User's Guide for the DNDC Model

(Version 9.5)

Institute for the Study of Earth, Oceans and Space
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I. DNDC OVERVIEW

1. Introduction

The DNDC model is a process-base model of carbon (C) and nitrogen (N) biogeochemistry in agricultural ecosystems. This document describes how to use the PC Windows versions of the DNDC model for predicting crop yield, C sequestration, nitrate leaching loss, and emissions of C and N gases in agroecosystems. Part I provides a brief description of the model structure with relevant scientific basis. Part II describes how to install the model. Part III and IV demonstrate how to conduct simulations with the site and regional versions of DNDC, respectively. Part V provides basic information for uncertainty analysis with DNDC. Part VI contains six case studies demonstrating the input procedures for simulating crop yield, soil C dynamics, nitrate leaching loss, and trace gas emissions. A list of relevant publications is included in Part VII. These publications provide more information about the scientific background and applications of DNDC far beyond this User's Guide.

DNDC can run in two modes: site or regional. By selecting the mode, the users will open a corresponding interface to manage their input information for the modeled site or region.

2. Model Description

The Denitrification-Decomposition (DNDC) model is a process-oriented computer simulation model of carbon and nitrogen biogeochemistry in agroecosystems. The model consists of two components. The first component, consisting of the soil climate, crop growth and decomposition sub-models, predicts soil temperature, moisture, pH, redox potential (Eh) and substrate concentration profiles driven by ecological drivers (e.g., climate, soil, vegetation and anthropogenic activity). The second component, consisting of the nitrification, denitrification and fermentation sub-models, predicts emissions of carbon dioxide (CO_2), methane (CH_4), ammonia (NH_3), nitric oxide (NO), nitrous oxide (N_2O) and dinitrogen (N_2) from the plant-soil systems. Classical laws of physics, chemistry and biology, as well as empirical equations generated from laboratory studies, have been incorporated in the model to parameterize each specific geochemical or biochemical reaction. The entire model forms a bridge between the C and N biogeochemical cycles and the primary ecological drivers (Figure 1).

Plant growth plays an important role in regulating the soil C, N and water regimes, which could further affect a series of biochemical or geochemical processes occurring in the soil. A sub-model was built in DNDC to simulate the crop growth. A group of crop parameters can be provided or modified by the users to define their own crop. The crop parameters include maximum yield, biomass portioning, C/N ratio, season accumulative temperature, water demand, and N fixation capacity. The crop growth will be simulated driven by the accumulative temperature, N uptake, and water stress at a daily time step. The modeled daily photosynthesis, respiration, C allocation, and water and N uptake are recorded so that the users can check the modeled results against their observations to make sure the crops are simulated correctly. All the crop parameters are accessible on the user's input interface so that the users can modify the parameters in a prompt mode. Crop demand for N is calculated based on the optimum daily crop growth and the plant C/N ratio. The actual N uptake by crop could be limited by N or water availability during the growing season. After harvest, all the root biomass is left in the soil profile, and a user-defined fraction of the above-ground crop residue remain as stubble in the field until next tilling application, which incorporates the stubble onto (for no-till) or into (for conventional tillage) the soil profile. The crop residue incorporated in the soil will be partitioned into three soil litter pools, namely very labile, labile and resistant litter pools, based on its C/N ratio. The litter incorporation provides essential input for the soil organic matter (SOM) storage and hence integrates the plant and soil into a biogeochemical system.

In DNDC, SOM resides in four major pools: plant residue (i.e., litter), microbial biomass, humads (i.e., active humus), and passive humus. Each pool consists of two or three sub-pools with different specific decomposition rates. Daily decomposition rate for each sub-pool is regulated by the pool size, the specific decomposition rate, soil clay content, N availability, soil temperature, and soil moisture. When SOC in a pool decomposes, the decomposed carbon is partially lost as CO_2 with the rest allocated into other SOC pools. Dissolved organic carbon (DOC) is produced as an intermediate during decomposition, and can be immediately consumed by the soil microbes. During the processes of SOC decomposition, the decomposed organic nitrogen partially transfers to the next organic matter pool and is partially mineralized to ammonium (NH_4^+). The free NH_4^+ concentration is in equilibrium with both the clay-adsorbed NH_4^+ and the dissolved ammonia (NH_3). Volatilization of NH_3 to the

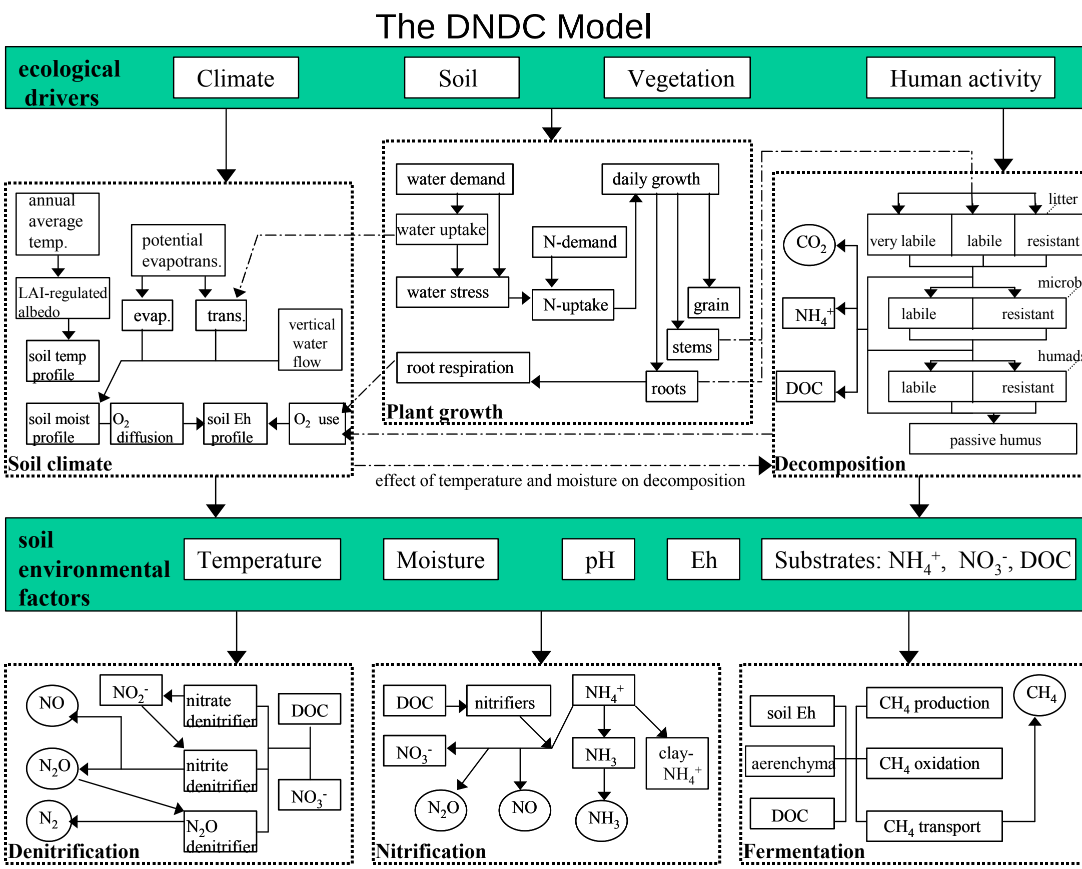


Figure 1. Structure of the DNDC model.

atmosphere is controlled by NH_3 concentration in the soil liquid phase and subject to soil environmental factors (e.g., temperature, moisture, and pH). When a rainfall occurs, NO_3^- is leached into deeper layers with the soil drainage flow. A simple kinetic scheme "anaerobic balloon" in the model predicts the soil aeration status by calculating oxygen or other oxidants content in the soil profile. Based on the predicted redox potential, the soil in each layer is divided into aerobic and anaerobic parts where nitrification and denitrification occur, respectively. When the anaerobic balloon swells, more substrates (e.g., DOC, NH_4^+, and N oxides) will be allocated to the anaerobic microsites to enhance denitrification. When the anaerobic balloon shrinks, nitrification will be enhanced due to the reallocation of the substrates into the aerobic microsites. Gases NO and N_2O produced in either nitrification or denitrification are subject to further transformation during their diffusion through the soil matrix. Long-term (e.g., several days to months) submergence will activate fermentation, which produces hydrogen sulfide (H_2S) and methane (CH_4) driven by decreasing of the soil Eh.

The entire model is driven by four primary ecological drivers, namely climate, soil, vegetation, and management practices. It is inherently important for a successful simulation to obtain adequate and accurate input data about the four primary drivers. This User's Guide provides detailed information to explain how to prepare the input parameters through the interface introduction as well as the case studies.

II. PC WINDOWS VERSION OF DNDC

1. Overview of a Modeling Session

The DNDC model predicts C and N biogeochemistry in agricultural ecosystems at site or regional scale. For site runs, the users need to input all of the required driving parameters through the user's input interface. For regional simulations, DNDC reads all of the driving parameters from a preset database that contains the spatially differentiated information of weather, soil, vegetation and management on a polygon or grid cell basis for the modeled domain. The DNDC-simulated time span is through a year to centuries.

The model is written in Visual C++ 6.0 and must be executed in the Microsoft Windows environment.

2. Hardware Requirements

The DNDC model requires a PC or compatible with Windows installed. A minimum memory of 64M is required. The computers with speed of 350MHz or higher are highly recommended. A graphics adapter of SVGA or higher is recommended. The output files resulted from a 100-year simulation requires about 0.5 MB of disk space.

3. Installation

You can download a zipped package at our web site http://www.dndc.sr.unh.edu, which contains a zipped file named DNDC. After unzipping the package, please copy the entire folder DNDC to a root directory of your computer.

The folder DNDC in your root directory contains the latest version of DNDC (e.g., DNDC9.5) as well as supporting data sets. At C or D:\DNDC\Database\, there is a subdirectory named Shangrila, which contains a complete set of regional input files, which provide an example showing the contents and formats of the input data required for regional simulations. Following the formats of the files of Shangrila, the users can easily create their own databases for their own regions.

Now, you should be about ready to run DNDC. Let's go to C or D:\DNDC, and click DNDC95.exe to start the model.

4. Site and Regional Modes

When the model starts, a main menu will be shown on the screen (Figure 2).

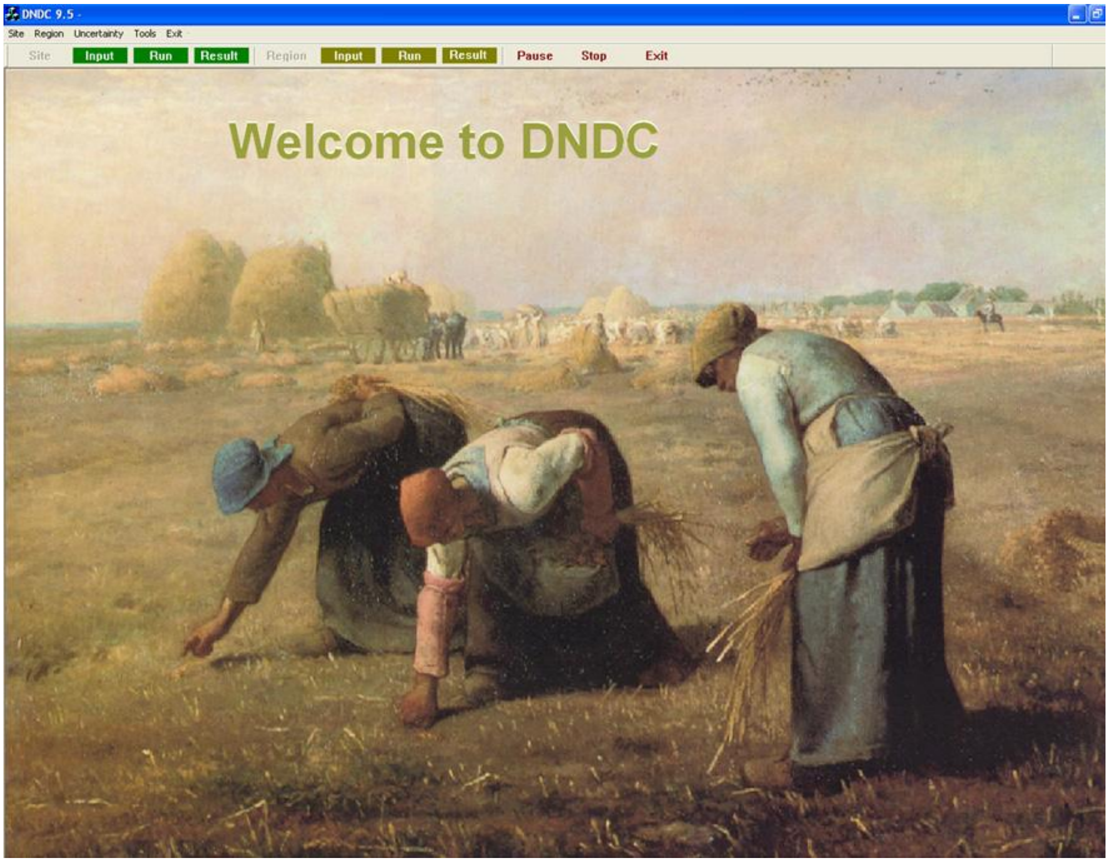


Figure 2. Main menu of DNDC

***The Site Mode*:**

Clicking the “Input” button by the sign “Site” on the main menu will initiate the input procedure for a site-scale simulation. There are three major pages for inputting (1) climate, (2) soil and (3) farming management information, respectively. The farming management page contains eight sub-pages to allow you to define the most popular management practices, such as crop type and rotation, tillage, fertilization, manure amendment, irrigation, flooding, plastic film use, grazing and grass cutting. During the input process, you can come back to any specific page to make modifications. The only thing you may like to keep in your mind is to click the “Accept” button every time when you think you have finished the input or modification for the page. If you didn’t do so, the data you inputted or modified would be lost as soon as you leave from the page. When all the inputs have been typed in for all the pages, click the OK button at the bottom of the interface to end the input procedure. When the OK button is clicked, all the input data will be automatically converted to DNDC internal input files, and you will be ready to execute the simulation by clicking button “Run” on the top of the interface.

You may feel curious about what DNDC will do after “Run” is clicked. Let’s have a brief description. At the beginning of each simulation, DNDC first reads in all the input information from the internal input files which are stored at C or D:\DNDC\Result\Inputs\.

For each simulated year, DNDC executes the sub-models in the order “soil climate – plant growth – decomposition – nitrification and denitrification – fermentation” at a daily time step. The soil climate profiles (e.g., temperature, moisture, oxygen concentration, Eh) are first calculated based on the daily weather data, soil physical properties and vegetation status. Then DNDC simulates plant growth by quantifying the growth stage based on accumulative temperature, water demand and uptake, N demand and uptake. DNDC partitions the crop biomass production increment to leaves, stems, roots and grain based on plant growth stage at a daily time step. Decomposition is calculated based on quantity and quality of the existing SOC pools, soil climate profiles and soil N availability at a daily time step. Nitrification and denitrification are then predicted driven by dynamics of the soil Eh and relevant substrates (e.g., DOC, NH4+, NO3-, NO, N2O). If a flooding event occurs, DNDC will track the soil Eh decrease driven by the sequential reductions of nitrate, nitrite, Mn^{4+}, Fe^{3+} and sulfate. At certain low Eh conditions, the fermentation sub-model will be activated to calculate methane (CH_4) production. DNDC records modeled daily results of crop growth, soil temperature and moisture profiles, soil C pools/fluxes, soil N pools/fluxes, nitrate leaching losses, and gas fluxes at the end of each of the simulated days. Following the above-described daily sequence, DNDC continuously runs day-by-day until the last day of the year. When the simulation reaches the last day of a year, DNDC will make an annual report summarizing the yearly crop production as well as pools and fluxes of C, N and water for the simulated system. After doing the annual report, DNDC will automatically shift to the first day of the next simulated year. The simulation will continue year-by-year until reaching the last year. All the daily and annual files resulted from the simulation are stored in subdirectory "C or D:\DNDC\Result\Record\Site\".

The Regional Mode:

To run DNDC in the regional mode, you will need to have all the input data compiled in a database in advance for your target region. The region is presented as a typical Geographic Information System (GIS). It means the region is divided into many polygons or grid cells. The database consists of spatially differentiated information of location, climate, soil properties, cropping systems, and farming management practices for each polygon or grid cell for the entire modeled domain. We highly encourage you to review the “Shangrila” GIS data files provided with the DNDC package to make yourselves familiar with the structure, content and format of the database if you are ready to move to regional simulations.

As soon as your regional database is set up, you will be ready to conduct the regional simulations. The detailed information about the regional database preparation, the regional input procedure, and regional result review is provided in section “III. Model Operation: 2. Regional Mode”.

III. MODEL OPERATION

By clicking DNDC95.exe at C or D:\DNDC\, you will start the model. At first, you will see a main menu (Figure 2). On this menu, you can choose to run DNDC in the site or regional mode.

1. Site Mode

In the site mode, most of the input parameters need to be typed in manually through the input interface pages. Let's start. Click the "Input" button by "Site" in the main menu. See, a new page is opened. This is the "Climate" page (Figure 3).

1.1. Input Parameters

Page 1. Climate

This is the first page on which you will start the input procedure for site simulations. This page allows you to input site location and climate information. You need to type in the site name and other required information. DNDC provides default values for atmospheric background concentrations of ammonia (NH_3) and carbon dioxide (CO_2). You can keep or modify the default values. The required daily climate data file(s) can be selected by clicking button "Select Climate File". When you finish all the input items on this page, just click button "Accept" to move all of the input information into the computer's memory. If there is any error in the climate file(s), an error message will appear when you click "Accept".

