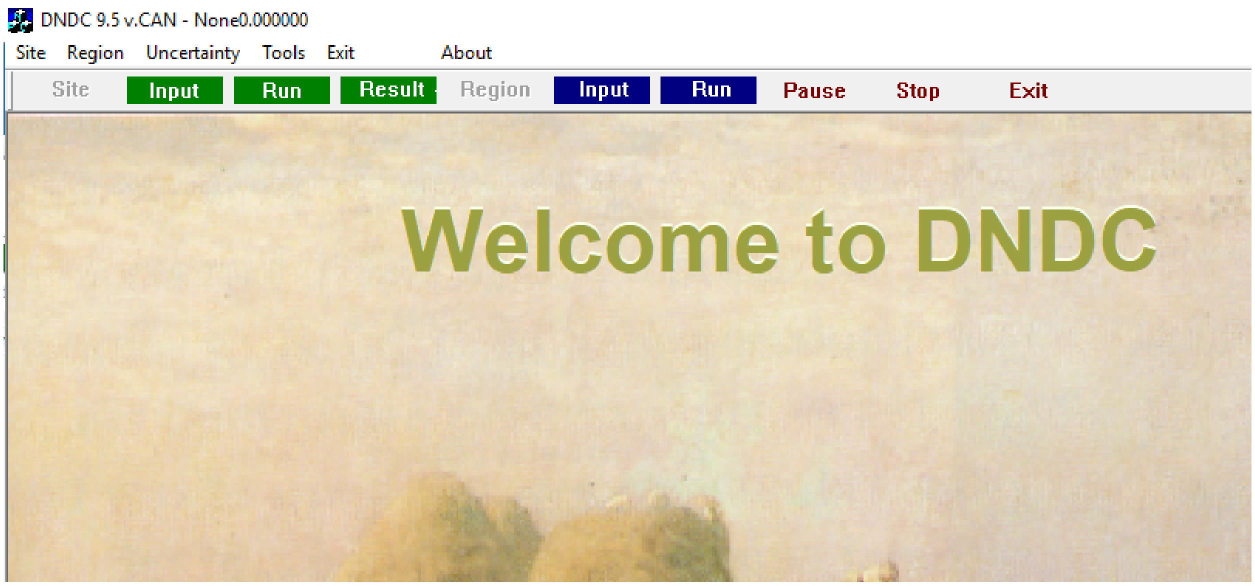
Section 1: DNDCv.CAN: Basics



The DNDC model is a simple model to get running compared with some of the other popular ecosystem models available. This version which is modified from the base U.S. release is built off the 2015 DNDCv95 codebase. The primary user guide can still be useful for understanding this version of the model (http://www.dndc.sr.unh.edu/model/GuideDNDC95.pdf) and should be referred to if you aren't familiar with DNDC. All model inputs are saved to a single file with the file type defined as a ".dnd" file. This file can be edited with a text editor once one becomes familiar with the format structure. The model, however, expects a very specific line by line formatting of the inputs. The major differences in this version of the model are listed below.

Current Development (as of August 2020):

1. Model Extension to 200 cm from 50 cm
2. File Outputs aggregated into a single file instead of yearly
3. Heterogeneous Profile Description
4. Root Density, Depth Functions
5. Manure Slurry additional characterization (pH, N content, dry matter content etc)
6. Dynamic Water Table or Free Drainage Simulation
7. Tile Drainage, Controlled Drainage, and Sub-Irrigation capabilities
8. Improved Soil Temperature, Evapotranspiration
9. Germination timing for Corn/Soybean
10. Additional Parameterization Controls on Trace Gas Emissions, Evaporation, N movement, Urea Hydrolysis, crop interception

11. Read CO2 from File location, AutoHarvest Capabilities, AutoFertilization with Farm Agent Manager (soil testing N methodology), Read from Spinup file to shorten batch simulation timing.

Future Developments: In the works

1. Additional Controls on Vegetative and Reproductive Water Stress Timing
2. Dynamic Leaf, Stem, Root, Fractions with C:N
3. Germination timing across additional crops
4. CO2 respiration controls per major crop type (Legumes vs Cereals)
5. Grazing Controls on grass productivity
6. Radiation/Thermal GDD hybrid growth system

Section 2: Installing DNDC

The DNDC model does not have a built in front-end for installing. The model should be installed to the main drive directory. This can be your C: , D: or whatever drive.

For example if installing DNDC to the C: drive the directory structure would look like

C:\DNDC

With Subdirectories

C:\DNDC\Database

C:\DNDC\Library

C:\DNDC\Result

The model outputs all simulation outputs to one of two directories

DNDC\Result\Record\Site\ for single site simulations.

Or

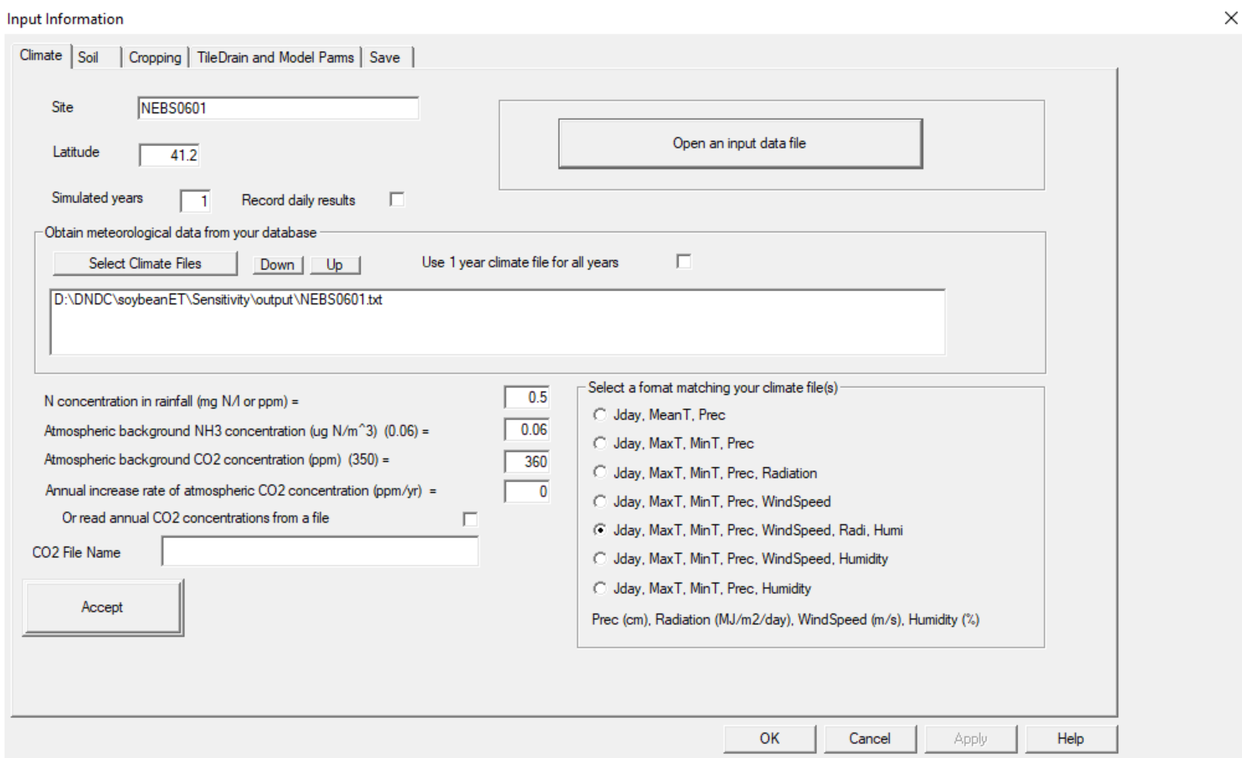
DNDC\Result\Record\Batch\ for multiple batch run simulations

