouraged to gain understandings of the microbe-mediated mechanisms of gas production controlled by plant growth and/or soil physical and chemical processes that will be helpful to improve the modeled gas emissions.

14. As soon as the calibration is done using one plot of the plots employed in the field experiment, all the crop and soil parameters should be fixed. These parameters will be used in the simulations for the rest plots in the experiment for validation, if all the plots share same crop and soil properties.

15. Daily field measurements are then interpolated to estimate annual and season methane emissions from rice. Linear interpolation is used since methane emissions tend to not be highly episodic like nitrous oxide emissions.

16. Interpolated field measurements are then compared directly with DNDC modeled emissions. The difference between measured and modeled emission are used to quantify DNDC model uncertainty.