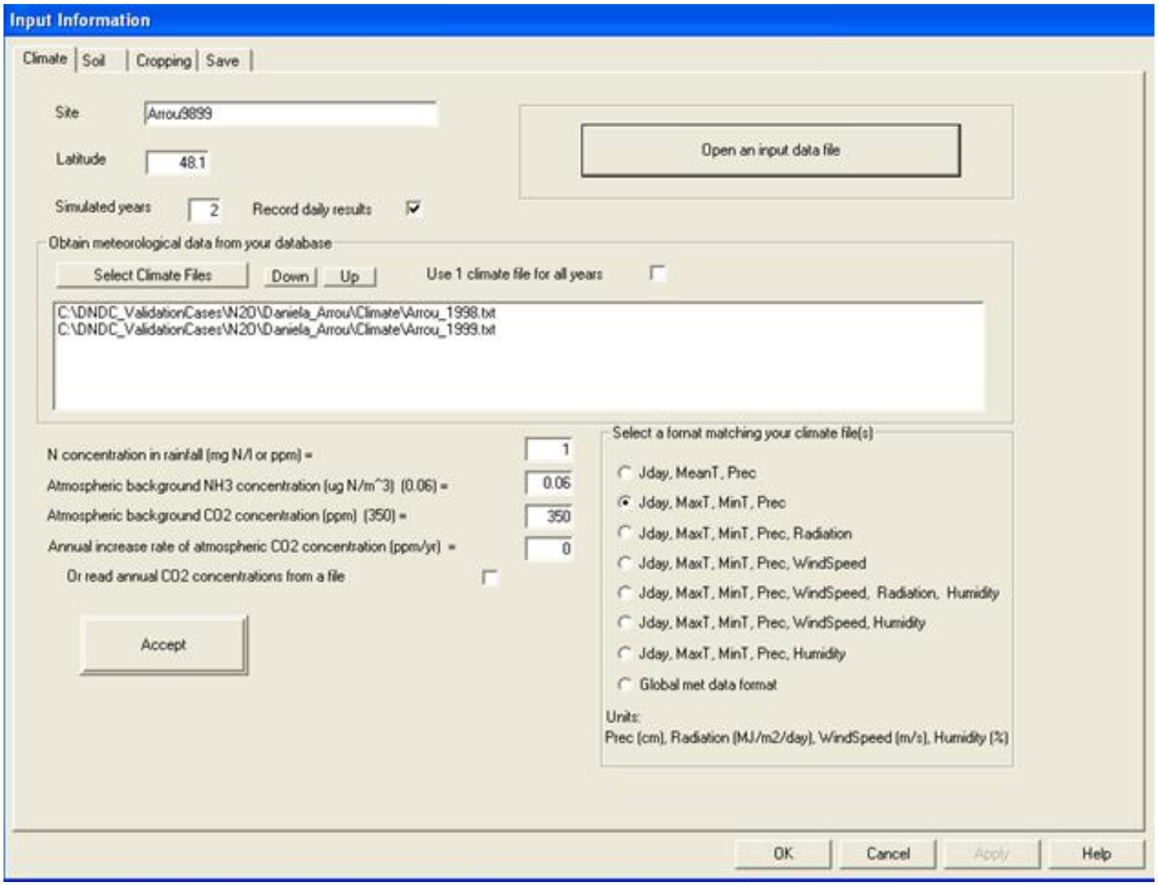
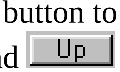


Figure 3. Input information for location and climate

[***Site name***]: A string (no space is allowed in the string);
[***Latitude***]: Latitude (decimal unit) of the site;
[***Simulated years***]: Number of total simulated years (an integer).
[***Record daily results***]: Check this box to allow DNDC to record daily results.
[***Select a format matching your climate file***]: Select the format consistent with your climate data file(s);
[***Select Climate Files***]: Click this button to browse and select the climate file(s) for this simulation. Use 

and 

to adjust the order of the climate files. Double-clicking a file name deletes it from the list.
[***Use 1 climate file for all years***]: Checking this box will enable DNDC to use one climate file for all the simulated years.
[***N concentration in rainfall (mg N/l or ppm)***]: Annual average N (dissolved nitrate and ammonium) concentration in rainfall in unit mg N/l or ppm.
[***Atmospheric background NH_3 concentration (ug N/m^3) (0.06)***]: Average background concentration of NH_3 in the air (the default value is 0.06 ug N/m^3), which affects NH_3 dry deposition on plants.
[***Atmospheric background CO2 concentration (ppm) (350)***]: Atmospheric background CO_2 concentration with a default value 350 ppm, which affects plant photosynthesis.
[***Annual increase rate of atmospheric CO2 concentration (ppm/yr)***]: For multi-year

simulations, the atmospheric CO_2 concentration can be changed by setting this annual change rate.

Daily meteorological data file(s) must be prepared in advance with 365 days for a year. Each year has an individual file. The file(s) should have a plain text (i.e., ASCII) format. The climate data file can be constructed with eight different formats based on the original data source. The units for temperature, precipitation, wind speed, solar radiation and relative humility are ºC, cm, m/s, MJ/m2/day, and %, respectively.

Format 1:

Line 1: file name.
Column 1: Julian day; 2: daily average air temperatures; 3: daily precipitation.

```
IA1987
1      -2.5        0.0
2      -1.0        1.2
3      -0.5        0.5
4       1.7        0.0
.
.
365     5.6        0.0
```

Format 2:

Line 1: file name.
Column 1: Julian day; 2: daily maximum air temperatures; 3: daily minimum air temperatures; 4: daily precipitation.

```
IA1987
1      -0.5    -4.5    0.0
2       0.0    -1.2    1.2
3       3.5     0.8    0.5
4       5.7     2.0    0.0
.
.
365     5.6    -0.2    0.0
```

Format 3:

Line 1: file name.
Column 1: Julian day; 2: daily maximum air temperatures; 3: daily minimum air temperatures; 4: daily precipitation; 5: radiation.

```
IA1987
1      -0.5    -4.5    0.0    19.169
2       0.0    -1.2    1.2    16.321
3       3.5     0.8    0.5    17.418
4       5.7     2.0    0.0    21.009
.
.
365     5.6    -0.2    0.0    17.239
```

Format 4:

Line 1: file name.
Column 1: Julian day; 2: daily maximum air temperatures; 3: daily minimum air temperatures; 4: daily precipitation; 5: daily average wind speed.

```
IA1987
1       -0.5    -4.5    0.0     0.25
2       0.0     -1.2    1.2     1.10
3       3.5     0.8     0.5     0.80
4       5.7     2.0     0.0     0.02
.
.
365     5.6     -0.2    0.0     0.00
```

Format 5:

Column 1: Julian day; 2: daily maximum air temperatures; 3: daily minimum air temperatures; 4: daily precipitation; 5: wind speed; 6: radiation; 7: humidity.

```
IA1987
1       -0.5    -4.5    0.0     0.25    19.169  45
2       0.0     -1.2    1.2     1.10    16.321  50
3       3.5     0.8     0.5     0.80    17.418  80
4       5.7     2.0     0.0     0.02    21.009  76
.
.
365     5.6     -0.2    0.0     0.00    17.239  34
```

Format 6:

Column 1: Julian day; 2: daily maximum air temperatures; 3: daily minimum air temperatures; 4: daily precipitation; 5: wind speed; 6: humidity.

```
IA1987
1       -0.5    -4.5    0.0     0.25    45
2       0.0     -1.2    1.2     1.10    50
3       3.5     0.8     0.5     0.80    80
4       5.7     2.0     0.0     0.02    76
.
.
365     5.6     -0.2    0.0     0.00    34
```

Format 7:

Column 1: Julian day; 2: daily maximum air temperatures; 3: daily minimum air temperatures; 4: daily precipitation; 5: humidity.

```
IA1987
1       -0.5    -4.5    0.0     45
2       0.0     -1.2    1.2     50
3       3.5     0.8     0.5     80
4       5.7     2.0     0.0     76
.
.
365     5.6     -0.2    0.0     34
```

Format 8:

Column 1: Julian day; 2: daily maximum air temperatures; 3: daily minimum air temperatures; 4: daily precipitation; 5: wind speed; 6: humidity.

IA1987

1	-0.5	-4.5	0.0	0.25	45
2	0.0	-1.2	1.2	1.10	50
3	3.5	0.8	0.5	0.80	80
4	5.7	2.0	0.0	0.02	76
.					
.					
365	5.6	-0.2	0.0	0.00	34

Page 2: Soil

Click the "***Soil"*** button at the top of the interface to open the soil page (Figure 4). All of the soil parameters, including the defaults and the user-defined, will be provided on this page.

When the input process is done, don't forget clicking the 

button to move the input data into the computer's memory. Leaving the page without clicking "Accept" will lose the newly input or modified data.

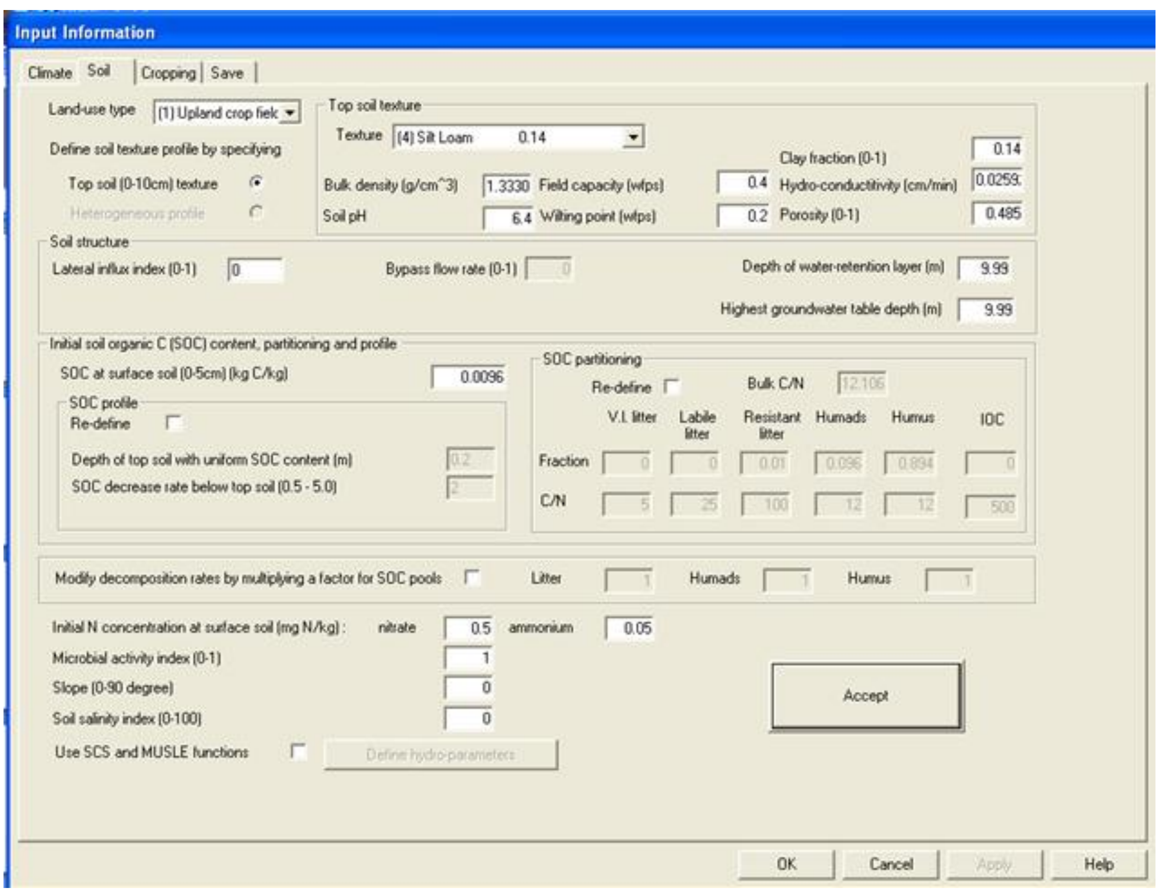


Figure 4. Input information for soil properties

[***Land-use type***]: Select a current land use. Options are *upland crop field, rice paddy field, moist grassland/pasture, dry grassland/Pasture, wetland, and tree plantation.*

[***Soil Texture***]: Select a soil type based on either its texture or clay fraction. There are 12 soil types including s*and, loamy sand, sandy loam, silt loam, loam, sandy clay loam, silty clay loam, clay loam, sandy clay, silty clay, clay, and organic soil.*

[***Bulk density (g/cm^3)***]: Bulk density (g/cubic cm) of top soil (0-10 cm).

[***Soil pH***]: pH of top soil.

[***Clay content (0-1)*****]:** Clay fraction of soil by weight. When soil texture is selected, a default clay content will be given although it can be modified by users.

[***Field Capacity (0-1)***]: Water-filled porosity (WFPS) at soil field capacity. When soil texture is selected, a default field capacity value will be given although it can be modified by users.

[***Wilting Point (0-1)***]: Water-filled porosity (WFPS) at soil wilting point. When soil texture is selected, a default wilting point value will be given although it can be modified by users.

[***Hydro-conductivity (m/hr)***]: Hydrological saturation conductivity in m/hr. When soil texture is selected, a default hydro-conductivity value will be given although it can be modified by users.

[***Porosity (0-1)***]: Soil porosity, a fraction. When soil texture is selected, a default porosity value will be given although it can be modified by users.

[***Macro-pores***]: Select "Yes" if there are macro-pores and bypass flow applicable to this soil (usually for tropical soils).

[***By-pass flow rate (0-1)***]: If the soil has macro-pores, the by-pass flow rate can be fined as a fraction.

[***Depth of water retention layer (m)***]: Depth of water retention layer in m, which could be formed by soil compaction (common for intensively grazed pasture) or clay pan.

[***Water logging problem***]: Select "Yes" if there are water logging problem due to the surface soil compaction.

[***Highest groundwater table depth (m)***]: The default value is 9.99 m, much deeper than the bottom depth of the simulated soil profile (0-0.5 m). The default value can be modified if the groundwater table is seasonally higher than the soil profile bottom depth.

[***SOC at surface soil (0-5cm) (kg C/kg)***]: Content of total soil organic carbon (SOC), including litter residue, microbes, humads, and passive humus at surface layer (0-5 cm). After defining the total SOC content, the default SOC profile as well the SOC partitioning values for litter, humads and passive humus will be automatically determined by DNDC.

[***SOC profile: Re-define***]: Checking this box will allow the user to re-define the SOC profile.

[***Depth of top soil with uniform SOC content (m)***]: A depth, above which the SOC content is uniform.

[***SOC decrease rate below top soil (0.5 – 5.0)***]: A rate, which determines how fast the SOC content decreases below the top soil. The higher the rate, the faster the SOC content decreases. A fraction value (i.e., <1.0) means SOC content increases along with increase in the soil depth (such as for peat soil).

[***Soil partitioning: Re-define***]: Checking this box will activate the process to re-define the

SOC partitioning.
[***V.l. litter***]: Fraction of very labile litter pool.
[***L. litter***]: Fraction of labile litter pool.
[***R. litter***]: Fraction of resistant litter pool.
[***Humads***]: Fraction of humads (active humus) pool.
[***Humus***]: Fraction of passive humus pool.
[***IOC***]: Fraction of inorganic carbon (such as chark) pool.
[***C/N***]: C/N ratio for each of the SOC pools.
[***Modify decomposition rates by multiplying a factor to each of the three SOC pools***]: The three factors for litter, humads and humus provide an opportunity to allow the users to systematically change the SOC decomposition rates to deal with unusual situations.
[***Initial NO3(-) concentration at surface soil (mg N/kg)***]: DNDC automatically calculates the default initial nitrate content at surface layer based on soil organic carbon content. The default value can be modified by the users.
[***Initial NH4(+)concentration at surface soil (mg N/kg)***]: DNDC automatically calculates the default initial ammonium content at surface layer based on soil organic carbon content. The default value can be modified by the users.
[***Microbial activity index (0-1)***]: An index raging from 0.0 to 1.0 for indicating impact of soil toxic materials on soil microbial activity. The default value 1.0 is for normal soils.
[***Slope (%)***]: Slope of the soil surface in percentage (0-100). The slope for a level soil is 0.
[***Soil salinity index (0-100)***]: Soil salinity index. If the index > 0, the soil salinity will affect crop growth and soil microbial activity.
[***Use SCS and MUSLE functions***]: Click this button to activate the Soil Conservation Service (SCS) curve number method and the Modified Universal Soil Loss Equation (MUSLE) approach to simulate soil surface runoff and soil erosion.

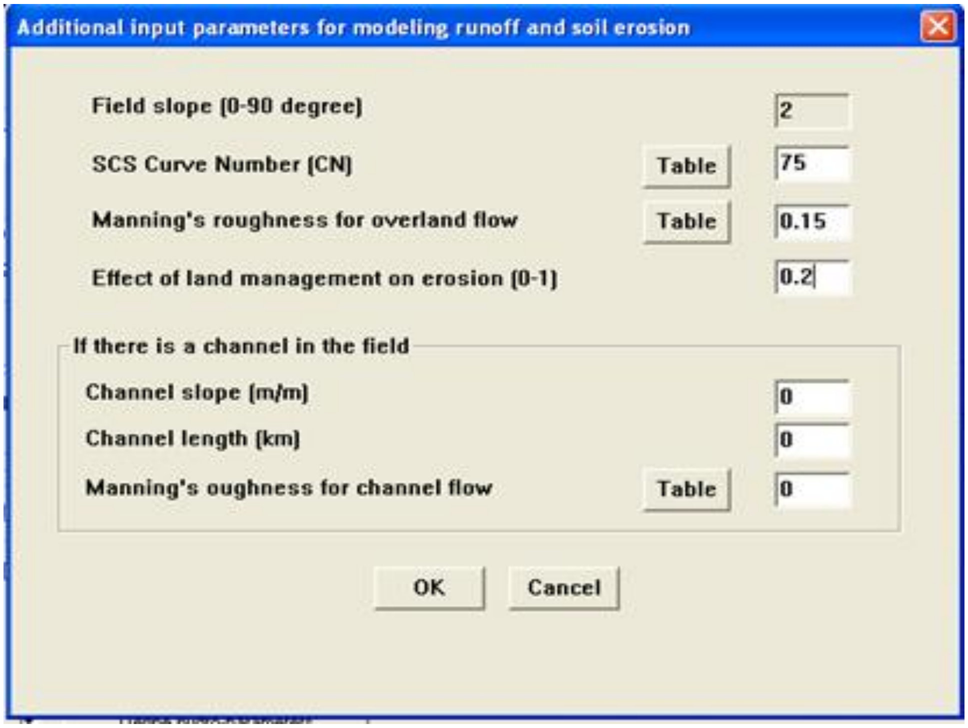


Figure 5. Soil hydrological parameters

[***SCS Curve Number***]: Define soil hydrological curve number regulating soil surface runoff flow.
[***Manning's roughness for overhead flow***]: Define soil surface roughness for calculating runoff flow.
[***Effect of land management on erosion (0-1)***]: Define an index for adjusting land management on runoff flow.
[***Channel slope (m/m)***]: Define channel slope.
[***Channel length (km)***]: Define channel length.
[***Manning's roughness for channel flow***]: Define channel surface roughness for calculating channel flow.

Page 3. Cropping

Clicking the Cropping button at the top of the interface will open a new page to allow you to input all the cropping management information. The simulated cropping systems are defined with total simulated years, number of cropping systems applied during the total years, the years of each cropping system, and the years of a cycle of each cropping system. Farming management practices need to be defined for each year of a cycle of each cropping system.

[***Total years***]: The number of total years modeled in this simulation. This number is automatically set by DNDC based on the total years input on page "Climate".
[***Number of cropping systems applied during the total simulated years***]: The number of different cropping systems consecutively applied during the entire simulated time span.

[***Cropping system #***]: Sequential number of the cropping system going to be defined.
[***Duration of this cropping system (yrs)***]: The number of years this cropping system lasts for.
[***Duration of a cycle in this cropping system (yrs)***]: The number of years a cycle of this cropping system lasts for.
[***Year # in the cycle in this copping system***]: Sequential number of the year in a cycle for current input process.

The input data on this page construct a chronology to frame all the cropping systems in sequence you are going to model in this simulation. By clicking the arrow buttons beside "Cropping system #" you will be able to shift from a cropping system to another cropping system. By clicking the arrow buttons beside "Year # in this cycle" you will be able to shift from a year to another year within a cycle. For each year, the management input data required include information of crop types, planting/harvest dates, tillage, fertilization, manure amendment, irrigation, flooding, plastic film use, grazing, and grass cutting. For a long-term simulation with several different cropping systems applied in series, you will need to define the farming management practices for each year within a cycle of each cropping system to meet the total simulated years. It sounds complex, isn't it? Maybe, especially for the people who have no rich experience in the farm field work. Don't worry. Let's go through an example which may provide more insights about the cropping system definitions.