Important: Output Files have for the most part combined into single files. This is quite different from base version DNDC95 which generated single year files for each output. I.e. Day_Climate1, Day_Cimate2, Day_Climate3 are now all reported in Day_Climate1

Section 3: Explaining the Graphic User Input Interface differences between DNDC95 and DNDCv.CAN

Climate:

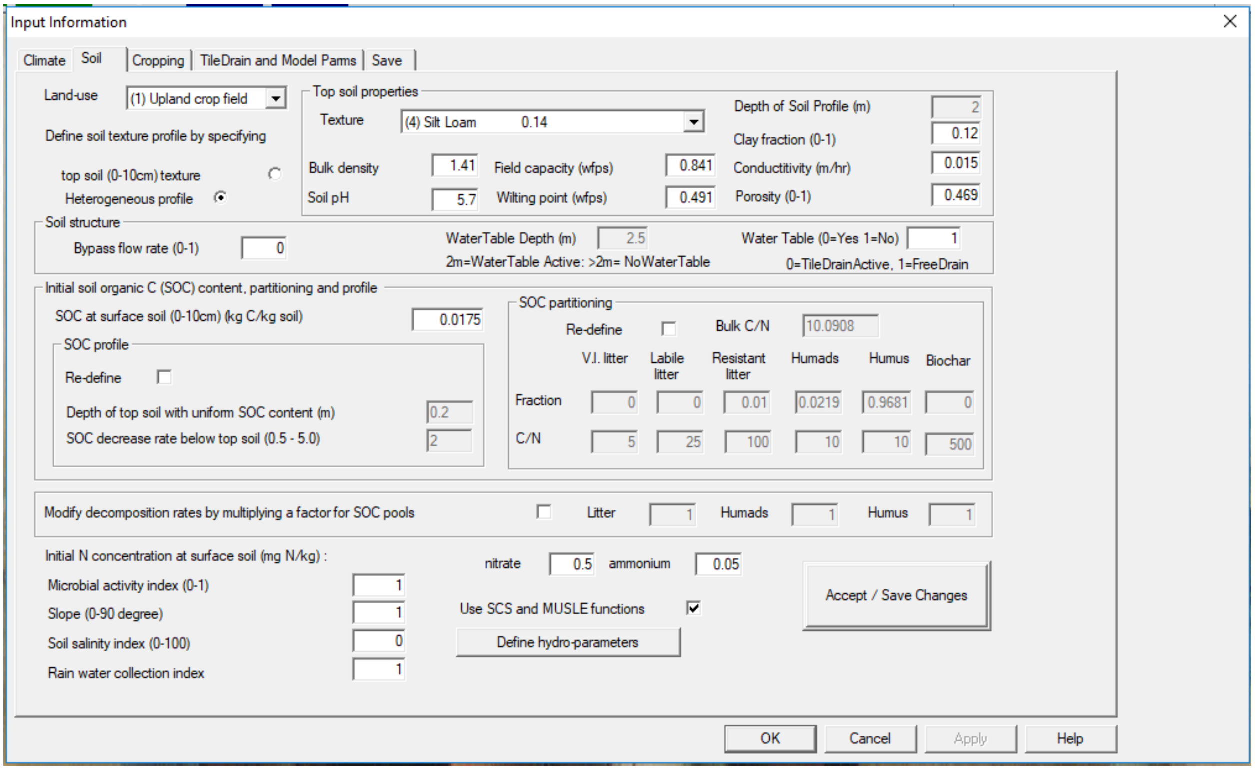
Table 1: Climate Tab



Mostly the same as previous DNDC95 versions. The biggest difference is that a pathname can now be provided to link to the MultiYear_CO2 file that was previously input in the DNDC\Results\inputs folder. The file now can be located in any location and the pathname will be saved to the dnd model output file.

Soil Tab:

Table 2: Soil Tab



The primary new feature here is controlling whether to run the model with a dynamic water table and tile drains. Should do both at the same time (dynamic water table + tile drains OR no water table)

Water Table (0=Yes 1=No) parameter: Water Table = 0 means Dynamic Water Table is ON (sorry a bit of reversed logic here - will fix in future). Boundary conditions at the bottom profile (200cm) are set to not drain. In this case, tile inputs need to be parameterized in the **TileDrain and Models Parms tabs**.

Water Table = 1 means boundary conditions are set to free drainage at the bottom 200cm layer. Water Table is off. By default here there is no tile information read by the model if the water table is off.

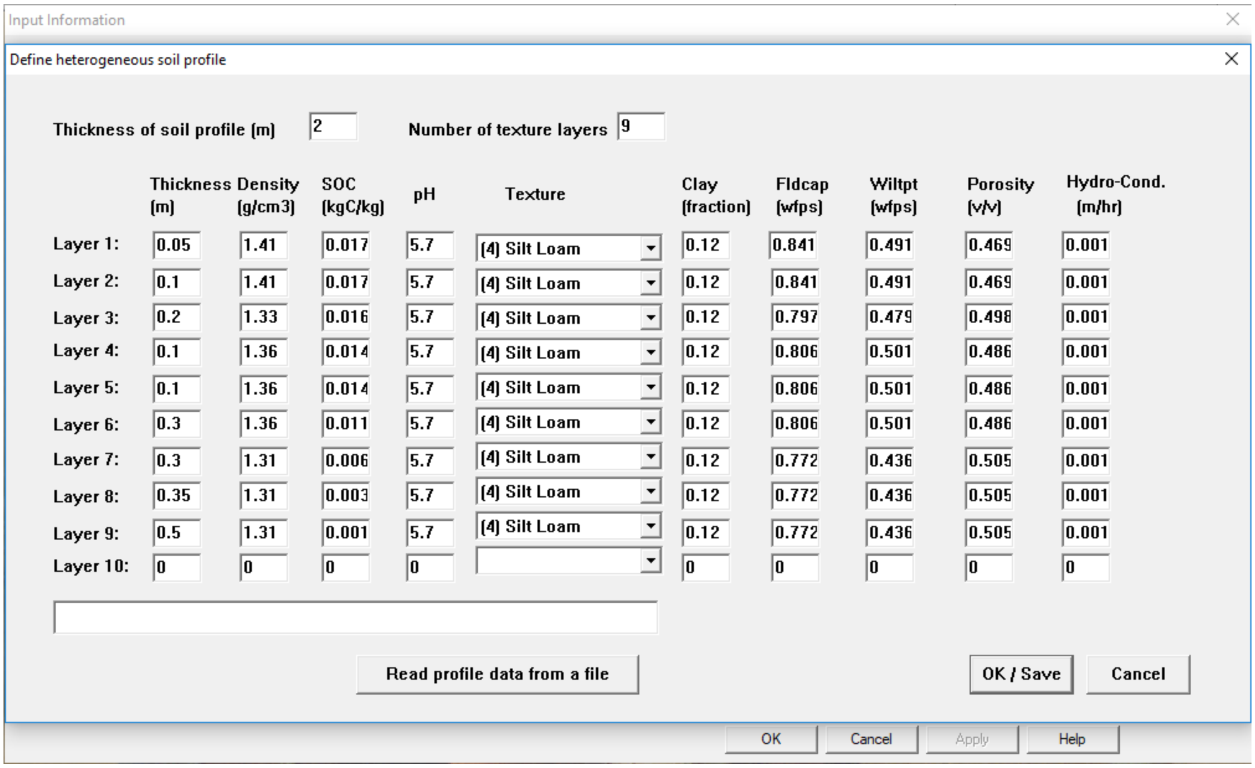
Note: the **Water Table Depth (m)** will change and indicate what the water table boundary conditions are when you change the Water Table (0=Yes 1=No) parameter.

Define soil texture profile by selecting the radio button either for

Top soil (0-10cm) texture = homogeneous soil profile (default)

Heterogeneous Profile = will launch Table 3 : Heterogeneous Soil Profile

Table 3: Heterogeneous Soil Profile



Input Information

Define heterogeneous soil profile

Thickness of soil profile (m) 2 Number of texture layers 9

	Thickness (m)	Density (g/cm3)	SOC (kgC/kg)	pH	Texture	Clay (fraction)	Fldcap (wfps)	Wiltpt (wfps)	Porosity (v/v)	Hydro-Cond. (m/hr)
Layer 1:	0.05	1.41	0.017	5.7	[4] Silt Loam	0.12	0.841	0.491	0.469	0.001
Layer 2:	0.1	1.41	0.017	5.7	[4] Silt Loam	0.12	0.841	0.491	0.469	0.001
Layer 3:	0.2	1.33	0.016	5.7	[4] Silt Loam	0.12	0.797	0.479	0.498	0.001
Layer 4:	0.1	1.36	0.014	5.7	[4] Silt Loam	0.12	0.806	0.501	0.486	0.001
Layer 5:	0.1	1.36	0.014	5.7	[4] Silt Loam	0.12	0.806	0.501	0.486	0.001
Layer 6:	0.3	1.36	0.011	5.7	[4] Silt Loam	0.12	0.806	0.501	0.486	0.001
Layer 7:	0.3	1.31	0.006	5.7	[4] Silt Loam	0.12	0.772	0.436	0.505	0.001
Layer 8:	0.35	1.31	0.003	5.7	[4] Silt Loam	0.12	0.772	0.436	0.505	0.001
Layer 9:	0.5	1.31	0.001	5.7	[4] Silt Loam	0.12	0.772	0.436	0.505	0.001
Layer 10:	0	0	0	0		0	0	0	0	0

Read profile data from a file

OK / Save

Cancel

OK Cancel Apply Help

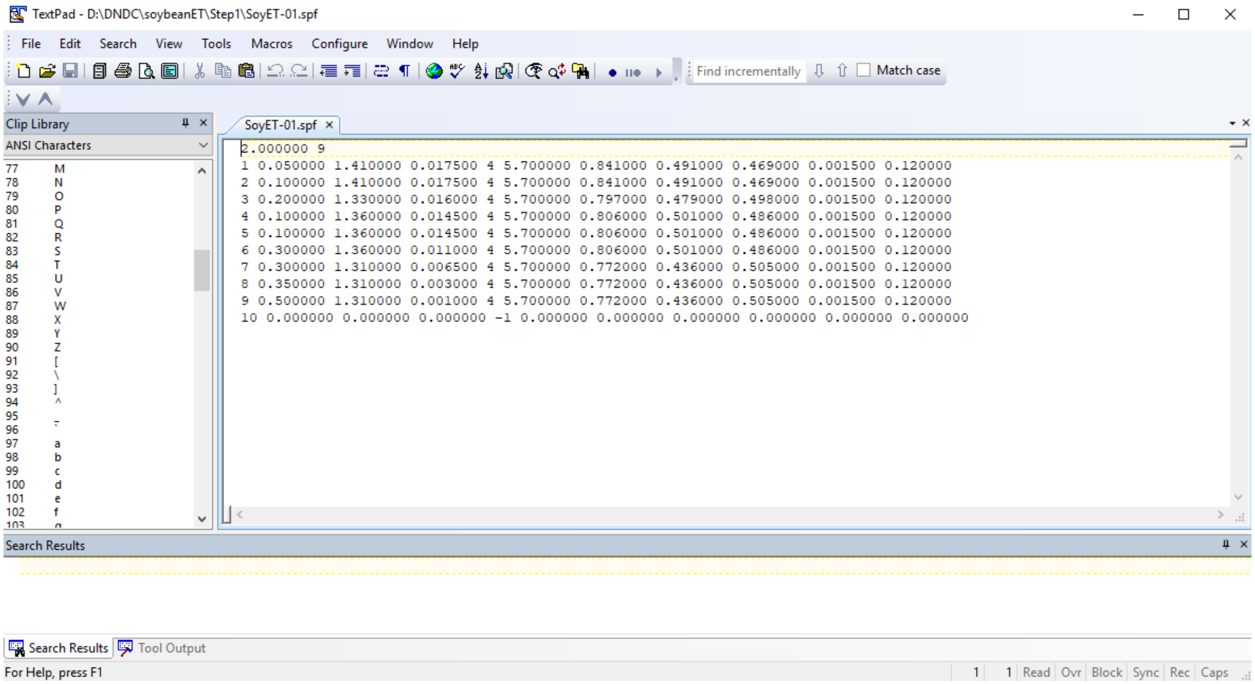
Define the soil layers here.

The thickness of Soil profile should always be set to 2m regardless if your soil profile measurements characterize the full depth. Just extend the deepest measured layer to the bottom of the profile or estimate the deeper profiles.

Note: You will be required to save your soil profile file even if you don't make any changes. (will fix in a later date).

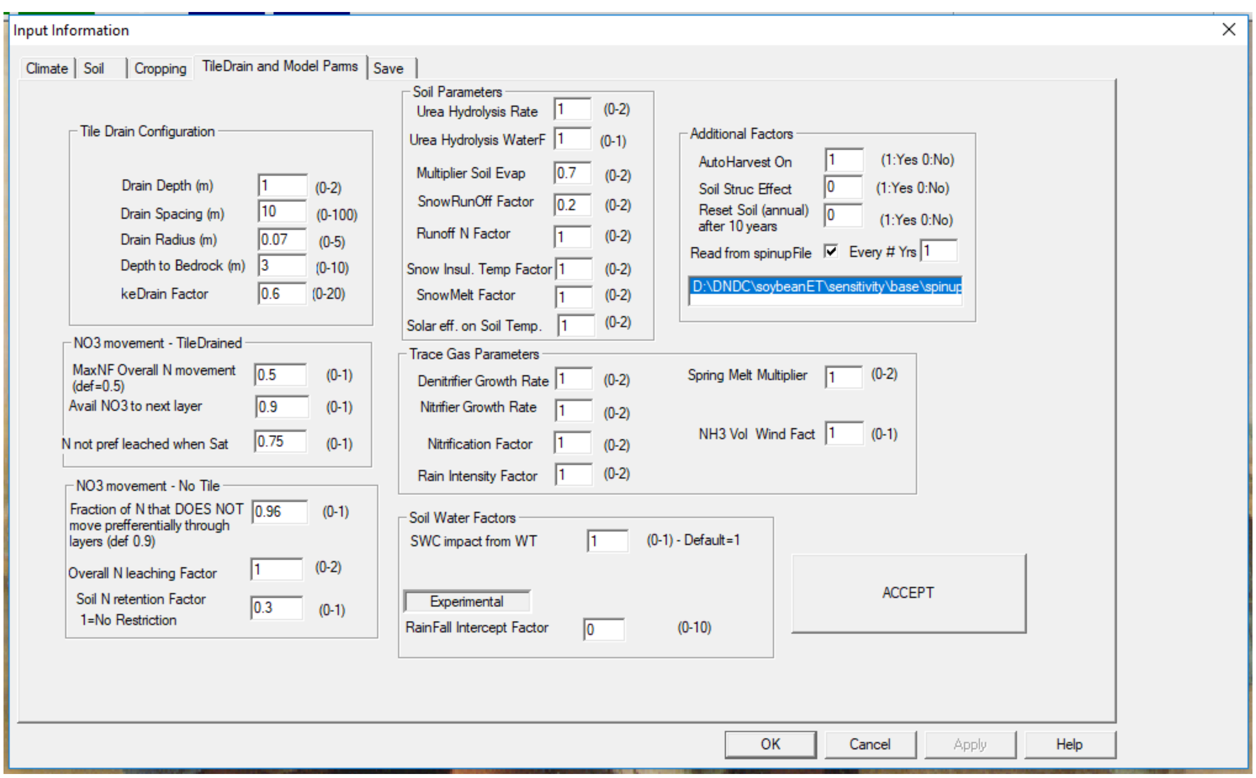
Important!: Currently, the SOC pool fractions will be set to default after the heterogeneous soil tab is edited. Please reset to your intended values (also slated to be fixed).