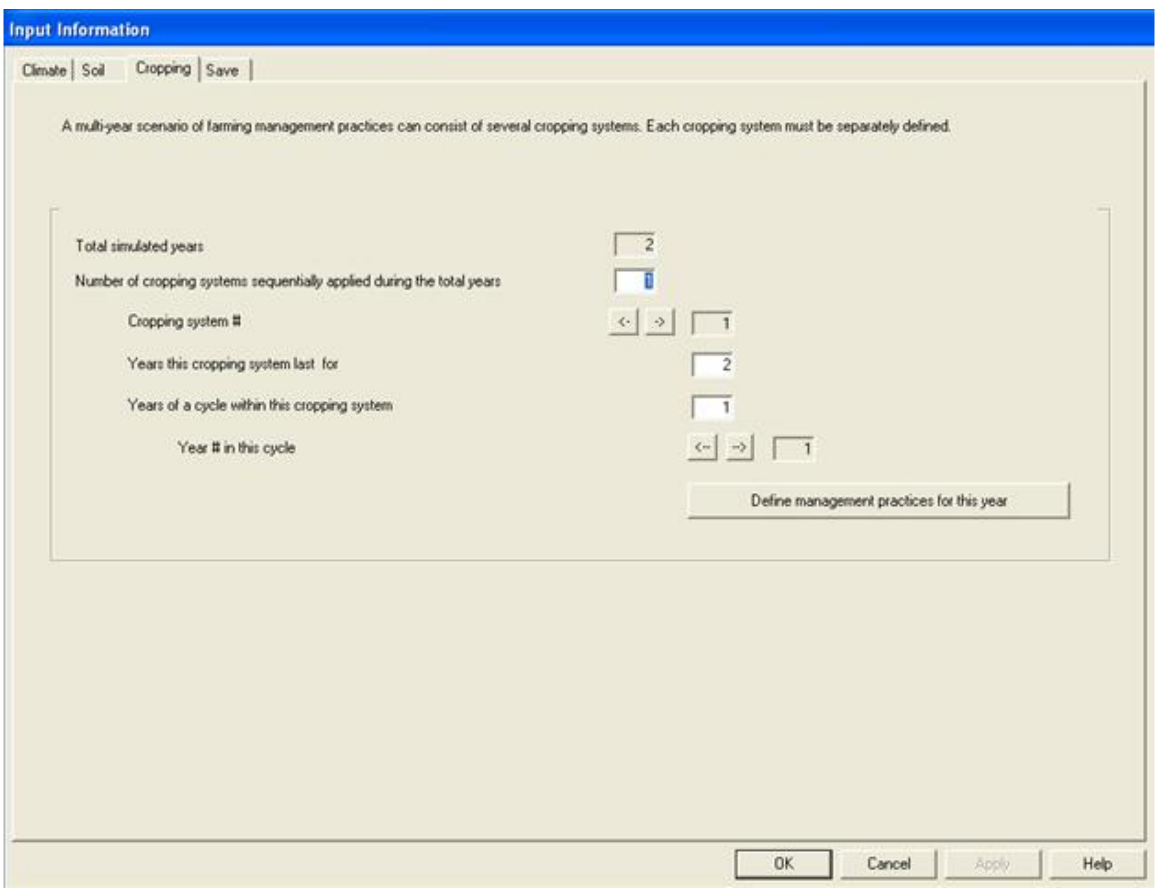


Figure 6. Rotation information: Cropping systems and cycles

Let's assume you will conduct a long-term simulation at a field where cropping systems altered during the modeled time period. To define the chronology of the cropping management history, you will need to answer several questions as follows:

(1) How many years I am going to simulate totally:
  - 100 years;
(2) How many cropping systems are involved in the simulation:
  - 2 cropping systems (corn-soybean rotation system, and then winter wheat-fallow-alfalfa rotation system);
(3) How many years each cropping system lasts for:
  - The corn-soybean system lasts for 40 years, and the winter wheat-fallow-alfalfa system lasts for 60 years;
(4) How many years a cycle takes place for in each cropping system:
  - A cycle of the corn-soybean system takes 2 years, and a cycle of the winter wheat-fallow-alfalfa system takes 3 years;
(5) What farming practices take place in each year of each cycle:
  - For year 1 of the corn-soybean cycle, corn is planted with two applications of conventional tillage and a surface application of 120 kg urea-N/ha. For year 2 of the cycle, soybean is planted with two applications of conventional tillage with no fertilizer used.
  - For year 1 of the winter wheat-fallow-alfalfa cycle, winter wheal is planted with two applications of tillage and an application of 100 kg urea-N/ha. For year 2 of the cycle, the field is left fallow after harvest of the winter wheat with no tillage and no fertilizer used. For year 3 of the cycle, alfalfa is planted as a cover crop with an application of tillage and no fertilizer used.

A scheme can be plotted based on the above-described 100-year cropping systems as follows:

Total years (100):
- Total cropping systems (2):
  - Years of system 1 (40)
    - Years of a cycle of system 1 (2)
      - Crop for year 1 of the cycle: corn
      - Crop for year 2 of the cycle: soybean
  - Years of system 2 (60)
    - Years of a cycle of system 2 (3)
      - Crop for year 1 of the cycle: winter wheat
      - Crop for year 2 of the cycle: fallow
      - Crop for year 3 of the cycle: alfalfa

.

When you have manually defined the farming management practices for the five specific years (i.e., 2 years for cropping system 1 and 3 years for cropping system 2), a 100-year chronology scenario will be automatically built up by DNDC based on (1) the years of each cropping system lasts, (2) years of a cycle of each cropping system, and (3) farming practices assigned for each year in each cycle of each cropping system.

The following several paragraphs further specify how to define the farming management practices for each specific year.

Page 4. Crop

The page "Crop" allows you to define (1) types of the crops consecutively or simultaneously planted in this year, (2) planting and harvest dates, (3) crop residue management, and (4) crop physiological and phenology parameters (DNDC provides the default values but you can modify them) (Figure 7).

[***Number of new crops consecutively planted in this year:***]: The number of crops consecutively planted in this year. Only the new crops planted within this year are counted.

[***Crop #***]: Crop sequential number.

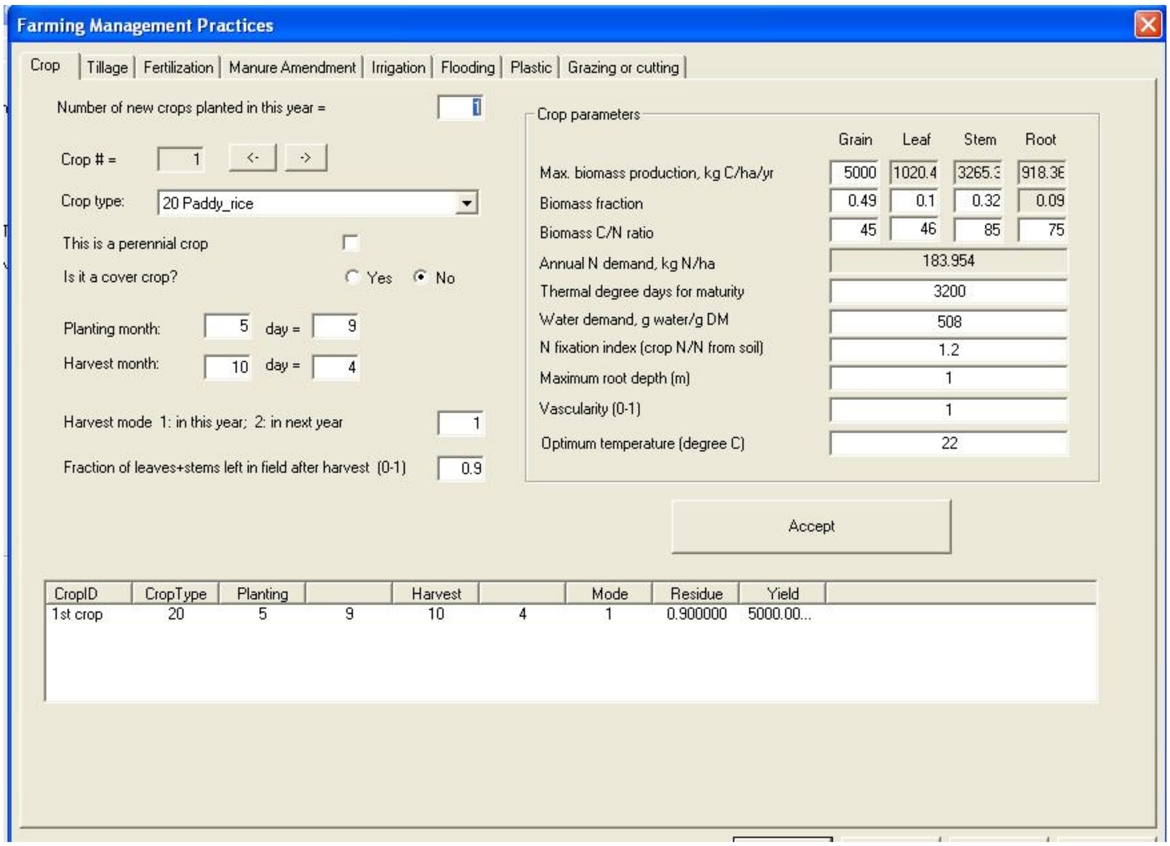


Figure 7. Input information for crop type, planting/harvest dates, residue management and crop physiological/phenology parameters

[***Crop type***]: Select one of the crop types parameterized in DNDC. The options are

0 Fallow
1 Corn
2 Winter_wheat
3 Soybean
4 Legume_hay
5 Non_legume_hay
6 Spring_wheat
7 Sugarcane

8 Barley
9 Oats
10 Alfalfa
11 Grassland
12 Perennial_grass
13 Sorghum
14 Cotton
15 Rye
16 Vegetables
17 Papaya
18 Potato
19 Beet
20 Paddy_rice
21 Banana
22 Celery
23 Peanut
24 Upland_rice
25 Rapeseeds
26 Tobacco
27 Millet
28 Sunflower
29 Beans
30 DW_rice
31 Onion
32 Palm
33 Strawberry
34 Lettuce
35 Artichoke
36 Nursery_flowers
37 Brussels_sprout
38 Berries
39 Truck_crops
40 Fruit_trees
41 Citrus
42 Grape
43 Spring_corn
44 Hops
45 Tomato
46 Rainfed_rice
47 Cover_crop
48 Safflower
49 Flax
50 Sedge
51 Cassava
52 Cattail
53 UCSC_broccoli

54 TropicEvergreens
55 Cabbage
56 Green_onion
57 Mustard
58 Tule
59 Moss
60 Radish
61 Shrub
62 Boreal_sedge
63 New_crop
64 New_crop
65 New_crop
66 New_crop
67 New_crop
68 New_crop
69 New_crop
70 New_crop
71 New_crop
72 New_crop
73 New_crop
74 New_crop
75 New_crop
76 New_crop
77 New_crop
78 New_crop
79 New_crop

You may have noticed that there are a number of “New_crop” in the list, which are the spaces holders for the new crops that the users want to add in the list.

[***This is a perennial crop***]: Checking this box will define the crop as a perennial crop.
[***Is it a cover crop***]: Defining the crop as a cover crop by selecting “Yes”. As a cover crop, its biomass will be totally left in the field without any fraction harvested by the end of the crop season.
[***Planting month and day***]: A number from 1 to 12 for the month; and a number from 1 to 31 for the day.
[***Harvest month and day***]: A number from 1 to 12 for the month; and a number from 1 to 31 for the day.
[***Harvest mode***]: A integer number automatically set by DNDC or manually set by the user, which indicates if the crop is harvested in this year in which the crop is planted (1), or harvested in the next year (2) or a specific later year (3, 4 …).
[***Faction of leaves and stems left in the field after harvest (0-1)***]: A fraction of the above-ground crop residue left as stubble in the field after harvest.

Crop simulation plays a crucial role in modeling C and N biogeochemistry in agroecosystems. By taking water and N from as well as depositing litter into soil, plant growth regulates the soil water, C and N regimes which turn to determine a serious of biogeochemical reactions including C sequestration and trace gas emissions. To ensure this biogeochemistry model will work in a decent mode, the users are required to have their crops simulated correctly first. For the purpose, DNDC provides an approach on this page to allow the users to modify the crop physiological and phenology parameters either for the specific case or for the default data permanently stored in the crop library of DNDC.

As soon as a new crop type is selected from the box of "Crop type", the default physiological/phenology parameters for the crop will be read out from the crop library, and shown in the block "Crop parameters for this case" on the page. All the independent parameters in the matrix can be modified by the users.

[***Maximum biomass, kg C/ha***]: The maximum biomass productions for grain, leaves+stems and roots under optimum growing conditions. The unit is kg C/ha (1 kg dry matter contains 0.4 kg C).
[***Biomass fraction***]: The grain, leaf, stem and root fractions of total biomass at maturity.
[***Biomass C/N ratio***]: Ratio of C/N for grain, leaves, stems and roots.
[***Total N demand, kg N/ha***]: Amount of the total N demanded by the crop to reach the maximum production.
[***Thermal degree days, °C***]: Accumulative air temperature from seeding till maturity of the crop.
[***Water demand, g water/g dry matter***]: Amount of water needed for the crop to produce a unit of dry matter of biomass.
[***N fixation index***]: The default number is 1 for non-legume crops. For legume crops, the N fixation index is equal to the ratio (total N content in the plant)/(plant N taken from soil).
[***LAI adjustment factor***]: A factor for adjusting default specific leaf weight.
[***Vascularity, 0-1***]: A fraction number representing the vascularity of wetland plants.
[***Optimum temperature***]: The optimum temperature (°C) for the crop growth.

If your crop growth is not corrected simulated with the default parameters, you may like to modify the default values that will adjust the crop heat/water/N demands, growth curve, biomass partitioning or yield. The adjusted parameter values will be saved for this case when you finally execute the saving process to save all the input data for the case.

Page 5. Tillage

Fill up the tillage page (Figure 8) to define the timing and method of each tilling application.

[***How many applications in this year***]: Number of tilling applications in the year.
[***Tilling #***]: Sequential number of each application.
[***Month/Day***]: Date of the tilling application.
[***Tilling method***]: Define tilling depth by selecting one of the default methods as (1) no-till (i.e., only mulching) (0 cm), (2) ploughing slightly (5 cm), (3) ploughing with disk

or chisel (10 cm), (4) ploughing with moldboard (20 cm), or (5) deep ploughing (30 cm).

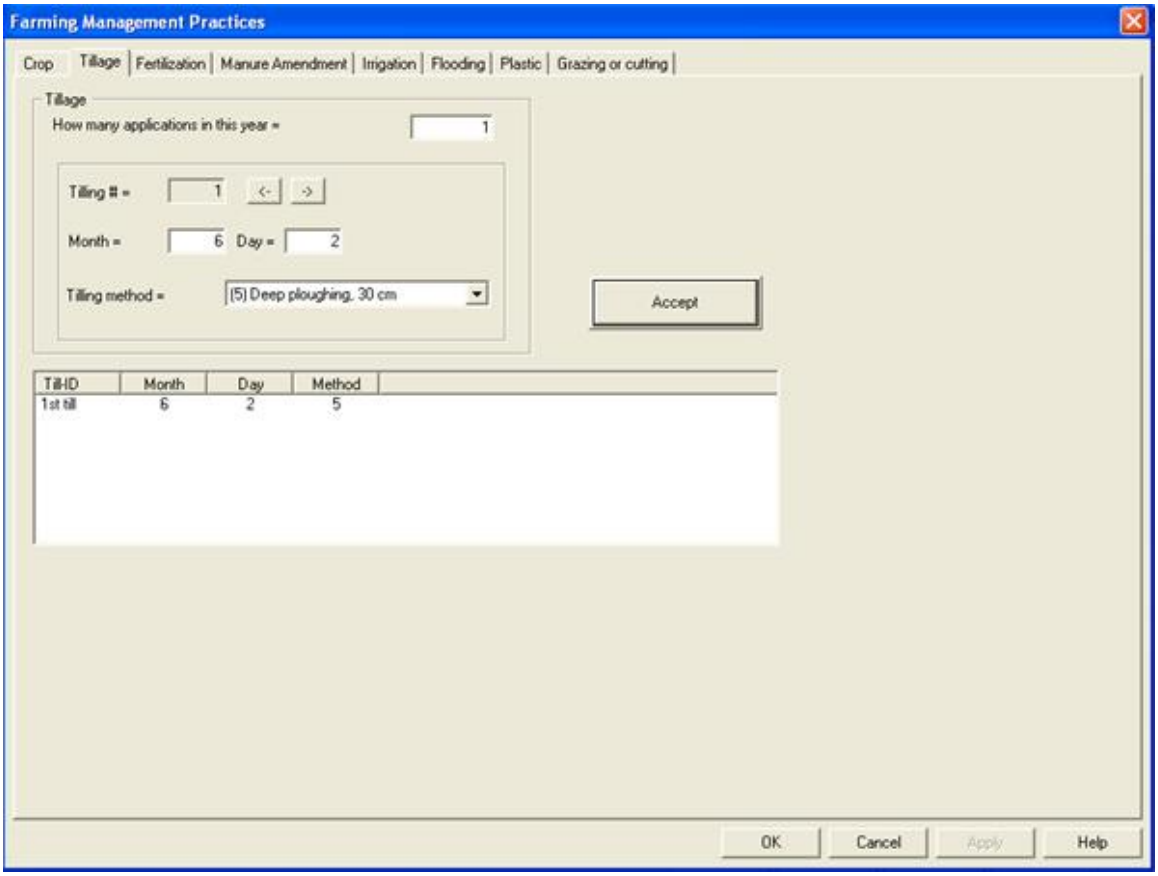


Figure 8. Iput information for tillage

Page 6. Fertilization

There are three options for fertilization: manual application, auto-fertilization and fertigation. The manual application is traditional for most farms, which is defined by specifying the times, timing, method, and fertilizer type and rate for each application (Figure 9).

[***How many applications in this year***]: Number of applications in the year.
[***Fertilization #***]: Sequential number of each application.
[***Application date: month/Day***]: Date of each application.
[***Application depth: Surface or injection***]: Select surface application with a default depth 0.2 cm, or injection with a default depth 15 cm.
[***Applied amount of fertilizers (kg N/ha)***]: Seven types of fertilizers can be singly or collectively selected by specifying the amount (kg N/ha) for each.
[***It is a controlled release fertilizer***]: If this button is checked, the total days during which the fertilizer-N will be uniformly released must be specified.
[***Using nitrification inhibitor***]: If this button is checked, the efficiency and effective

duration (days) of the nitrification inhibitor must be specified.

[***Using urease inhibitor***]: If this button is checked, the efficiency and effective duration (days) of the urease inhibitor must be specified.

If auto-fertilization is selected, DNDC will calculate the N deficit and automatically add the amount of fertilizer (as urea) into the soil at a daily basis.

If fertigation is selected, the button "select fertigation file" will be activated that allow the user to select a preset file containing daily water and fertilizer-N amounts applied for the site.