Table 5: Sample heterogeneous soil.spf file after saving from DNDC graphic user interface

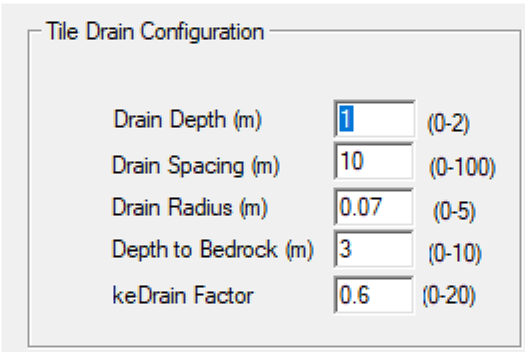


TileDrain and Model Parms Tab*:*

Table 6: TileDrain and Model Parms Tab



This tab is meant to define the general tile drain setup for the simulation (if the water table is simulated - otherwise ignore) and allows for greater control over internal parameters that affect major outputs (Trace gas, N movement/leaching, soil temperature, water balance, etc)



The tile flow rate is based on the houghoudt equation.

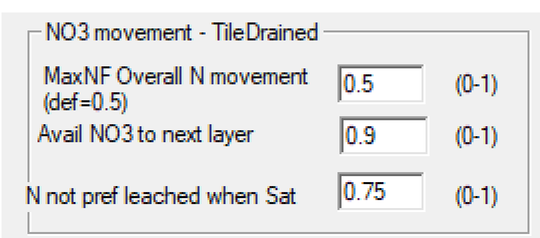
Drain Depth (m) = Tile drain location in the 2 m profile. Should be placed within the profile so typically it is between 50cm and 150 cm.

Drain Spacing (m) = This is a mainly a 1-d model but the drain spacing is empirically used to simulate quasi-2d flow rate to tiles. Wider drain spacing will result in lower flow to tiles.

Drain Radius (m) = This also controls the flow rate of water to tiles. Larger radius results in higher flow rates.

Depth to Bedrock (m) = by default set to 3m. Flow rate to drains is directly proportional to effective depth.

keDrain Factor = rate of horizontal effective saturated conductivity to the tiles. It is a function of the saturated conductivity defined in the soil profile but this factor can be used to slow or increase the horizontal flow rate.

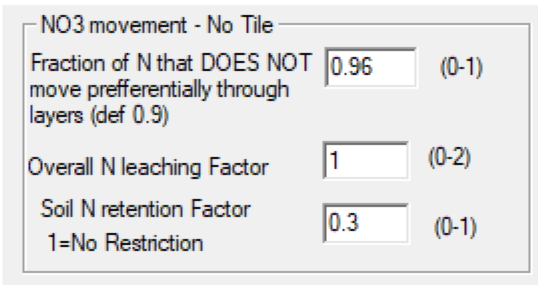


These parameters again are only involved if tile drains are present.

MaxNF = Primary control that influences the maximum nitrogen movement across the soil layers. It is a factor that controls that maximum threshold value.

Avail NO3 to next layer = At a timestep of 1 hour, this determines the amount of NO3 available to be mobilized with water flux to move to the next layer.

N not pref leached when Sat = The fraction of N that is not susceptible to preferential leaching (i.e. bypass all layers to move directly to the tiles) when the water table is above the tiles.



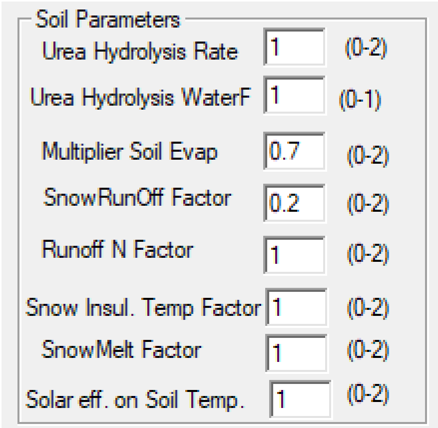
These parameters are used to control N movement when tiles are not present in the simulation.

Fraction of N that does not move preferentially = self-explanatory but it is defined as the N that does not bypass the layer to layer movement on N to preferentially leach out of the soil profile.

Overall N leaching Factor = A factor that controls the fraction of NO3 (and a small amount of Urea) in a layer that moves with water fluxes between layers.

Soil N retention Factor = A control used to restrict N movement on a per-layer basis. This is an exponential algorithm that makes N more and more difficult to be moved as the absolute amount of N in a layer decreases.

Urea Diffusion Factor = A control used to control how fast urea can diffuse into the soil matrix. The default is 0.08 and increasing the value upwards will increase the rate of urea diffusion.



Urea Hydrolysis Rate = Controls the overall hydrolysis rate (temp, water, [substrate])

Urea Hydrolysis WaterF = Controls the effect of water content on hydrolysis

Multiplier Soil Evap = Controls the effective soil evaporative rate. >1 = increased soil evap.

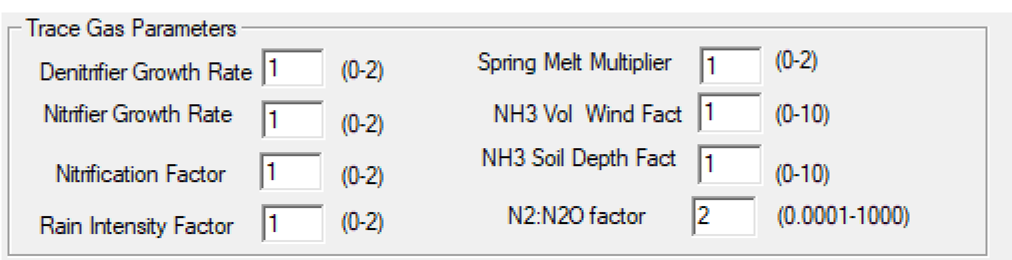
SnowRunoff Factor = Fraction of excess snowmelt that can't infiltrate the soil that leads directly to runoff

Runoff N Factor = Factor that controls the amount of N that moves with runoff from the top 2 soil layers.

Snow Insul Temp Factor = Factor that controls the influence of snow on surface soil temperatures.

SnowMelt Factor = Controls the Rate of Snowmelt as a function of air temperature.

Solar Effect on Soil Temp = Controls the effect of solar radiation on surface soil temperature. A higher value will increase overall soil temperatures in the peak of summer growing season.



Trace Gas Parameter controls

Denitrifier Growth Rate = Controls the growth rate of microbial denitrifiers in the anaerobic balloon

Nitrifier Growth Rate = Controls the growth rate of microbial nitrifiers in the anaerobic balloon

Nitrification Factor = Controls maximum nitrification kg/ha amount per hour

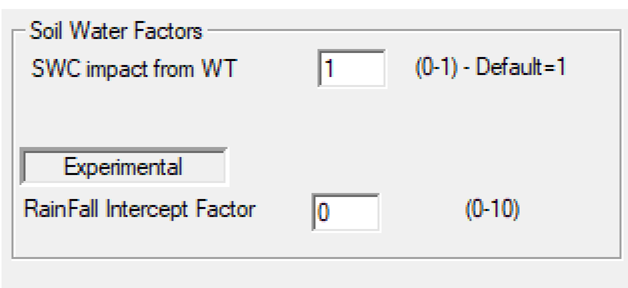
Rain Intensity Factor = Controls the influence of rain on the denitrification rate. This is an empirical factor that increases N_2O, NO and N_2 emission peaks in response to rainfalls

Spring Melt Multiplier = Controls the influence of freezing events on substrate availability to promote dentrifier activity in the spring melt period.

NH_3 Vol Wind Factor = Controls the influence of windspeed on the volatilization rate of ammonia produced during the NH_3:NH_4 equilibrium and Henry's law.

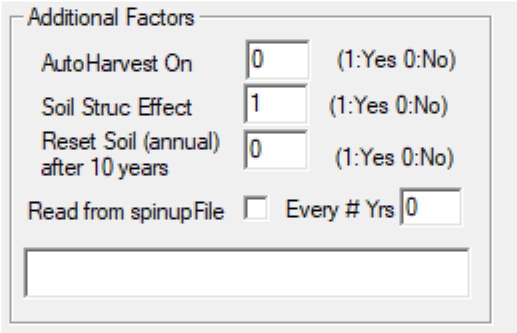
NH_3 Soil Depth Factor= Controls the influence of soil depth on reducing NH_3 emissions. This represents in a crude way the diffusivity ease of NH_3 from depth along with the binding of NH_3 to soil colloids within the soil matrix. Default = 1.0. Decreasing this value will make the impact of depth greater.

N_2:N_2O Factor: Larger values increases the amount of N_2 formed from N_2O



SWC impact from WT = this is tied to the influence of the water table on water contents above the water table and the extractability of this water for transpiration. A lower value will force more water update from the water table (and increase soil water contents).

Rainfall Intercept Factor = This allows the user to control the amount of intercepted rainfall that is lost to the canopy and evaporated.



AutoHarvest On = let the model autoharvest crops when GDD/TDD reaches maturity and after a brief drying out of the crop

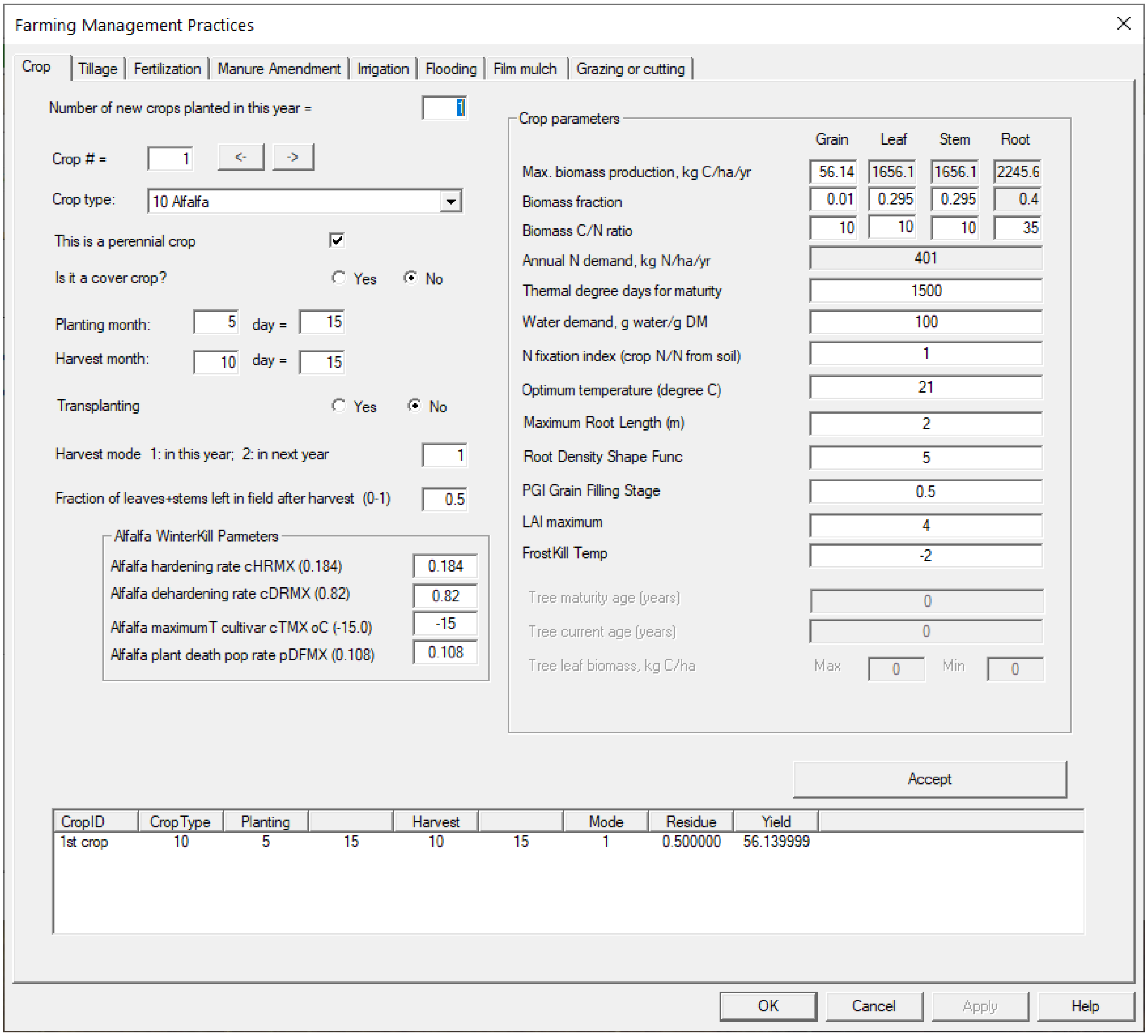
Soil Struc Effect = Let soil characteristics (i.e. water holding capacity) change be correlated with soil organic matter changes (i.e. as a proxy of soil health)

Reset Soil (annual) after 10 years: After a 10 year sequence (normally tied to a spinup period) let the soil conditions be reset every year afterwards so that every subsequent year is using the end of the 10th year as its initial conditions (i.e. year 11, year 12 +++)

Read from spinup File = click to read from file and the frequency to read from that file (every 1 year, 2 years etc). This file is in the format that is automatically written out in the DNDC\Result\inter\ directory and labelled soil_1, soil_2 etc

Farming Management Practices Tab
Crop:

Table 7: Crop Tab.