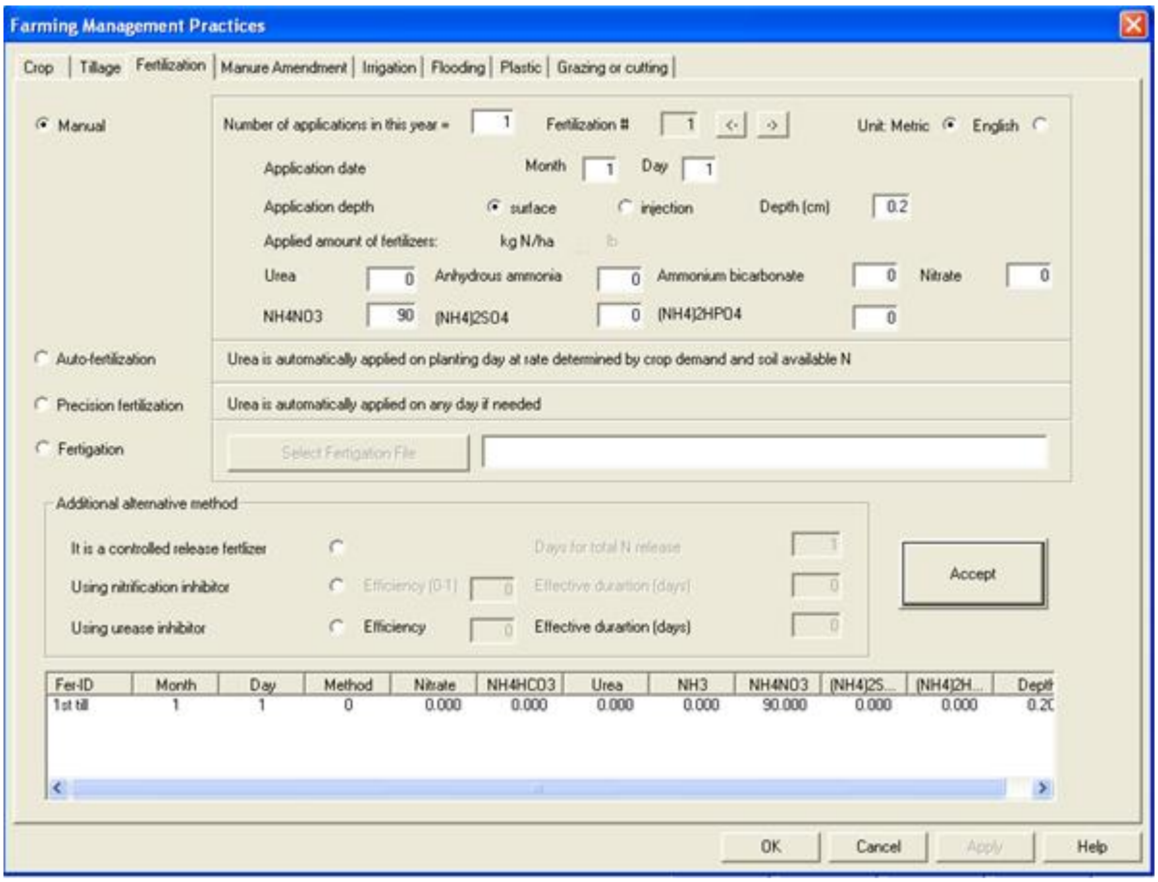


Figure 9. Input information for fertilization

The fertigation files can be created following the format as follows:

Line 1: Name of the file

Column 1: Julian day; 2: irrigated water (cm); 3: nitrate; 4: ammonium bicarbonate; 5: urea; 6: anhydrous ammonia; 7: ammonium nitrate; 8: ammonium sulfate; 9: ammonium phosphate (kg N/ha) dissolved in the irrigation water.

```
OrganicFarm_UCSC_2005
1    12    0.0    0.0    8.0    0.0    0.0    0.0    0.0
```

2	7	0.0	0.0	5.0	0.0	0.0	0.0	0.0
.								
.								
365	10	0.0	0.0	10.0	0.0	0.0	0.0	0.0

Two special fertilizer features can be selected. They are “Controlled release fertilizer” and “Use nitrification inhibitor”. For the controlled release fertilizer, the releasing span (days) will need to be defined. For the nitrification inhibitor, the inhibiting efficiency and effective duration will need to be specified.

Page 7. Manure amendment

Manure application is defined by the timing, type and amount for each application (Figure 10).

[***How many applications in this year***]: Number of applications in the year.
[***Application #***]: Sequential number of each application.
[***Month/Day***]: Date of each application.
[***Manure type***]: Select a type of manure. Ten types of manure (e.g., farmyard manure, green manure, straw, slurry animal waste, compost, bean cake, human waste, poultry waste, sewage sludge, and meat or blood meal) are parameterized in DNDC.
[***Amount (kg C/ha)***]: Specify the amount of manure as kg C/ha applied for the application.
[***C/N ratio***]: Ratio of C/N in the manure. The default value is provided by DNDC but can be modified by the user.
[***Application method: Surface spreading or Incorporation***]: Specify the application method.

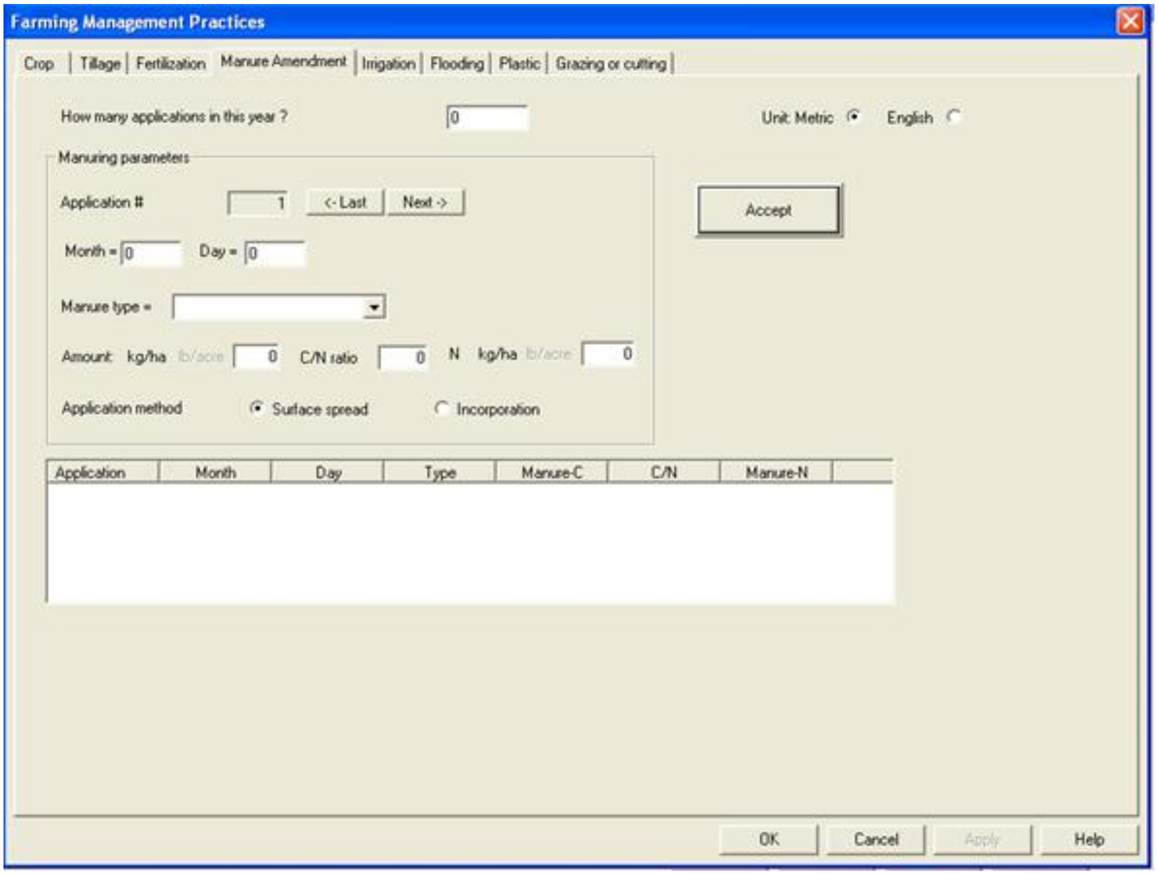


Figure 10. Input information for manure amendment

Page 8. Irrigation

Irrigation is define as supplement of water to the field without causing long-term (> 24 hours) ponding water on the soil surface.

[***Irrigation input mode***]: There are two ways to define irrigation. The first option is to define irrigation events by specifying their dates, water amounts and application methods (i.e., flood or drip/sprinkler). The second way is to define an irrigation index between o and 1. If a modeled water stress occurs, a fraction, equal to the index, of the water will be automatically delivered to the soil to meet the predicted water deficit.

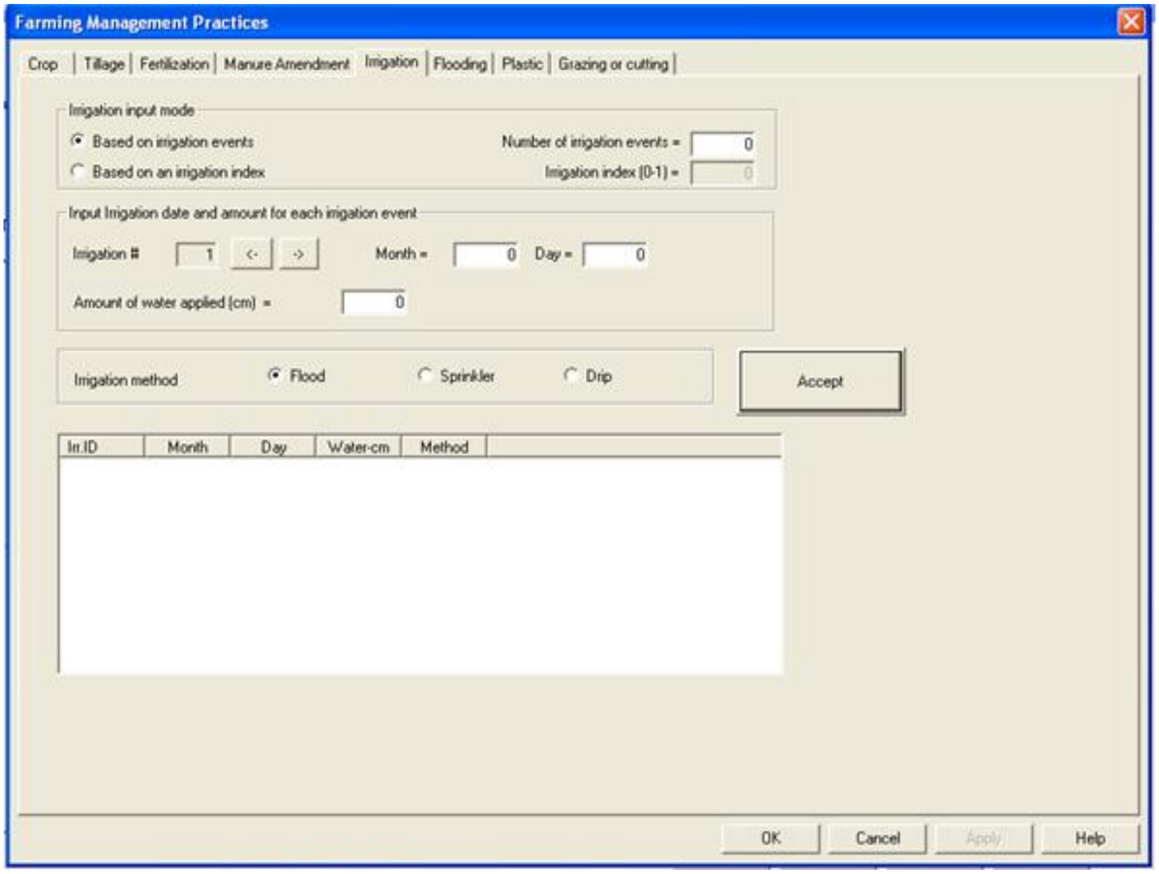


Figure 11. Input information for irrigation

[***Irrigation method***]: Flood, sprinkler and drip are options subject to different evaporation or leaching water losses and hence have different water use efficiencies.

Page 9. Flooding

Flooding practice is usually applied for paddy rice or other wetland crops. There are three options to define flooding duration by (1) irrigation (Control 1), (2) rainfed (Control 2), (3) observed water table fluctuation data (Control 3), and (4) empirical parameters (Control 4).

For Control 1 (i.e., scheduled irrigation), the required input parameters include

[***How many times the field is flooded in this year***]: Number of flooding applications in the year.
[***Flooding #***]: Sequential number of each application.
[***Start on month/day***]: Starting date of each flooding application.
[***End on month/day***]: End date of each flooding application.
[***Conventional flooding (10 cm)***]: Conventional flooding with ponding water layer of 10 cm.
[***Marginal flooding (-5-5 cm)***]: Marginal flooding with ponding water layer thickness varying between –5 and 5 cm.

[***N received with flood water (kg N/ha)***]: Inorganic N received with the flooding water in kg N/ha per application.

[***Water leaking rate (mm/day)***]: Rate of the flood water leaking from the bottom of the flooded soil profile in mm water/day.

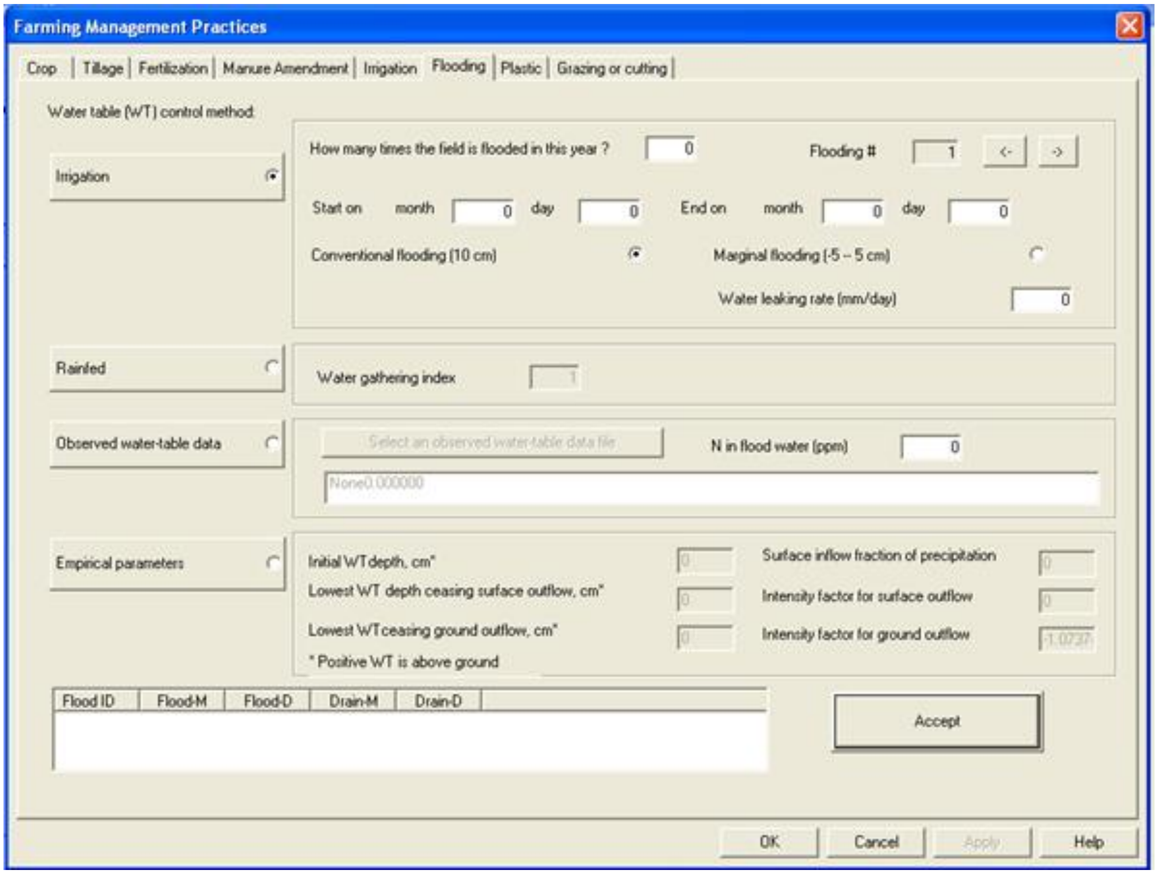


Figure 12. Input information for flooding

For Control 2 (i.e., rainfed), the required input parameter is

[***Watershed index***]: A factor (> or = 1) indicating the area from which the rain water is collected to supply a unit of the crop field (ha/ha).

For Control 3 (i.e., observed water-table data), the user will need to select a preset file recording daily water table depth. The file format is as follows:

```
Coalburn_UK_1990_C_WETLand   (file name)
Julian_day    WaterTable_cm
1             -1.3
10            -5.2
22            -7.0
35            -3.9
40            -1.3
```

51	-2.0
102	-6.6
150	9.4
203	8.3
250	24.8
300	17.1
307	8.2
317	-1.0
321	-4.5
338	-2.2
340	-1.0
356	-6.0
360	-4.9

In the data, negative values mean the water table is below the soil surface; and positive above the soil surface.

For Control 4, the modeled water table (WT) is controlled by a group of hydrological parameters which can be induced based on the actual water table depth data observed at the site in the past. The parameters include (1) initial WT depth in cm, (2) surface inflow fraction of precipitation, (3) lowest WT depth ceasing surface outflow in cm, (4) intensity factor for surface outflow, (5) lowest WT ceasing ground outflow in cm, and (6) intensity factor for ground outflow.

Page 10. Plastic

Plastic film can be utilized to construct greenhouse or mulch the ground. The practices can substantially alter the temperature-moisture regimes in the soil, and hence affect the crop growth as well as all the microbial activities in the ecosystems.

[***Method***]: Two options: greenhouse or film mulch.
[***Applications***]: Number of the greenhouse or film mulch applications per year.
[***From Month= Day=***]: Initial date of an application.
[***To Month= Day=***]: Ending date of an application.
[***Covered fraction***]: If film mulch is applied, the film-covered fraction of soil surface must be defined.

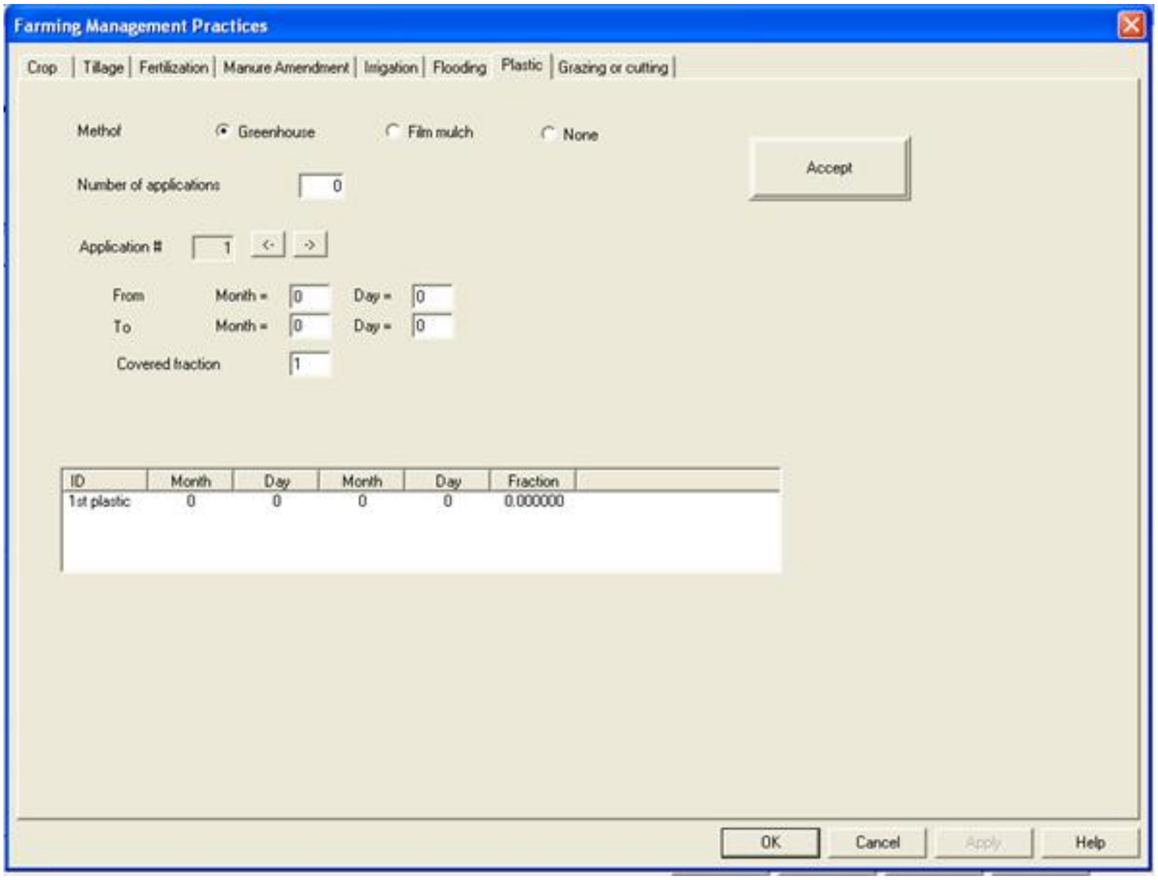


Figure 13. Input information for greenhouse or plastic film mulch

Page 11. Grazing and Grass Cutting

Grazing is usually applied to grassland or pasture. Grazing practice is defined by specifying the livestock type, heads and the grazing duration, which will be used to quantify feeding intensity and waste deposition of the livestock when they stay in the field.