Some new parameters have been added to the crop parameters tab for DNDCv.CAN

Nfixation index = this has changed from default DNDC. 0= no crop N fixation, 1 = full crop N fixation capability

Maximum Root Length = Root length for crop into the soil profile

Root Density Shape Func = The shape of the density distribution from the surface to maxim root length. 1= more emphasis on surface roots, 8 = more even distribution of root density

PGI Grain Filling Stage = Plant Growth Stage (0-1) at which grain filling occurs

LAI maximum (important) - This should be set to the maximum LAI value for a particular crop type. This has relevance for calculation potential evapotranspiration rates

FrostKill Temp (not used atm)

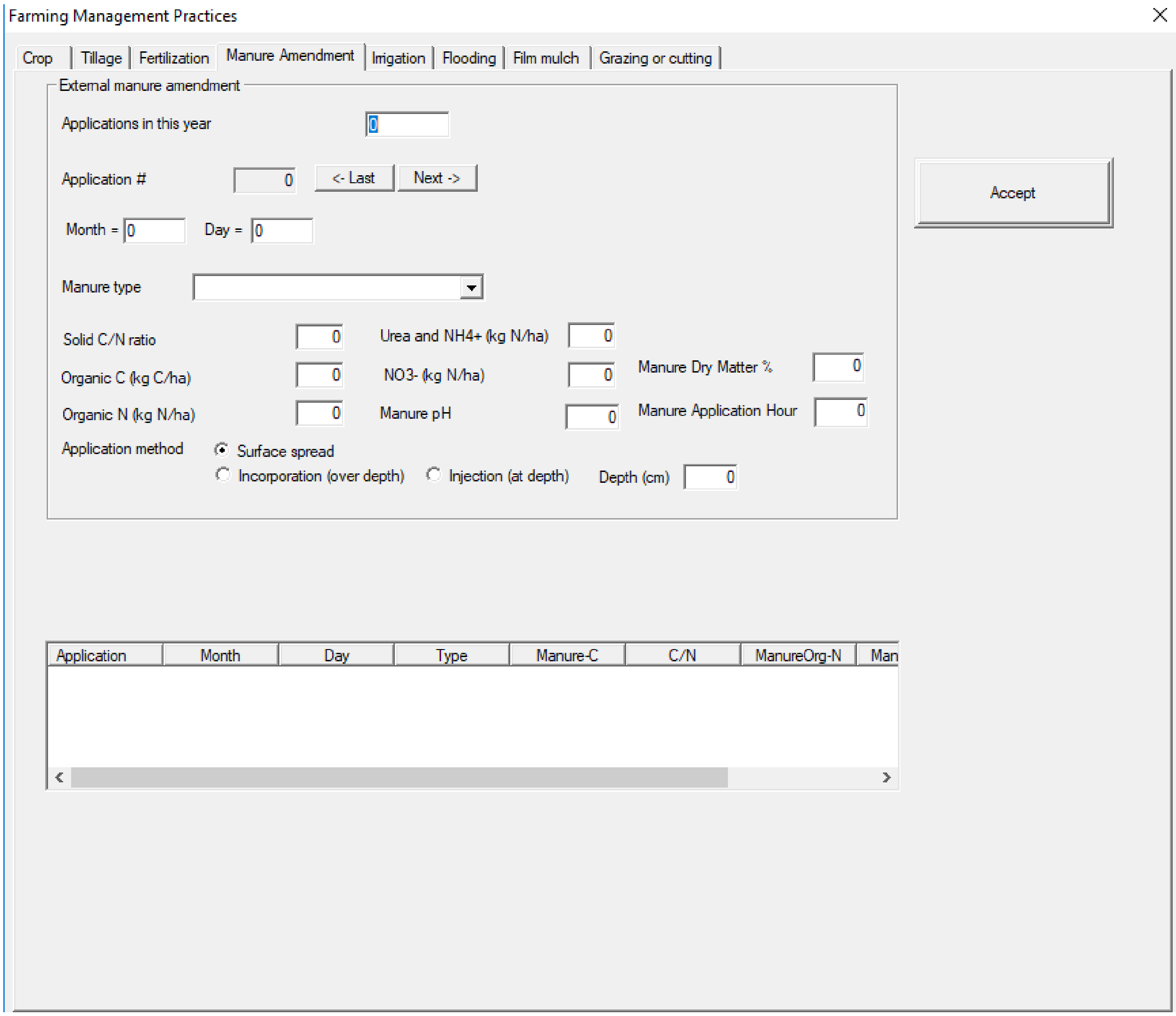
Alfalfa Winterkill Parameters

CHRMX = hardening rate of alfalfa (oC d-1) - default 0.184
CDRMX = dehardening rate of alfalfa (oC d-1) default 0.82
cTMX = maximum cold tolerance of alfalfa cultivar (oC) default -15.0
pDFMX = plant population death rate (oC d-1 below cTMX) default 0.108

See (Kanneganti, V. Rao, C. Alan Rotz, and Richard P. Walgenbach. "Modeling freezing injury in alfalfa to calculate forage yield: I. Model development and sensitivity analysis." *Agronomy Journal* 90, no. 5 (1998): 687-697)