[***Number of grazing time periods***]: Number of grazing application periods in the year.
[***Start month/day***]: Starting date of each grazing period.
[***End month/day***]: End date of each grazing period.
[***Grazing hours per day***]: Hours per day the livestock stay in the field during the grazing period.
[***Grazing intensity (heads/ha)***]: Number of cattle, horse, or sheep grazing in the field for each grazing period.

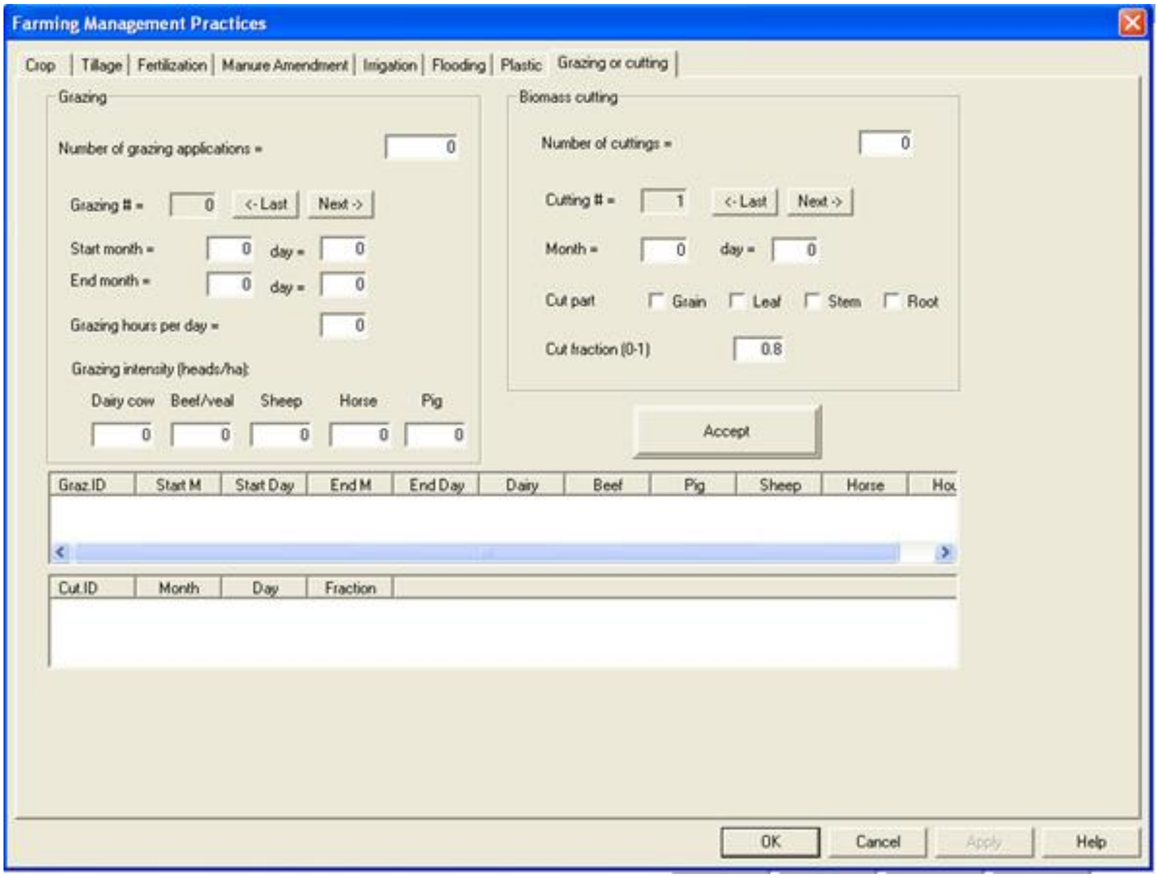


Figure 14. Input information for grazing and grass cutting

For grass cutting, the required input parameters include

[***Number of grass cutting***]: Number of cutting applications in the year.
[***Cutting #***]: Sequential number of each cutting.
[***Month/Day***]: Date of each cutting.
[***Cut part***]: Define which part of the plant is cut. The options are grain (or fruit), leaf, stem and/or root.
[***Cut fraction (0-1)***]: Cut fraction of the defined part(s). The default value is 0.8.

So far, we have gone through all the input procedures for site simulations. At this moment, if you have typed your input data on the relevant pages of the interface, you can click "OK" at the bottom of the main menu that will ask DNDC to automatically convert your input information into a group of DNDC-formatted, internal input files stored at C:\DNDC\Result\Inputs\. That means DNDC is ready to execute simulation for this case now or later.

1.2. Save and Open an Input File

After going through the long, sometimes tedious, input procedure, you may like to save all the input information for future use. To do so, please go to the last page on the input interface by clicking “Save” on the main menu. Clicking button “Save input data to a file” will allow you to create a file name and path to save all the input information you have manually typed in.

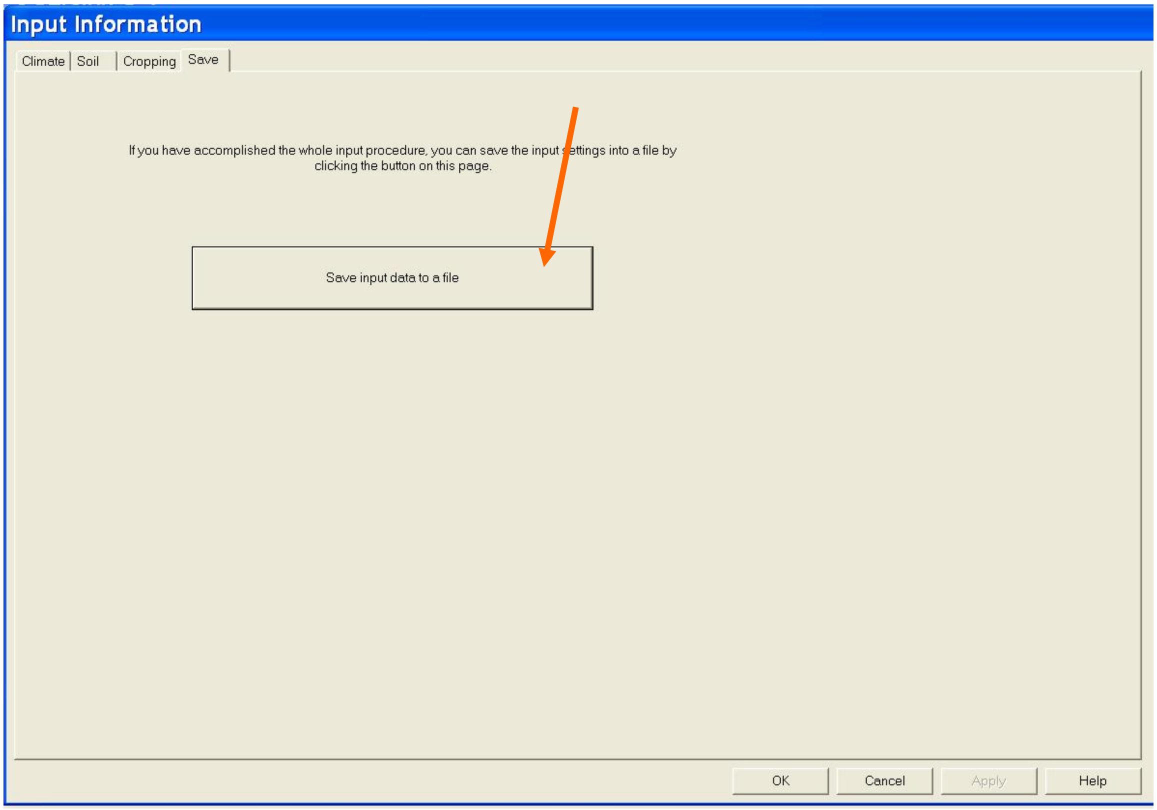


Figure 15. Save input data in a file

The saved file is in a plain text format so that it can be reviewed and even modified by the users with Notepad, WordPad, TextPad or other editors for plain text. Below-attached is an example input file, which contains a complete set of the input data provided by the user to simulate a specific case.

```
Input_Parameters:
----------------------------------------
Site_data:                    Arrou9899
Simulated_Year:               2
Latitude:                     48.100
Daily_Record:                      1
----------------------------------------
Climate_data:
Climate_Data_Type:            1
NO3NH4_in_Rainfall              1.0000
NO3_of_Atmosphere               0.0600
BaseCO2_of_Atmosphere         350.0000
Climate_file_count=           2
```

```
    1   C:\DNDC\N2O\Arrou\Climate\Arrou_1998.txt
    2   C:\DNDC\N2O\Arrou\Climate\Arrou_1999.txt
Climate_file_mode                 0
CO2_increase_rate            0.000000
----------------------------------------
Soil_data:
   Soil_Texture               4
   Landuse_Type               1
   Density                    1.29000
   Soil_pH                    6.40000
   SOC_at_Surface             0.00960
   Clay_fraction              0.13700
   BypassFlow                 0.00000
   Litter_SOC                 0.01000
   Humads_SOC                 0.04800
   Humus_SOC                  0.94200
   Soil_NO3(-)(mgN/kg)        0.59875
   Soil_NH4(+)(mgN/kg)        0.05988
   Moisture                   0.30000
   Temperature                7.45000
Field_capacity               0.400000
Wilting_point                0.200000
Hydro_conductivity           0.025920
Soil_porosity                0.485000
SOC_profile_A                0.200000
SOC_profile_B                2.000000
DC_litter_factor             1.000000
DC_humads_factor             1.000000
DC_humus_factor              1.000000
Humad_CN                     10.000000
Humus_CN                     10.000000
Soil_PassiveC                0.000000
Soil_microbial_index         1.000000
Highest_WT_depth                9.990000
Depth_WRL_m                  9.990000
Slope                        0.000000
Salinity                     0.000000
SCS_curve_use                0
----------------------------------------
Crop_data:
Rotation_Number=             1
  Rotation_ID=               1
  Totalyear=                 2
  Years_Of_A_Cycle=          2
    YearID_of_a_cycle=       1
    Crop_total_Number=       2
      Crop_ID=               1
```

```
    Crop_Type=          25
    Plant_time=         1 1
    Harvest_time=       6 1
    Year_of_harvest=    1
    Ground_Residue=     1.000000
    Yield=              2400.000000
    Leaf_fraction=      0.100000
    Leaf_CN=            46.000000
    Psn_efficiency=     0.000000
    Psn_maximum=        0.000000
    Initial_biomass=    0.000000
    Cover_crop=         0
    Perennial_crop=     0
    Grain_fraction=     0.490000
    Shoot_fraction=     0.320000
    Root_fraction=      0.090000
    Grain_CN=           45.000000
    Stem_CN=            85.000000
    Root_CN=            75.000000
    TDD=                3200.000000
    Water_requirement=  508.000000
    Optimum_temp=       22.000000
    N_fixation=         1.200000
    Vascularity=        1.000000
  Crop_ID=              2
    Crop_Type=          2
    Plant_time=         10 21
    Harvest_time=       7 12
    Year_of_harvest=    2
    Ground_Residue=     0.500000
    Yield=              3500.000000
    Leaf_fraction=      0.100000
    Leaf_CN=            46.000000
    Psn_efficiency=     0.000000
    Psn_maximum=        0.000000
    Initial_biomass=    0.000000
    Cover_crop=         0
    Perennial_crop=     0
    Grain_fraction=     0.490000
    Shoot_fraction=     0.320000
    Root_fraction=      0.090000
    Grain_CN=           45.000000
    Stem_CN=            85.000000
    Root_CN=            75.000000
    TDD=                3200.000000
    Water_requirement=  508.000000
    Optimum_temp=       22.000000
```

```
    N_fixation=         1.200000
    Vascularity=        1.000000
Tillage_number=         1
  Tillage_ID=           1
    Month/Day/method=   6 2 5
Fertil_number=          1
  fertilization_ID=     1
    Month/Day/method=   1 1 0
    Depth=              0.200000
    Nitrate=            0.000000
    AmmBic=             0.000000
    Urea=               0.000000
    Anh=                0.000000
    NH4NO3=             90.000000
    NH42SO4=            0.000000
    NH4HPO4=            0.000000
  Release_rate=         1.000000
  Inhibitor_efficiency= 0.000000
  Inhibitor_duration=   0.000000
  FertilizationOption=  0
Manure_number=          0
Plastic_film=            0
Ventilation=             0
Flood_number=           0
Leak_type=              1
Water_control=          0
Leak_rate=              0.000000
    Water_gather=   1.000000
    WT_file=        None0.000000
    Empirical_parameters= 0.0 0.0 0.0 0.0 0.0 0.0
Irrigation_number=      0
Irrigation_type=        0
Irrigation_Index=       0.000000
Grazing_number=           0
Cut_number=           0
YearID_of_a_cycle=      2
Crop_total_Number=      0
Tillage_number=         1
  Tillage_ID=           1
    Month/Day/method=   7 13 5
Fertil_number=          3
  fertilization_ID=     1
    Month/Day/method=   2 6 0
    Depth=              0.200000
    Nitrate=            0.000000
    AmmBic=             0.000000
    Urea=               0.000000
```

```
    Anh=                    0.000000
    NH4NO3=                 58.000000
    NH42SO4=                0.000000
    NH4HPO4=                0.000000
  Release_rate=             1.000000
  Inhibitor_efficiency=     0.000000
  Inhibitor_duration=       0.000000
  fertilization_ID=         2
    Month/Day/method=       3 12 0
    Depth=                  0.200000
    Nitrate=                0.000000
    AmmBic=                 0.000000
    Urea=                   42.000000
    Anh=                    0.000000
    NH4NO3=                 41.000000
    NH42SO4=                0.000000
    NH4HPO4=                0.000000
  Release_rate=             1.000000
  Inhibitor_efficiency=     0.000000
  Inhibitor_duration=       0.000000
  fertilization_ID=         3
    Month/Day/method=       3 27 0
    Depth=                  0.200000
    Nitrate=                0.000000
    AmmBic=                 0.000000
    Urea=                   20.000000
    Anh=                    0.000000
    NH4NO3=                 20.000000
    NH42SO4=                0.000000
    NH4HPO4=                0.000000
  Release_rate=             1.000000
  Inhibitor_efficiency=     0.000000
  Inhibitor_duration=       0.000000
  FertilizationOption=      0
Manure_number=              0
Plastic_film=                0
Ventilation=                 0
Flood_number=               0
Leak_type=                  1
Water_control=              0
Leak_rate=                  0.000000
    Water_gather=    1.000000
    WT_file=         None0.000000
    Empirical_parameters= 0.0 0.0 0.0 0.0 0.0 0.0
Irrigation_number=          0
Irrigation_type=            0
Irrigation_Index=           0.000000
```

```
    Grazing_number=            0
    Cut_number=           0
Crop_model_approach         0
```

In future, if you want to retrieve the input data, just click button “Open an input data file” on the “Climate” page that will allow you to find a previously saved input data file and load all the input information to DNDC. After opening the file, you can go to any page to modify the data, or just click “Run” to re-run the case.

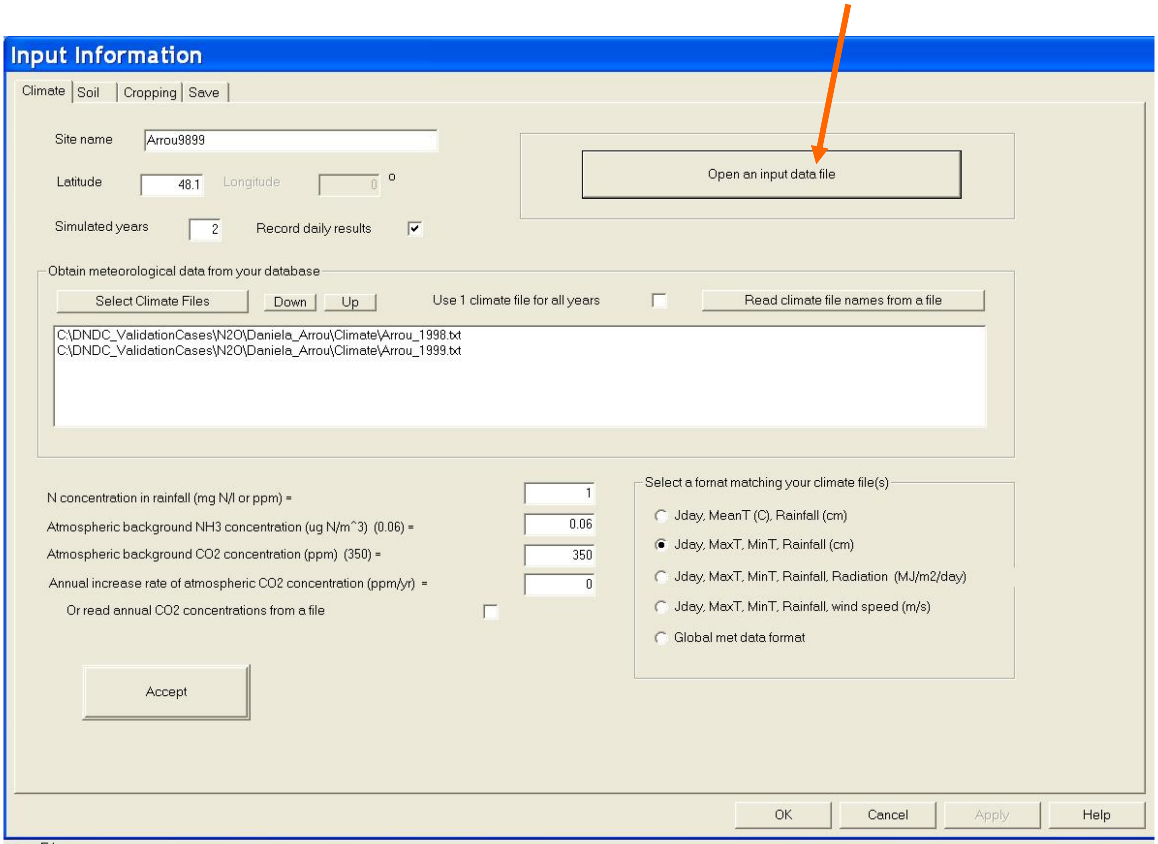


Figure 16. Open an input data file

1.3. Run DNDC at Site Mode

When the input procedure is accomplished, you can click the button "Run" to start the simulation for the site. During the simulation, there are seven windows appearing on the screen to demonstrate the daily dynamics of the simulated meteorological conditions, soil climate and chemistry, crop growth, soil microbial activities, gas emissions, and soil C and N profiles (Figure 17).

Figure 17. The seven windows allow users to monitor daily dynamics of several major simulated factors during the model run.

Window 1 (up-left corner) shows site name, simulated year, and crop type.

Window 2 (middle-left) shows soil carbon and nitrogen profiles for 0-50 cm.

Window 3 (top in the middle) shows daily air temperature, precipitation, snow pack, evaporation, and transpiration.

Window 4 (second in the middle) shows crop biomass, N uptake, water stress and N stress.

Window 5 (third in the middle) shows soil temperature, moisture, Eh, ice content, available N, and water leaching flow.

Window 6 (forth in the middle) shows daily rates of decomposition, nitrification, denitrification, methanogenesis, and methanotrophy.

Window 7 (bottom-middle) shows daily fluxes of NH_3, CH_4, N_2O, NO, and N_2.

These windows allow users to observe the general dynamics of several key factors during the model runs.

1.4. A Quick View of Modeled Results

The simulated results including daily and annual crop biomass, C and N pools/fluxes, water budget and greenhouse gas emissions, are recorded in a series of files stored at \DNDC\Result\Record\Site\. All the files are in a plain text format so that they can be retrieved and reprocessed with any spreadsheet tools (e.g., Excel). The contents of the result files are described in detail in "IV. Modeled Results". However, DNDC provides a handy tool to allow the users to have a quick view on results from the just finished simulation. By clicking button "Result" on the main menu (Figure 2), you will open a new page, on which you can select the year and the item you'd like to observe (Figure 18).

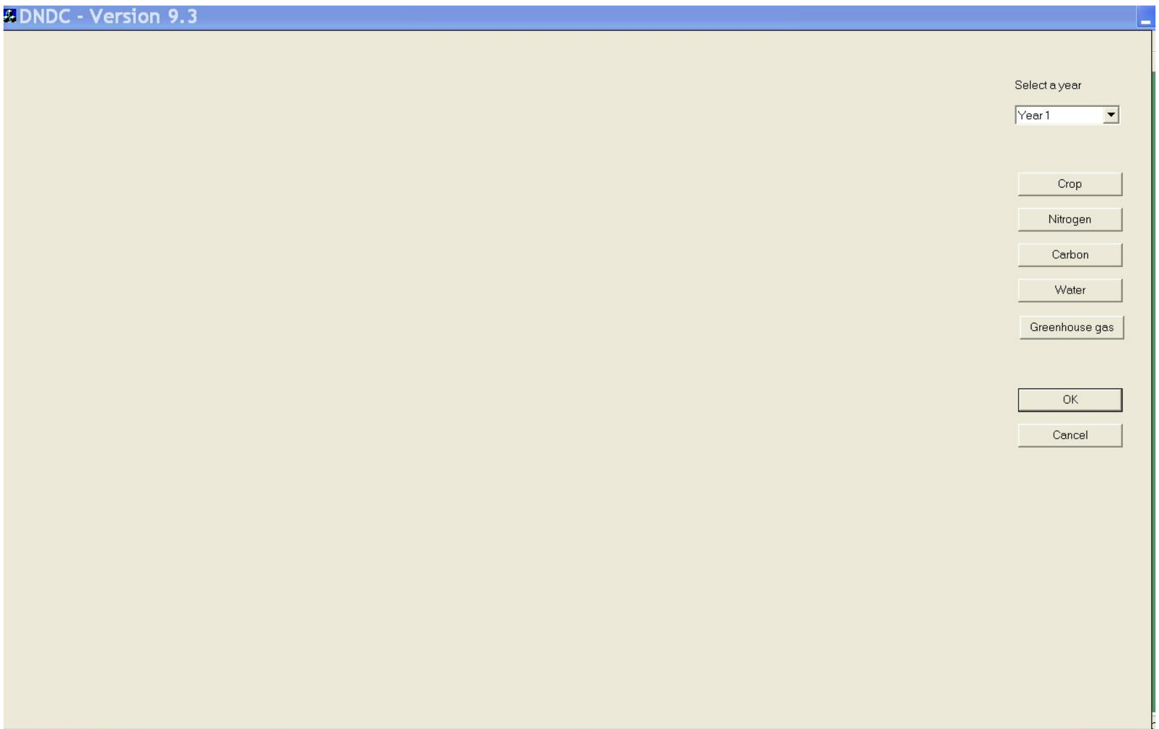


Figure 18. Main menu for quick view of modeled results

On this menu, Clicking button "Crop" will draw a chart of crop production as shown in Figure 19. In this chart, the yellow bars represent the maximum production for grain, leaf + stem, or root; and the green bars for the actual production simulated by DNDC. If the actual production is lower than the maximum values, the stresses of temperature, water and/or N should be identified by comparison between the demand and the uptake bars for temperature, water or N. This quick look would provide you an opportunity to understand why the simulated crop yield met or didn't meet the maximum yield. If the modeled productions are not in agreement with observations, it means adjustments with the current crop physiological/phenology parameters would be required for your crop.

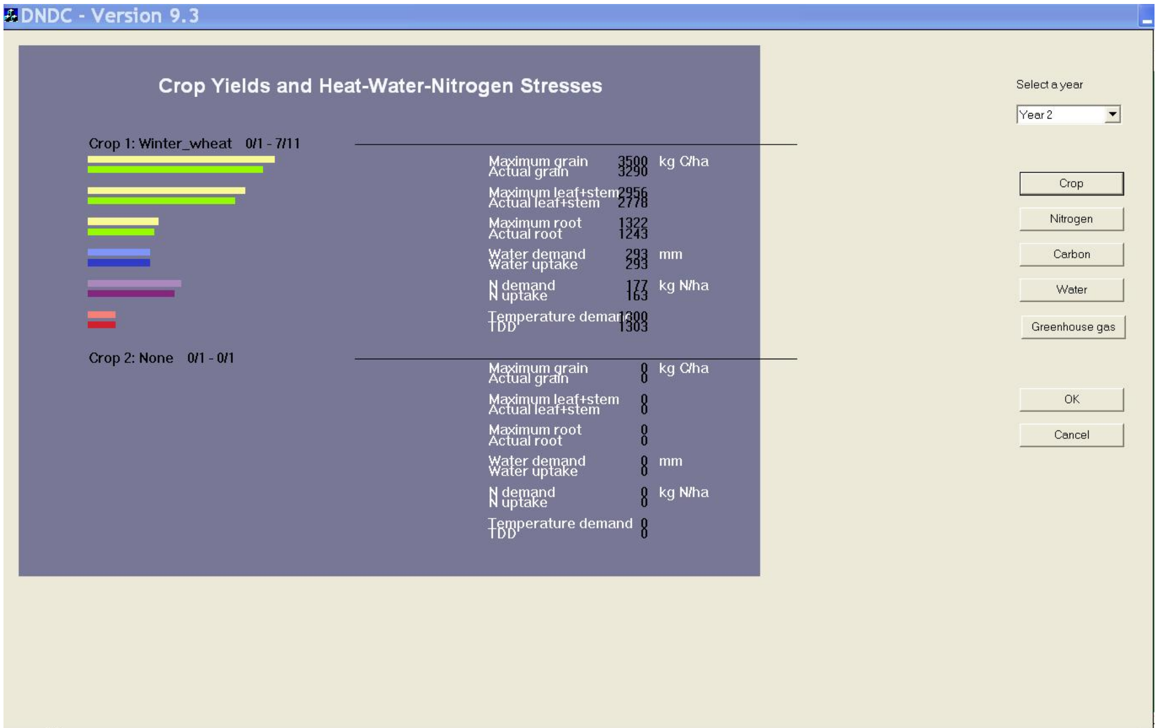


Figure 19. Modeled result 1: Crop biomass production and stresses of temperature, water or nitrogen. (TDD – accumulative thermal degree days of crop growth season)

Clicking button “Nitrogen” will draw a chart of annual N budget for the plant-soil system as shown in Figure 20. The N gained by the system includes the input fluxes from manure amendment, crop residue (stub and roots) and weeds incorporation, atmospheric deposition, synthetic fertilizer application, and biotic N fixation. The N lost from the system includes the output fluxes due to leaching, runoff, crop uptake, weeds uptake, ammonia volatilization, and emissions of nitrous oxide, nitrite oxide and dinitrogen.

Clicking button “Carbon” will draw a chart of annual C budget for the plant-soil system as shown in Figure 21. The C gained by the system includes the input fluxes from manure amendment, crop residue (stub and roots) and weeds incorporation. The C lost from the system includes the output fluxes due to soil heterotrophic respiration, DOC leaching, and methane emission.

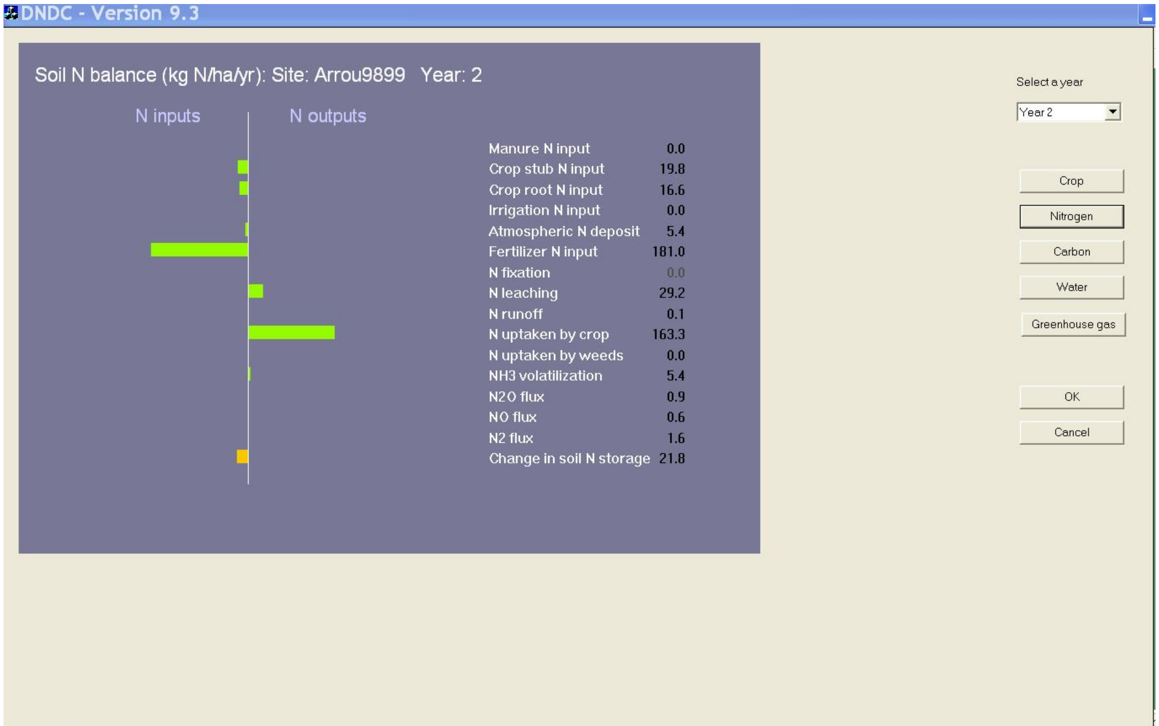


Figure 20. Modeled result 2: Soil N budget.

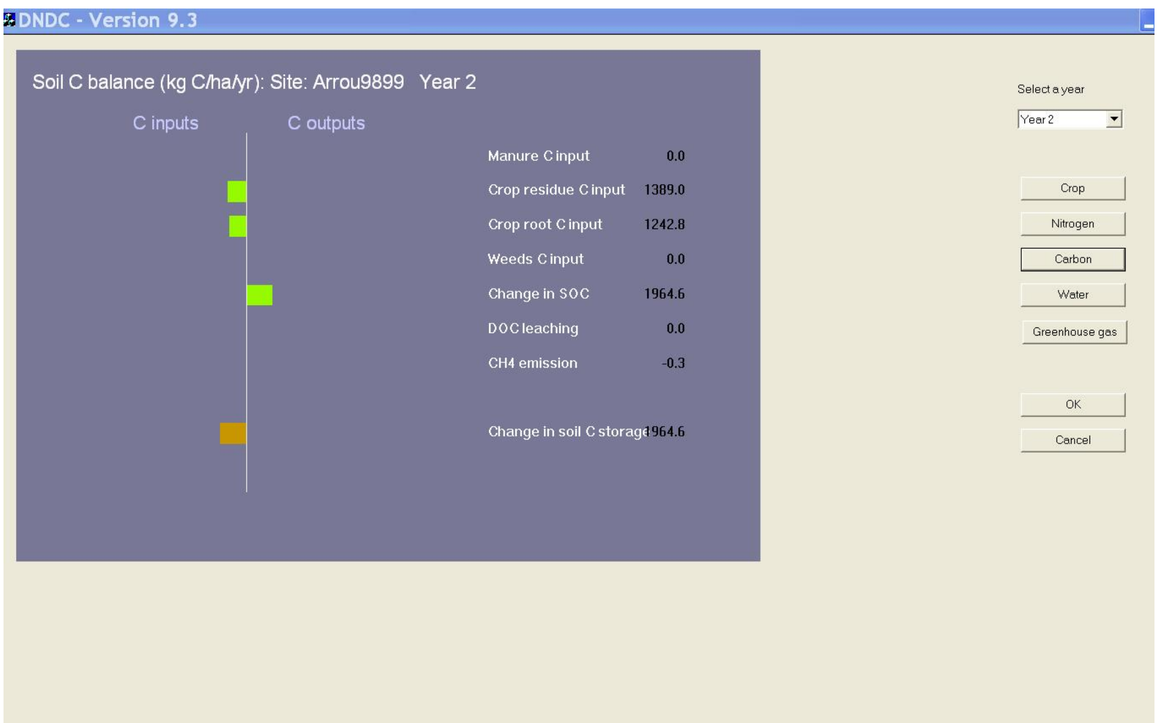


Figure 21. Modeled result 3: Soil C budget.

Clicking button “Water” will draw a chart of annual water budget for the plant-soil system as shown in Figure 22. The water received by the system includes the input fluxes from precipitation, irrigation and groundwater supply. The water lost from the system includes the output fluxes due to transpiration, soil evaporation, surface water evaporation (for flooded soil), leaching and runoff.

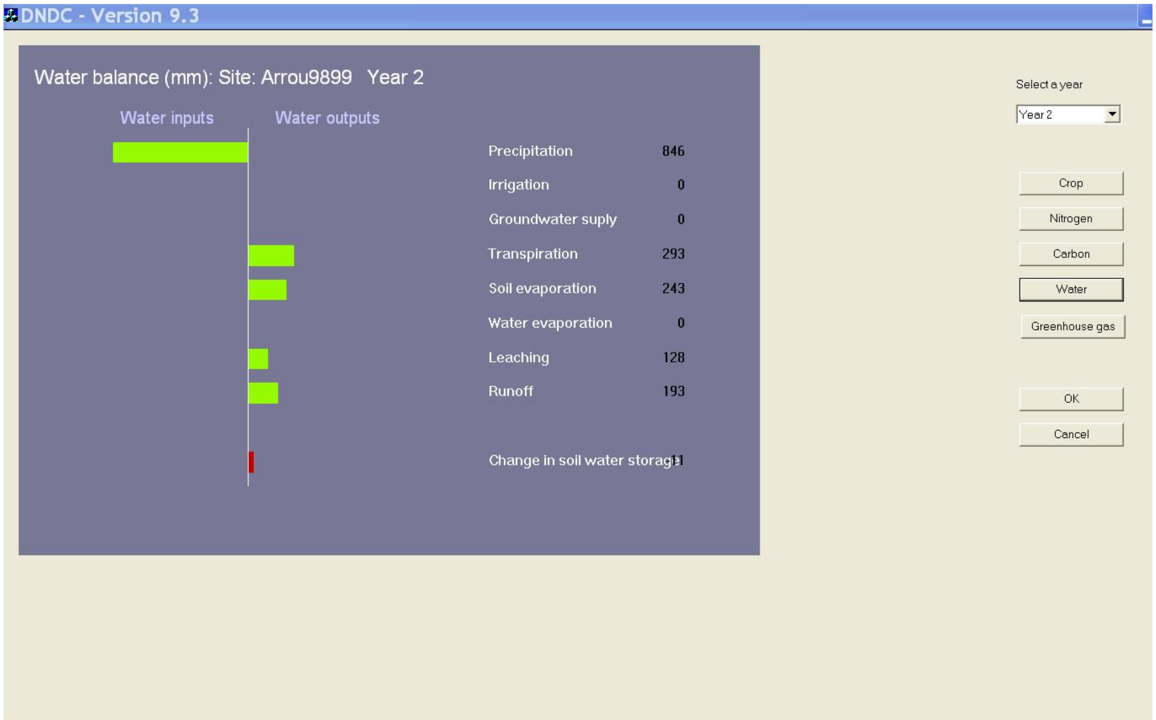


Figure 22. Modeled result 4: Water budget

Clicking button “Greenhouse gas” will demonstrate the modeled annual emissions of the three greenhouse gases, carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O) (Figure 23). The fluxes are also converted into 100-year Global Warming Potentials (GWPs) based on the warming forces of the gases, which is expressed as CO2-equevalent/ha/yr. The annual contribution of the modeled agroecosystem to global warming is the net GWP of the three gases emitted from the system.

The quick view function provides basic results from simulation to the users to let them learn the general dynamics of C, N and water in the modeled system without processing the detailed datasets resulted from the simulation. That could be a time-saver, especially during the model test stages.

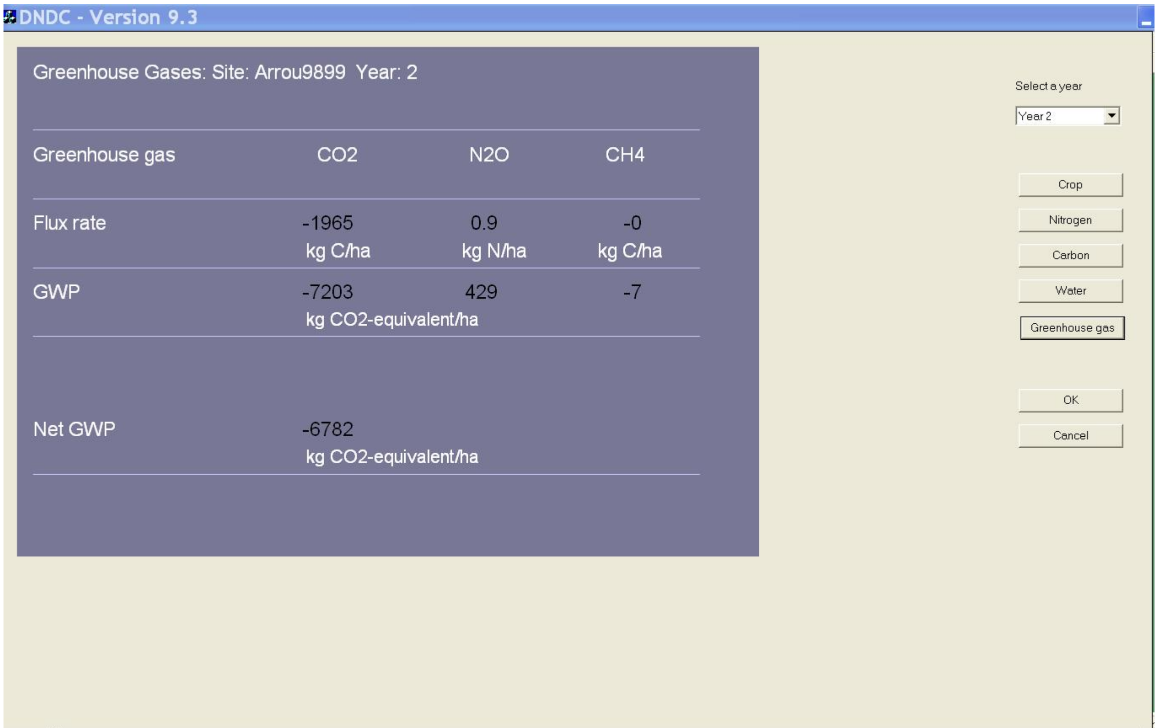


Figure 23. Modeled result 5: Net greenhouse gas emission

1.5. Batch run

Since the input files required by DNDC are in a plain text format, they can be created with a variety of word processors or programming software. The users can make a series of input files, and run them in batch. This could be an efficient approach for sensitivity test or uncertainty analysis, which requires repeated simulations with only a single or a few parameters varied. DNDC provides an interface to allow the users to use their batch files. When all the input files have been prepared, the user can make a file to indicate the total number of files and the path\name of each file as shown below:

```
5
C:\Database\Scenario_1.dnd
C:\Database\Scenario_2.dnd
C:\Database\Scenario_3.dnd
C:\Database\Scenario_4.dnd
C:\Database\Scenario_5.dnd
```

Total number of input files

Paths and names of input files

Clicking "Tools" and then "Run batch" on the main menu of DNDC, a dialog box will appear to allow you to select the file containing the names of the input files (Figure 24). After the selection, click OK to start the simulations.