Manure Amendment

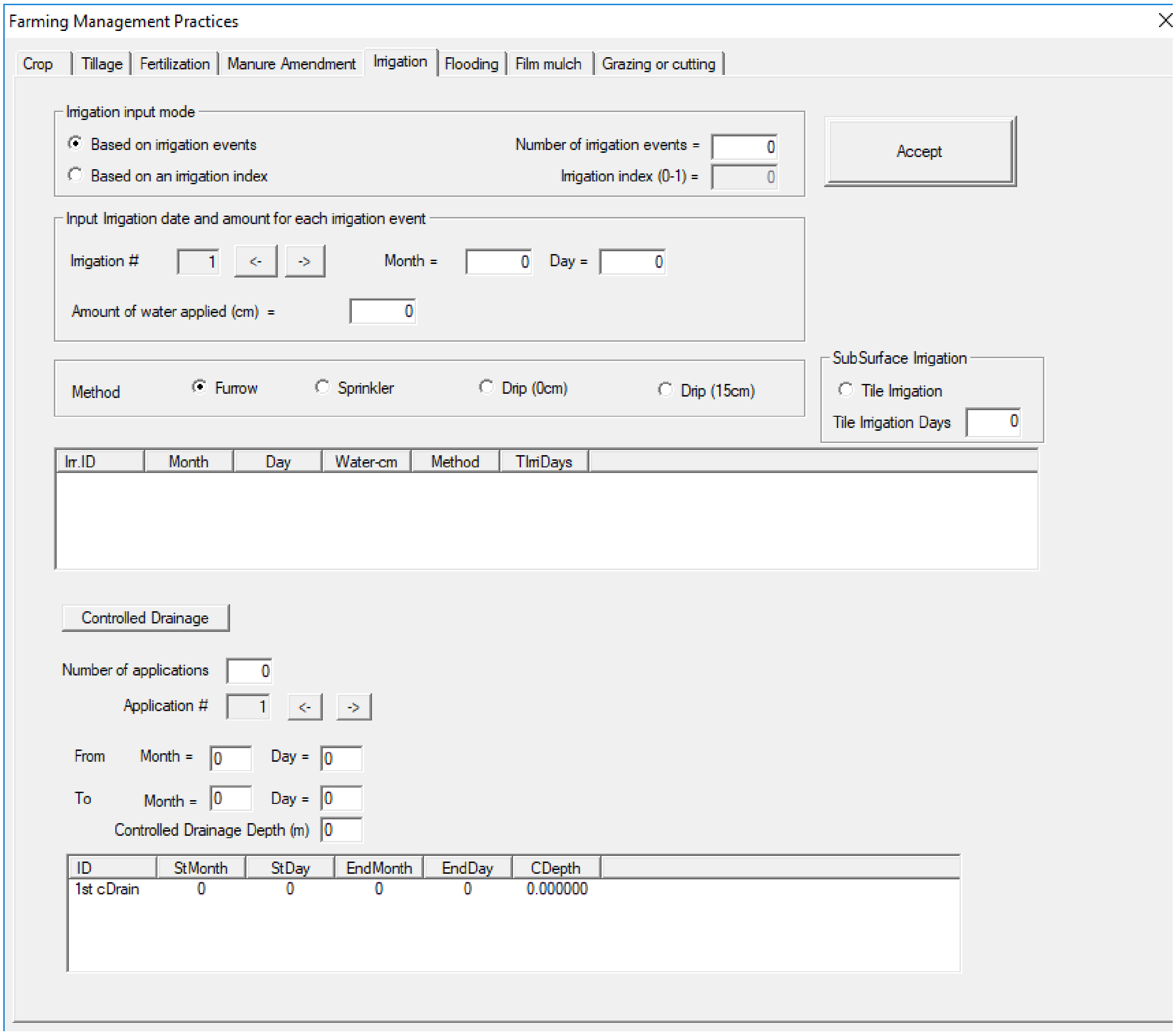
Table 9: Manure Parameters



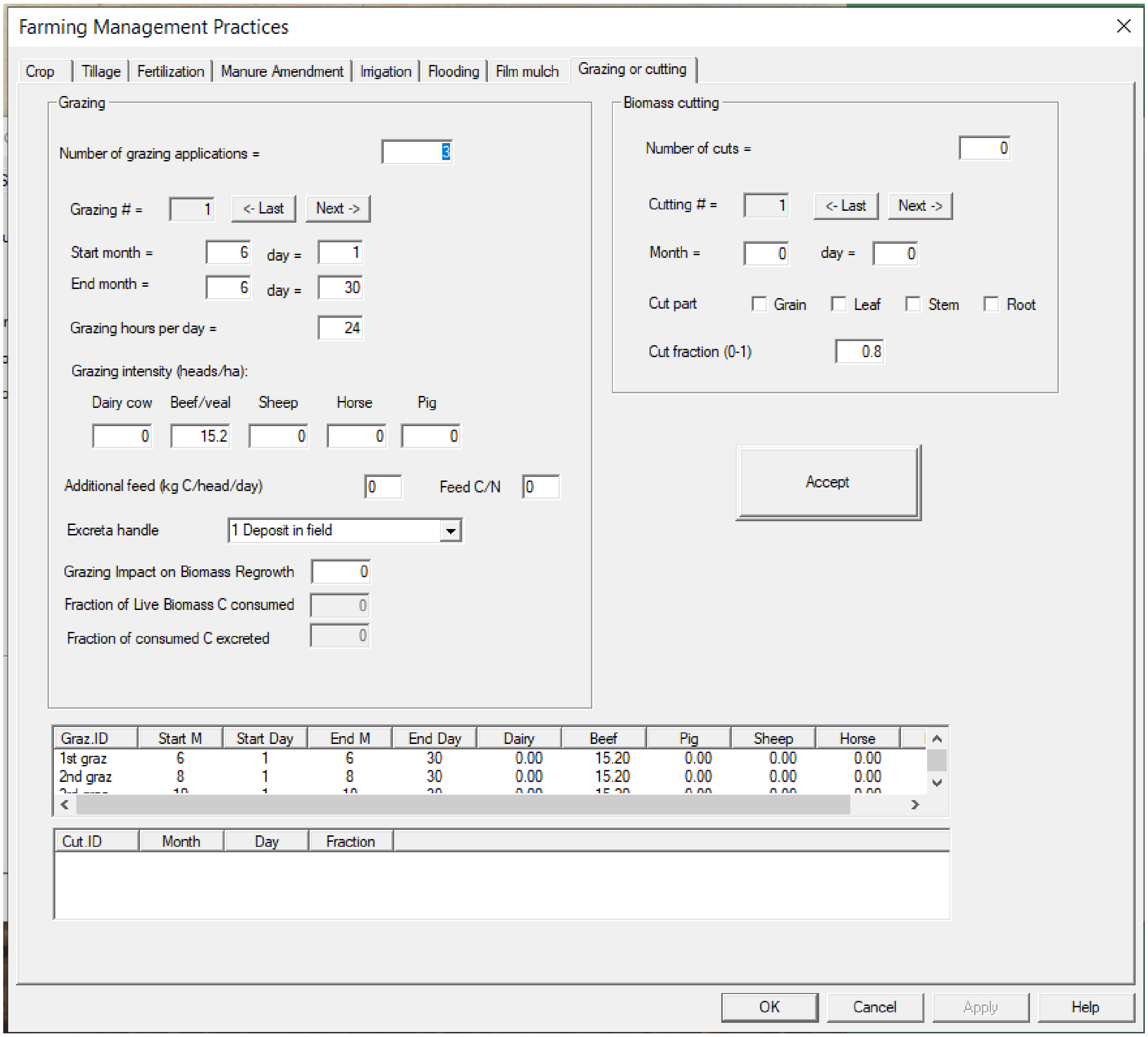
Irrigation Parameters

Controlled Drainage:

Allows the user to schedule drainage which is managed to keep the water table at a certain depth.

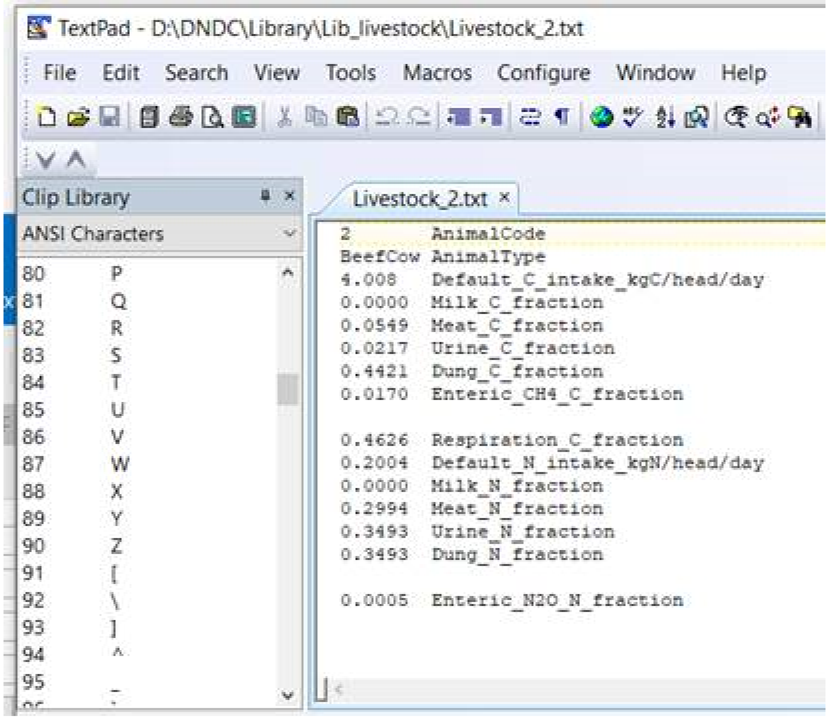


Grazing Management



Grazing IMpact on Biomass Regrowth: New parameter that allows one to put a stress factor during grazing events on growth. 1= no stress and 0.1 would be very high stress. It only affects perennial growth if the crop is not already at maturity. Grazing should in essence reset PGI but it currently does not and only reduces the aboveground biomass absolute amount.

The Livestock.txt files included in the DNDC\library\lib_livestock\ directory have animal consumption and C&N flow controls that can be adjusted to influence the way live biomass C is consumed and deposited back to the field. Please note that the summation of input and output fractions should add up to 1.0



Section 4: Building A New DNDC File using the Graphics User Interface.