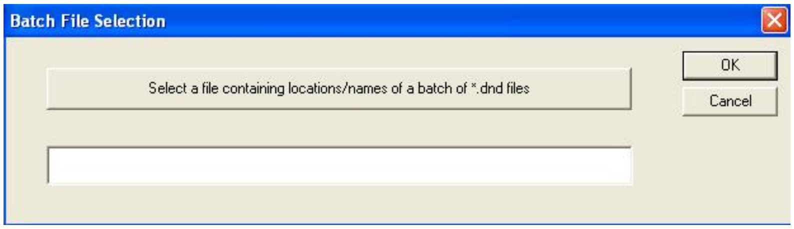


Figure 24. The dialog box allows user to select a file containing the paths and names of a batch of input files prepared in advance.

2. Regional Mode

For regional simulations, DNDC receives all of the input information from a database containing all the required input data for the simulated domain. To prepare the database, the user need to first divide the target region into polygons or grid cells, for each of which the climate and soil conditions are regarded uniform. The resolution of the polygon or grid system depends on the resolution of the coarsest data among the acquired input datasets.

A database supporting DNDC regional simulation consists of ten Geographic Information System (GIS) files plus a climate library. The GIS files contain information of the location, climate file ID, soil properties, cropping systems and their areas, and farming management practices for each polygon or grid cell. The climate library holds all the daily weather data for each polygon or grid cell. The DNDC package you received includes an example database for an illusive region named “Shangrila”. The database is located under directory “\DNDC\Database”. In the Shangrila database, there are two folders entitled “GIS” and “Lib_clim” holding the GIS files and the weather data library, respectively. (Figure 25).

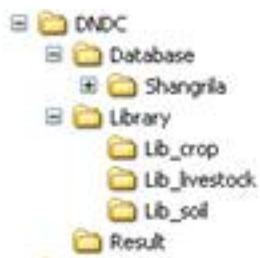


Figure 25. Structure of directories containing input information for regional simulations.

DNDC conducts regional simulations by running for each cropping system in each grid unit across the entire target domain. During the regional simulation, DNDC reads all the input data from the ten preset GIS files for each grid cell, and then reorganizes the information into the DNDC-required internal files to drive the simulation for the cell.

2.1. GIS Files

These are ten files stored under directory “\DNDC\Database\Shangrila\GIS\. The file names and contents are shown as follows:

File 1: **Shangrilar_ClimateSoil.txt** contains name, ID, atmospheric N deposition and soil properties for each grid cell:

General information of grid cells: location, climate station ID, and soil properies

20	Country	Country-name	Lon	Lat	Climate-file	N-dep	SOCmax	SOCmin	Claymax	Claymin	pHmax
	pHmin	Densmax	Densmin	Slope	SalinityIndex	Snow	Column	Row	Region		
20	Country	Country-name	Lon	Lat	Climate-file	N-dep	SOCmax	SOCmin	Claymax	Claymin	pHmax
	pHmin	Densmax	Densmin	Slope	SalinityIndex	Snow	Column	Row	Region		
230101	101	Shangrila	102.589	25.001	56763	0.84	0.014	0.007	0.6	0.5	6
	5	1.32	1.15	0	0	0	0	0	0		
230102	101	Shangrila	102.589	25.001	56763	0.84	0.014	0.01	0.05	0.01	7
	6	1.32	1.15	0	0	0	0	0	0		
230103	101	Shangrila	102.818	24.834	56763	0.85	0.014	0.007	0.6	0.5	6
	5	1.32	1.15	0	0	0	0	0	0		
230104	101	Shangrila	102.67	24.616	56763	0.85	0.014	0.007	0.6	0.5	6

	5	1.32	1.15	0	0	0	0	0	0		
230105	101	Shangrila	102.394	24.9	56763	0.85	0.01	0.007	0.6	0.5	6
	5	1.32	1.19	0	0	0	0	0	0		
230106	101	Shangrila	102.569	25.324	56763	0.84	0.01	0.007	0.6	0.45	6
	5	1.32	1.19	0	0	0	0	0	0		
230107	101	Shangrila	103.168	24.98	56763	0.96	0.014	0.007	0.6	0.5	6
	5	1.32	1.15	0	0	0	0	0	0		
230108	101	Shangrila	103.432	24.77	56763	0.96	0.01	0.007	0.6	0.5	6
	5	1.32	1.19	0	0	0	0	0	0		
230109	101	Shangrila	103.02	25.301	56763	1.01	0.014	0.007	0.6	0.5	6
	5	1.32	1.15	0	0	0	0	0	0		
230110	101	Shangrila	102.661	25.843	56763	0.84	0.014	0.005	0.6	0.2	7.5
	5	1.49	1.15	0	0	0	0	0	0		
230201	101	Shangrila	103.024	26.164	56684	1.08	0.014	0.005	0.6	0.35	7.5
	5	1.49	1.15	0	0	0	0	0	0		
230301	101	Shangrila	103.675	27.406	56586	1.24	0.01	0.005	0.5	0.35	7
	5	1.49	1.19	0	0	0	0	0	0		
230302	101	Shangrila	103.437	27.176	56586	1.24	0.01	0.005	0.5	0.35	7
	5	1.49	1.19	0	0	0	0	0	0		
230303	101	Shangrila	103.164	26.89	56684	1.08	0.034	0.005	0.5	0.35	7
	5	1.49	1.15	0	0	0	0	0	0		
230304	101	Shangrila	104.246	28.088	56485	1.58	0.014	0.01	0.05	0.01	7
	6	1.49	1.15	0	0	0	0	0	0		
230305	101	Shangrila	103.927	27.906	56586	1.24	0.014	0.005	0.5	0.35	7
	4	1.49	1.15	0	0	0	0	0	0		
230306	101	Shangrila	103.634	27.854	56485	1.24	0.034	0.005	0.5	0.1	7
	4	1.49	1.15	0	0	0	0	0	0		
230307	101	Shangrila	103.956	28.534	56485	1.33	0.014	0.005	0.45	0.1	5
	4	1.49	1.15	0	0	0	0	0	0		
230308	101	Shangrila	104.735	27.585	56586	1.47	0.014	0.007	0.45	0.2	5
	4	1.32	1.15	0	0	0	0	0	0		
230309	101	Shangrila	104.178	27.566	56586	1.47	0.014	0.007	0.6	0.5	6
	5	1.32	1.15	0	0	0	0	0	0		
230310	101	Shangrila	105.036	27.878	57608	1.44	0.014	0.007	0.45	0.35	5
	4	1.32	1.15	0	0	0	0	0	0		

20 – The number of listed items in the data shhet;
Country – Country ID;
Country-name – Country name;
lon – longitude;
lat – Latitude;
Climate-file – Climate file ID;
N_dep – N concentration in precipitation (ppm);
SOCmax – Maximum SOC content (kg C/kg);
SOCmin – Minimum SOC content (kg C/kg);
CLAYmax – Maximum soil clay fraction;
CLAYmin – Minimum soil clay fraction;
PHmax – Maximum soil pH;
PHmin – Minimum soil pH;
DENSmax – Maximum soil bulk density (g/cm^3);
DENSmin – Minimum soil bulk density (g/cm^3);
Slope – soil surface slope (0-90);
SalinityIndex – Soil salinity index (0-100);
Snow – Initial snow pack (mm);
Column – Column number in global map;
Row – Row number in global map;
Region – Region ID.

The last 6 items are effective only for the global database. For general, regional simulations, the values of the items can set set as 0.

File 2: **Shangrilar_CropArea.txt** contains acreage (ha) of cropping systems for each grid cell:

Crop acreage (ha)

9	Fallow	Corn	W_Wheat	Soybean	Rice	cor/wwt	rap/wwt	ric/wwt	ve/ve/ve
9	0	1	2	3	20	1_2	25_2	20_2	16_16_16
230101	0	1382	0	0	0	2115	367	0	0
230102	0	447	0	53	0	1825	42	0	0
230103	1593	0	0	115	0	593	31	0	2482
230104	0	0	0	0	0	2121	746	1882	0
230105	0	0	0	0	0	1984	909	0	427
230106	0	0	0	0	0	2564	68	0	0
230107	0	0	769	0	0	6301	342	0	0
230108	0	0	0	0	0	4294	524	0	1245
230109	0	0	0	0	0	4912	183	0	0
230110	0	0	0	0	0	7415	181	0	0
230201	0	1382	0	0	0	2115	367	0	0
230301	2180	13477	2834	504	716	0	0	0	0
230302	1798	10045	3770	908	0	0	0	0	0
230303	3550	13600	3901	693	0	0	0	0	0
230304	0	8034	0	0	0	1331	1999	0	0
230305	0	3891	0	0	0	3557	138	0	0
230306	0	1510	0	0	0	4158	798	0	0
230307	0	4076	644	660	0	2964	964	0	0
230308	0	5020	0	0	0	23323	1852	0	0
230309	0	16872	1040	731	0	5320	105	0	0
230310	0	328	0	0	0	7595	2602	0	0

9 (first row) – The number of simulated cropping systems (e.g., W_wheat – winter wheat; cor/wwt – corn-winter wheat rotation; rap/wwt – rapeseeds-winter wheat rotation; ric/wwt – rice-winter wheat rotation; cor/wwt – corn-winter wheat rotation; ve/ve/ve – vegetable-vegetable-vegetable rotation.
9 (second row) – Cropping system IDs.

File 3: **Shangrilar_CropParameters.txt** contains three major crop parameters (i.e., maximum yield (kg C/ha)_accumulative temperature (ºC)_water requirement (kg water/kg dry matter) for each crop in each grid cell:

Crop parameters: "/MaxGrainYieldC_TDD_WaterDemand"

7	Fallow	Corn	W_Wheat	Soybean	Rice	Rapeseeds	Vegetable
7	0	1	2	3	20	25	16
230101	0	/4900_3000_110	/3600_2500_200	/1035_2500_350	/3303_3000_508	/1200_3200_180	/950_1200_450
230102	0	/4900_3000_110	/3600_2500_200	/1035_2500_350	/3303_3000_508	/1200_3200_180	/950_1200_450
230103	0	/4900_3000_110	/3600_2500_200	/1035_2500_350	/3303_3000_508	/1200_3200_180	/950_1200_450
230104	0	/4900_3000_110	/3600_2500_200	/1035_2500_350	/3303_3000_508	/1200_3200_180	/950_1200_450
230105	0	/4900_3000_110	/3600_2500_200	/1035_2500_350	/3303_3000_508	/1200_3200_180	/950_1200_450
230106	0	/4900_3000_110	/3600_2500_200	/1035_2500_350	/3303_3000_508	/1200_3200_180	/950_1200_450
230107	0	/4900_3000_110	/3600_2500_200	/1035_2500_350	/3303_3000_508	/1200_3200_180	/950_1200_450
230108	0	/4900_3000_110	/3600_2500_200	/1035_2500_350	/3303_3000_508	/1200_3200_180	/950_1200_450
230109	0	/4900_3000_110	/3600_2500_200	/1035_2500_350	/3303_3000_508	/1200_3200_180	/950_1200_450
230110	0	/4900_3000_110	/3600_2500_200	/1035_2500_350	/3303_3000_508	/1200_3200_180	/950_1200_450
230201	0	/4900_3000_110	/3600_2500_200	/1035_2500_350	/3303_3000_508	/1200_3200_180	/950_1200_450
230301	0	/4900_3000_110	/3600_2500_200	/1035_2500_350	/3303_3000_508	/1200_3200_180	/950_1200_450
230302	0	/4900_3000_110	/3600_2500_200	/1035_2500_350	/3303_3000_508	/1200_3200_180	/950_1200_450
230303	0	/4900_3000_110	/3600_2500_200	/1035_2500_350	/3303_3000_508	/1200_3200_180	/950_1200_450
230304	0	/4900_3000_110	/3600_2500_200	/1035_2500_350	/3303_3000_508	/1200_3200_180	/950_1200_450
230305	0	/4900_3000_110	/3600_2500_200	/1035_2500_350	/3303_3000_508	/1200_3200_180	/950_1200_450
230306	0	/4900_3000_110	/3600_2500_200	/1035_2500_350	/3303_3000_508	/1200_3200_180	/950_1200_450
230307	0	/4900_3000_110	/3600_2500_200	/1035_2500_350	/3303_3000_508	/1200_3200_180	/950_1200_450
230308	0	/4900_3000_110	/3600_2500_200	/1035_2500_350	/3303_3000_508	/1200_3200_180	/950_1200_450
230309	0	/4900_3000_110	/3600_2500_200	/1035_2500_350	/3303_3000_508	/1200_3200_180	/950_1200_450
230310	0	/4900_3000_110	/3600_2500_200	/1035_2500_350	/3303_3000_508	/1200_3200_180	/950_1200_450

7 (first row) – The number of simulated crops.
7 (second row) – Crop IDs.

File 4: **Shangrilar_Fertilization.txt** contains fertilizer application rate (kg N/ha) for each crop in each grid cell:

Fertilizer application rate: kgN/ha

7	Fallow	Corn	W_Wheat	Soybean	Rice	Rapeseeds	Vegetable
7	0	1	2	3	20	25	16
230101	0	105	130	30	150	150	250
230102	0	105	130	30	150	150	250
230103	0	105	130	30	150	150	250
230104	0	105	130	30	150	150	250
230105	0	105	130	30	150	150	250
230106	0	105	130	30	150	150	250
230107	0	105	130	30	150	150	250
230108	0	105	130	30	150	150	250
230109	0	105	130	30	150	150	250
230110	0	105	130	30	150	150	250
230201	0	105	130	30	150	150	250
230301	0	105	130	30	150	150	250
230302	0	105	130	30	150	150	250
230303	0	105	130	30	150	150	250
230304	0	105	130	30	150	150	250
230305	0	105	130	30	150	150	250
230306	0	105	130	30	150	150	250
230307	0	105	130	30	150	150	250
230308	0	105	130	30	150	150	250
230309	0	105	130	30	150	150	250
230310	0	105	130	30	150	150	250

7 (first row) – The number of simulated crops.
7 (second row) – Crop IDs.

File 5: **Shangrilar_Flooding.txt** contains start date, end date and flooding method of each flooding event for each wetland crop in each grid cell:

Wetland crop flooding: "/StartDate_EndDatae_Method" (Methods: 1 continuous flooding, 2 midseason dranaige, 3. marginal flooding)

9	Fallow	Corn	W_Wheat	Soybean	Rice	cor/wwt	rap/wwt	ric/wwt	ve/ve/ve
9	0	1	2	3	20	1_2	25_2	20_2	16_16_16
230101	0	0	0	0	/120_278_2	0	0	/150_270_3	0
230102	0	0	0	0	/120_278_1	0	0	/151_264_3	0
230103	0	0	0	0	/120_278_2	0	0	/151_264_3	0
230104	0	0	0	0	/120_278_1	0	0	/151_264_3	0
230105	0	0	0	0	/120_278_1	0	0	/150_270_2	0
230106	0	0	0	0	/120_278_1	0	0	/150_270_2	0
230107	0	0	0	0	/120_278_1	0	0	/150_270_2	0
230108	0	0	0	0	/120_278_1	0	0	/150_270_2	0
230109	0	0	0	0	/122_270_3	0	0	/150_270_2	0
230110	0	0	0	0	/122_270_3	0	0	/150_270_2	0
230201	0	0	0	0	/122_270_3	0	0	/150_270_2	0
230301	0	0	0	0	/122_270_3	0	0	/150_270_2	0
230302	0	0	0	0	/122_270_3	0	0	/150_270_2	0
230303	0	0	0	0	/122_270_3	0	0	/150_270_2	0
230304	0	0	0	0	/122_270_3	0	0	/150_270_2	0
230305	0	0	0	0	/122_270_3	0	0	/150_270_1	0
230306	0	0	0	0	/120_278_2	0	0	/150_270_1	0
230307	0	0	0	0	/120_278_2	0	0	/150_270_1	0
230308	0	0	0	0	/120_278_2	0	0	/150_270_1	0
230309	0	0	0	0	/120_278_2	0	0	/150_270_1	0
230310	0	0	0	0	/120_278_2	0	0	/150_270_1	0

9 (first row) – The number of simulated cropping systems (e.g., W_wheat – winter wheat; cor/wwt – corn-winter wheat rotation; rap/wwt – rapeseeds-winter wheat rotation; ric/wwt – rice-winter wheat rotation; cor/wwt – corn-winter wheat rotation; ve/ve/ve – vegetable-vegetable-vegetable rotation.
9 (second row) – Cropping system IDs.

File 6: **Shangrilar_Irrigation.txt** contains irrigated percent for each upland crop in each grid cell:

Irrigation: irrigated percent of irrigated area only for upland crops

7	Fallow	Corn	W_Wheat	Soybean	Rice	Rapeseeds	Vegetable
7	0	1	2	3	20	25	16
230101	0	0	50	0	0	45	90
230102	0	0	30	0	0	90	90
230103	0	0	95	0	0	21	90
230104	0	0	100	0	0	87	90
230105	0	0	20	0	0	0	90
230106	0	0	25	0	0	0	90
230107	0	0	0	0	0	0	90
230108	0	0	0	0	0	0	90
230109	0	0	0	0	0	0	90
230110	0	0	33	0	0	45	90
230201	0	0	45	0	0	34	90
230301	0	0	43	0	0	35	90
230302	0	0	42	0	0	78	90
230303	0	0	67	0	0	34	90
230304	0	0	70	0	0	12	90
230305	0	0	22	0	0	13	90
230306	0	0	10	0	0	9	90
230307	0	0	5	0	0	10	90
230308	0	0	0	0	0	45	90
230309	0	0	12	0	0	36	90
230310	0	0	29	0	0	67	90

7 (first row) – The number of simulated crops.
7 (second row) – Crop IDs.