Background:

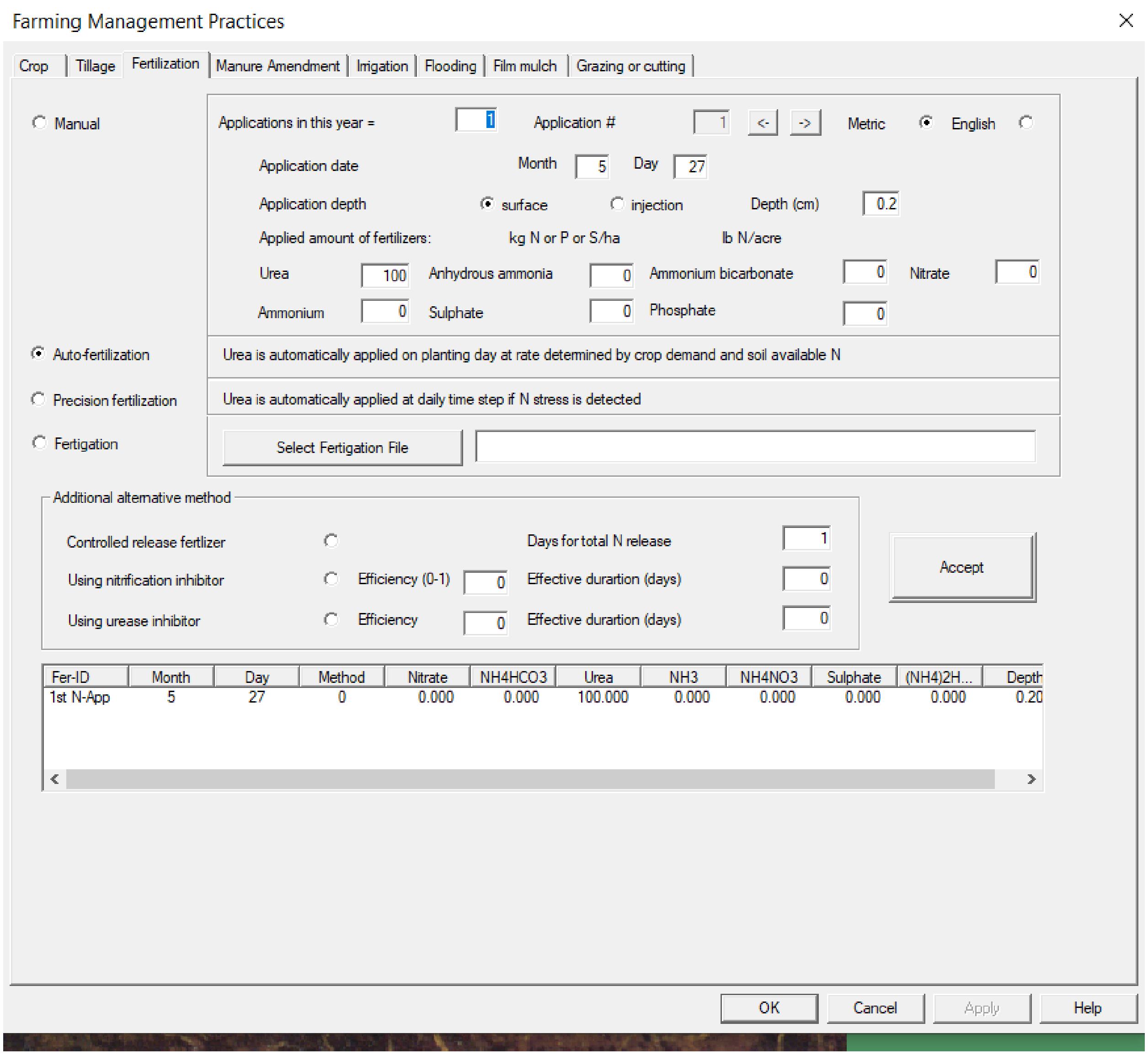
DNDC can be a bit problematic when trying to build complex time blocks. The logic used in the internal code can get confused when the process of building time blocks is not followed in a linear manner (i.e. done from the beginning to the end). To prevent the painful exercise of building complex management data only to have the model corrupt the sequence of the data after you try to save it, try to follow these steps. Try not to add new time blocks after you've done the following steps unless you do so with a text editor directly to the file.

Steps

1. Fill in the appropriate data for the **climate tab and click Accept.**
2. Fill in the appropriate data for the **soils tab and click Accept/save changes.**
3. Click on the **Crops Tab**.
4. Build the structure for your all of your time blocks without filling in any data. (i.e. 3 time blocks , block 1 – number of years this crop rotation occurs, number of unique crop years within this rotation.
5. Ensure you've built the structure for the number of time blocks so that it populates the full duration of your simulation years.
6. Now click **Define management practices for this year** and enter into the crop page.

7. On the crop page just click Accept (don't fill in any data) and then click OK.
8. Go onto the next unique year/time block and repeat steps 6-7 for each unique year/block.
9. Finally go to **TileDrain and Model Parms** tab and click **Accept**
10. Now go to Save and Save your file.
11. Now try to open your newly created dnd file and ensure your time block structure is correct.
12. If everything appears correct you can now proceed to enter in your specific management data for your time blocks in the **Define management practices for this year**
13. **Save your work.**

Explaining the auto-fertilizer farm agent routine



DNDCv.CAN has a built-in smart farmer algorithm that tries to emulate the concept of what a farmer with access to soil N testing would do to fertilize their field for the upcoming season. The routine works by assessing at time of fertilizer (planting or split application) what the current soil N levels (ammonium/nitrate + residue N) are and the optimal crop N requirements (for that specific cultivar) would be to estimate the incoming N requirements for that season. An estimate of the anticipated N losses (including volatililzed N, leaching N, N2O etc) are also factored in along with typical available N input from N mineralization. This is all wrapped into a crop-specific N stress factor that is used to come up with a scalar that is multiplied against the anticipated N fertilizer application (based on soil N testing etc). This crop-specific N stress factor is based on up to the last 10 occurrences of that crop type in the rotation over the past. It is conceived that the farmer would be noting how his crop (i.e. corn, barley etc) has been performing over the last 10 occurrences in the rotation and would be hedging his bets based on this gained insight to modify his fertilizer rate. The strength of this routine is that it can be used to carry forward climate change investigations that would have cascading impacts on crop yields and N availability without having to hard set fertilizer rates. If crop yields improve slowly under climate change due to CO2/water stress then the farmer would slowly increase his anticipated fertilizer rate to accommodate these improved growing conditions. Alternatively if yields decrease due to increased temperature stress then the farmer would decrease N applied to ensure N application matched crop N needs.

Capabilities of algorithm - Up to 10 unique crop types can be considered when using this algorithm. If your rotation includes more than 10 unique crop types you should avoid using autofertilizer.

Up to 2 applications can be utilized for autofertilization for a given year, thus allowing for split application.

The timing of the autofertilizer application should be entered along with the relative formulation (fertilizer type) to be be used (i.e. ammonium, UAN, urea). The absolute values for each of these is determined by the routine but the relative contribution is important to enter. Also in respect to split application the relative magnitude between applications is considered by the routine so if one wants a small starter and a larger split these should be entered into the 2 applications accordingly (actually this is hardset atm to 18 kg N for first application and the 2nd application is based on soil N requirements).

Section 5: Known DNDCv.Can issues

The DNDC model is in a constant development cycle. There are however many known quirks that are being addressed.

1. Monte Carlo uncertainty is not fully operational at this time. Some of the newer outputs have not been properly added to this feature and require development.
2. Output Files may not be fully defined for units in the header files.
3. Regional DNDC does not work. We see no advantage of running in this mode over the batch simulation mode already built into DNDC

Command Line Version of DNDC - New Nov 2021

A new command line (terminal version of DNDC is available and packaged with the DNDC release). It disables the Graphic User Interface and allows users to run batch simulations using a command line interface. This should allow the model to be run via scripting languages (R-Software, Perl etc) and allow for bayesian calibration methods to be employed to model simulations.

The operation of the command line version can be done with the separate included executable and run using the following command line.

From the command prompt:start /wait dndc95.exe -s [Batch File path]

Example: start /wait dndc95.exe -s D:\batch.txt

To enable/disable this compile in the source code modify dndc_main.h and Source_main.h to have enabled #define Console or disabled.