File 7: **Shangrilar_ManureAmendment.txt** contains manure application rate (kg N/ha) for each crop in each grid cell:

Manure amendment rate: kg N/ha

9	Fallow	Corn	W_Wheat	Soybean	Rice	cor/wwt	rap/wwt	ric/wwt	ve/ve/ve
9	0	1	2	3	20	1_2	25_2	20_2	16_16_16
230101	0	30	30	4	0	60	21	30	75
230102	0	30	30	4	0	60	34	30	75
230103	0	30	30	4	0	60	30	30	75
230104	0	30	30	4	0	60	7	30	75
230105	0	30	30	4	0	60	8	0	75
230106	0	45	30	4	0	60	30	0	75
230107	0	45	30	4	0	60	30	0	75
230108	0	45	30	4	0	60	30	0	75
230109	0	45	30	0	0	60	45	0	44
230110	0	45	30	0	0	60	30	0	44
230201	0	45	30	0	0	60	30	0	44
230301	0	45	30	0	0	60	30	5	44
230302	0	45	30	0	0	60	0	5	30
230303	0	30	30	8	0	60	0	5	30
230304	0	30	22	8	0	60	0	5	30
230305	0	30	22	8	0	60	3	5	30
230306	0	30	22	8	0	60	3	5	30
230307	0	30	22	8	0	60	2	5	30
230308	0	30	22	8	0	60	1	5	30
230309	0	30	22	8	0	60	1	5	30
230310	0	30	22	8	0	60	1	30	30

File 8: **Shangrilar_PlantingHarvestDates.txt** contains planting and harvest dates for each crop in each grid cell:

Planting and harvest dates: /PalntingDate_HarvestDate

9	Fallow	Corn	W_Wheat	Soybean	Rice	cor/wwt	rap/wwt	ric/wwt	ve/ve/ve	
9	0	1	2	3	20	1_2	25_2	20_2	16_16_16	
230101	0	/121_288	/300_200	/121_288	/121_288	/151_280/300_145		/151_280/300_145		/151_280/300_145
	/5_125/127_235/237_359									
230102	0	/121_288	/300_200	/121_288	/121_288	/151_280/300_145		/151_280/300_145		/151_280/300_145
	/5_125/127_235/237_359									
230103	0	/121_288	/300_200	/121_288	/121_288	/151_280/300_145		/151_280/300_145		/151_280/300_145
	/5_125/127_235/237_359									
230104	0	/121_288	/300_200	/121_288	/121_288	/151_280/300_145		/151_280/300_145		/151_280/300_145
	/5_125/127_235/237_359									
230105	0	/121_288	/300_200	/121_288	/121_288	/151_280/300_145		/151_280/300_145		/151_280/300_145
	/5_125/127_235/237_359									
230106	0	/121_288	/300_200	/121_288	/121_288	/151_280/300_145		/151_280/300_145		/151_280/300_145
	/5_125/127_235/237_359									
230107	0	/121_288	/300_200	/121_288	/121_288	/151_280/300_145		/151_280/300_145		/151_280/300_145
	/5_125/127_235/237_359									
230108	0	/121_288	/300_200	/121_288	/121_288	/151_280/300_145		/151_280/300_145		/151_280/300_145
	/5_125/127_235/237_359									
230109	0	/121_288	/300_200	/121_288	/121_288	/151_280/300_145		/151_280/300_145		/151_280/300_145
	/5_125/127_235/237_359									
230110	0	/121_288	/300_200	/121_288	/121_288	/151_280/300_145		/151_280/300_145		/151_280/300_145

									/5_125/127_235/237_359
230201	0	/121_288	/300_200	/121_288	/121_288	/151_280/300_145	/151_280/300_145	/151_280/300_145	/5_125/127_235/237_359
230301	0	/121_288	/300_200	/121_288	/121_288	/151_280/300_145	/151_280/300_145	/151_280/300_145	/5_125/127_235/237_359
230302	0	/121_288	/300_200	/121_288	/121_288	/151_280/300_145	/151_280/300_145	/151_280/300_145	/5_125/127_235/237_359
230303	0	/121_288	/300_200	/121_288	/121_288	/151_280/300_145	/151_280/300_145	/151_280/300_145	/5_125/127_235/237_359
230304	0	/121_288	/300_200	/121_288	/121_288	/151_280/300_145	/151_280/300_145	/151_280/300_145	/5_125/127_235/237_359
230305	0	/121_288	/300_200	/121_288	/121_288	/151_280/300_145	/151_280/300_145	/151_280/300_145	/5_125/127_235/237_359
230306	0	/121_288	/300_200	/121_288	/121_288	/151_280/300_145	/151_280/300_145	/151_280/300_145	/5_125/127_235/237_359
230307	0	/121_288	/300_200	/121_288	/121_288	/151_280/300_145	/151_280/300_145	/151_280/300_145	/5_125/127_235/237_359
230308	0	/121_288	/300_200	/121_288	/121_288	/151_280/300_145	/151_280/300_145	/151_280/300_145	/5_125/127_235/237_359
230309	0	/121_288	/300_200	/121_288	/121_288	/151_280/300_145	/151_280/300_145	/151_280/300_145	/5_125/127_235/237_359
230310	0	/121_288	/300_200	/121_288	/121_288	/151_280/300_145	/151_280/300_145	/151_280/300_145	/5_125/127_235/237_359

9 (first row) – The number of simulated cropping systems (e.g., W_wheat – winter wheat; cor/wwt – corn-winter wheat rotation; rap/wwt – rapeseeds-winter wheat rotation; ric/wwt – rice-winter wheat rotation; cor/wwt – corn-winter wheat rotation; ve/ve/ve – vegetable-vegetable-vegetable rotation.
9 (second row) – Cropping system IDs.

File 9: **Shangrilar_ResidueManagement.txt** contains incorporated percent of above-ground crop residue for each crop in each grid cell:

Fraction of above-ground crop residue incorporated:"/fraction of above-ground residue"

9	Fallow	Corn	W_Wheat	Soybean	Rice	cor/wwt	rap/wwt	ric/wwt	ve/ve/ve
9	0	1	2	3	20	1_2	25_2	20_2	16_16_16
230101	0	/0.2	/0.5	0	/1.0	0	/0/0	/1.0/0.2	/0/0/0
230102	0	/0.2	/0.5	0	/1.0	0	/0/0	/1.0/0.2	/0/0/0
230103	0	/0.2	/0.5	0	/1.0	0	/0/0	/1.0/0.2	/0/0/0
230104	0	/0.2	/0.5	0	/1.0	0	/0/0	/1.0/0.2	/0/0/0
230105	0	/0.2	/0.5	0	/1.0	0	/0/0	/1.0/0.2	/0/0/0
230106	0	/0.2	/0.5	0	/1.0	0	/0/0	/1.0/0.2	/0/0/0
230107	0	/0.2	/0.5	0	/1.0	0	/0/0	/1.0/0.2	/0/0/0
230108	0	/0.2	/0.5	0	/1.0	0	/0/0	/1.0/0.2	/0/0/0
230109	0	/0.2	/0.5	0	/1.0	0	/0/0	/1.0/0.2	/0/0/0
230110	0	/0.2	/0.5	0	/1.0	0	/0/0	/1.0/0.2	/0/0/0
230201	0	/0.2	/0.5	0	/1.0	0	/0/0	/1.0/0.2	/0/0/0
230301	0	/0.2	/0.5	0	/1.0	0	/0/0	/1.0/0.2	/0/0/0
230302	0	/0.2	/0.5	0	/1.0	0	/0/0	/1.0/0.2	/0/0/0
230303	0	/0.2	/0.5	0	/1.0	0	/0/0	/1.0/0.2	/0/0/0
230304	0	/0.2	/0.5	0	/1.0	0	/0/0	/1.0/0.2	/0/0/0
230305	0	/0.2	/0.5	0	/1.0	0	/0/0	/1.0/0.2	/0/0/0
230306	0	/0.2	/0.5	0	/1.0	0	/0/0	/1.0/0.2	/0/0/0
230307	0	/0.2	/0.5	0	/1.0	0	/0/0	/1.0/0.2	/0/0/0
230308	0	/0.2	/0.5	0	/1.0	0	/0/0	/1.0/0.2	/0/0/0
230309	0	/0.2	/0.5	0	/1.0	0	/0/0	/1.0/0.2	/0/0/0
230310	0	/0.2	/0.5	0	/1.0	0	/0/0	/1.0/0.2	/0/0/0

9 (first row) – The number of simulated cropping systems (e.g., W_wheat – winter wheat; cor/wwt – corn-winter wheat rotation; rap/wwt – rapeseeds-winter wheat rotation; ric/wwt – rice-winter wheat rotation; cor/wwt – corn-winter wheat rotation; ve/ve/ve – vegetable-vegetable-vegetable rotation.
9 (second row) – Cropping system IDs.

File 10: **Shangrilar_Tillage.txt** contains tilling date and method for each cropping system in each grid cell:

Tillage: "/Date_Method" (Method: 1- Notill, 2 - 5cm, 3 - 10cm, 4 - 20cm, 5 - 30cm)

9	Fallow	Corn	W_Wheat	Soybean	Rice	cor/wwt	rap/wwt	ric/wwt	ve/ve/ve
9	0	1	2	3	20	1_2	25_2	20_2	16_16_16
230101	0	/121_4/320_3	/121_3	/121_4/320_3	/121_4/320_3	/150_3/300_2	/150_3/300_2	/150_3/300_2	/5_2/127_1/237_1
230102	0	/121_4/320_3	/121_3	/121_4/320_3	/121_4/320_3	/150_3/300_2	/150_3/300_2	/150_3/300_2	/5_2/127_1/237_1
230103	0	/121_4/320_3	/121_3	/121_4/320_3	/121_4/320_3	/150_3/300_2	/150_3/300_2	/150_3/300_2	/5_2/127_1/237_1
230104	0	/121_4/320_3	/121_3	/121_4/320_3	/121_4/320_3	/150_3/300_2	/150_3/300_2	/150_3/300_2	/5_2/127_1/237_1
230105	0	/121_4/320_3	/121_3	/121_4/320_3	/121_4/320_3	/150_3/300_2	/150_3/300_2	/150_3/300_2	/5_2/127_1/237_1
230106	0	/121_4/320_3	/121_3	/121_4/320_3	/121_4/320_3	/150_3/300_2	/150_3/300_2	/150_3/300_2	/5_2/127_1/237_1
230107	0	/121_4/320_3	/121_3	/121_4/320_3	/121_4/320_3	/150_3/300_2	/150_3/300_2	/150_3/300_2	/5_2/127_1/237_1
230108	0	/121_4/320_3	/121_3	/121_4/320_3	/121_4/320_3	/150_3/300_2	/150_3/300_2	/150_3/300_2	/5_2/127_1/237_1

230109	0	/121_4/320_3	/121_3	/121_4/320_3	/121_4/320_3	/150_3/300_2	/150_3/300_2	/150_3/300_2	/5_2/127_1/237_1
230110	0	/121_4/320_3	/121_3	/121_4/320_3	/121_4/320_3	/150_3/300_2	/150_3/300_2	/150_3/300_2	/5_2/127_1/237_1
230201	0	/121_4/320_3	/121_3	/121_4/320_3	/121_4/320_3	/150_3/300_2	/150_3/300_2	/150_3/300_2	/5_2/127_1/237_1
230301	0	/121_4/320_3	/121_3	/121_4/320_3	/121_4/320_3	/150_3/300_2	/150_3/300_2	/150_3/300_2	/5_2/127_1/237_1
230302	0	/121_4/320_3	/121_3	/121_4/320_3	/121_4/320_3	/150_3/300_2	/150_3/300_2	/150_3/300_2	/5_2/127_1/237_1
230303	0	/121_4/320_3	/121_3	/121_4/320_3	/121_4/320_3	/150_3/300_2	/150_3/300_2	/150_3/300_2	/5_2/127_1/237_1
230304	0	/121_4/320_3	/121_3	/121_4/320_3	/121_4/320_3	/150_3/300_2	/150_3/300_2	/150_3/300_2	/5_2/127_1/237_1
230305	0	/121_4/320_3	/121_3	/121_4/320_3	/121_4/320_3	/150_3/300_2	/150_3/300_2	/150_3/300_2	/5_2/127_1/237_1
230306	0	/121_4/320_3	/121_3	/121_4/320_3	/121_4/320_3	/150_3/300_2	/150_3/300_2	/150_3/300_2	/5_2/127_1/237_1
230307	0	/121_4/320_3	/121_3	/121_4/320_3	/121_4/320_3	/150_3/300_2	/150_3/300_2	/150_3/300_2	/5_2/127_1/237_1
230308	0	/121_4/320_3	/121_3	/121_4/320_3	/121_4/320_3	/150_3/300_2	/150_3/300_2	/150_3/300_2	/5_2/127_1/237_1
230309	0	/121_4/320_3	/121_3	/121_4/320_3	/121_4/320_3	/150_3/300_2	/150_3/300_2	/150_3/300_2	/5_2/127_1/237_1
230310	0	/121_4/320_3	/121_3	/121_4/320_3	/121_4/320_3	/150_3/300_2	/150_3/300_2	/150_3/300_2	/5_2/127_1/237_1

9 (first row) – The number of simulated cropping systems (e.g., W_wheat – winter wheat; cor/wwt – corn-winter wheat rotation; rap/wwt – rapeseeds-winter wheat rotation; ric/wwt – rice-winter wheat rotation; cor/wwt – corn-winter wheat rotation; ve/ve/ve – vegetable-vegetable-vegetable rotation.
9 (second row) – Cropping system IDs.

The format of DNDC-required GIS database provides the users flexibility to define the spatially differentiated and crop-specified cropping management practices to meet the demands of the simulations.

During the regional simulations, the above-listed seven files will be read to provide input data for each cropping system in each grid cell across the entire targeted domain.

2.2. Climate Library Data

Daily meteorological data files are stored at \DNDC\Database\Shangrila\Lib_clim\2000\. Each file is for a single year and a single grid cell or a cluster of cells.

Example file name: 56763

File name

Maximum and minimum air temperature (°C)

Precipitation (cm)

Station_56763

1	14.4	0.5	0
2	13.1	0.7	0
3	12	0.2	0
4	7.8	1.3	0
5	15.1	1.5	0
6	9.7	5.5	0
7	9.5	5	0
8	11.1	4.2	0
9	8	5.4	0
10	8.2	3.7	0
11	7.7	4.9	0
12	7	4.4	0.05
…	…	…	…
…	…	…	…
365	6.4	3.8	0.02

2.3. Common Library Data

There are two folders, Lib_soil and Lib_crop, at \DNDC\Library\, which contain common input data for soils and crops, respectively to support both site and regional simulations.

Lib_soil: Soil hydraulic data for each of 12 soil textures

Example file name: Soil_5 (for loam soil)

```
Loam  texture
0.19   clay_fraction
0.451  porosity
0.042  satu_conductivity
0.49   field_capasity
0.22   wilting_point
```

Clay_fraction – soil clay fraction by weight;
Porosity – soil porosity as a fraction;
Satu_conductivity – soil saturation conductivity in m/hr;
Field_capasity – soil moisture in water filled porosity (WFPS) at the field capacity point;
Wilting_point – soil moisture in water filled porosity (WFPS) at the plant wilting point.

Lib_crop: Default crop physiological and phonological data for each type of crop

Example file name: Crop_1 (for corn)

1	crop_code
CO	crop_name_1
Corn	crop_name_2
11145	total_biomass_C
0.370000	portion_of_grain
0.380000	portion_of_shoot
0.250000	portion_of_root
59.971802	plant_CN
50.000000	grain_CN_ratio
85.000000	root_CN_ratio
60.000000	shoot_CN_ratio
323.000000	water_requirement
5.000000	max_LAI
2.000000	max_height
2550.000000	TDD
1.000000	N_fixation
25.0	Optimum teperature

total_biomass_C – Maximum total crop biomass at maturity (kg C/ha);
portion_of_grain – Grain fraction of total biomass;
portion_of_shoot – Leaves+stems fraction of total biomass;
portion_of_root – Root fraction of total biomass;
plant_CN – C/N ratio for total plant;
grain_CN_ratio – C/N ratio for grain;
root_CN_ratio – C/N ratio for roots;
shoot_CN_ratio – C/N ratio for leaves+stems;
water_requirement – Water demanded for producing a unit plant biomass (kg water for kg dry matter);
max_LAI – Maximum leaf area index;
max_height – Maximum plant hight (m);
TDD – Thermal degree days, i.e., accumulative air temperature from seeding till maturity (°C);
N_fixation – N fixation index (= total plant N / plant N from soil);
Optimum_temperature – Optimum temperature for crop growth (°C);

The crop file can be created or modified with the tool “Crop Creator” available at DNDC’s user’s input interface.

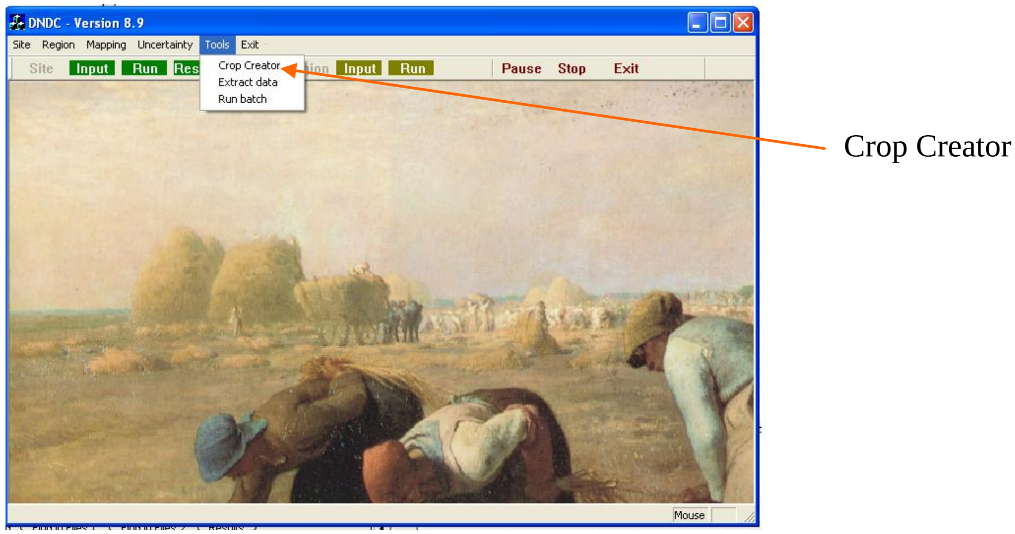


Figure 26. Open "Crop Creator"

By clicking "Crop Creator" in the Tools list, you will open a new page "Crop creator" on which you are able to create a new crop or permanently change the default parameter values stored in the crop library of DNDC for the existing crops (Figure 27).

[***Crop ID***]: Crop sequential number in the crop library of DNDC.
[***Crop name***]: Name of the crop.
[***Maximum grain production, kg dry matter/ha***]: Grain production or yield of the crop under optimum growing conditions.
[***Grain fraction of total biomass***]: Grain fraction (0-1) of total biomass (i.e., grain + leaves + stems + roots) at maturity.
[***Leaf+stem fraction of total biomass***]: Leaves+stems fraction (0-1) of total biomass at maturity.
[***Root fraction of total biomass***]: Root fraction (0-1) of total biomass at maturity.
[***C/N ratio for grain***]: Ratio of C vs. N contents in the crop grain.
[***C/N ratio for leaf+stem***]: Ratio of C vs. N contents in the crop leaves and stems.
[***C/N ratio for root***]: Ratio of C vs. N contents in the crop roots.
[***N fixation index***]: For legume crops, the N fixation index equals ratio of total N content in the plant/the plant N taken from soil.
[***Water requirement***]: Potential water demand of the crop, which is defined as the water required to produce a unit of crop biomass (kg water/kg dry matter of crop).
[***LAI adjustment factor***]: A factor for adjusting default specific leaf weight.
[***Maximum height, m***]: Maximum height of the crop in meter.
[***Accumulative degree days for maturity (TDD), °C***]: The accumulative daily average air temperature (>0°C) from seeding to maturity for the crop.
[***Vascularity, 0-1***]: A fraction number representing the vascularity of wetland plants.
[***This is a perennial plant***]: Checking this box will define the plant as a perennial one.

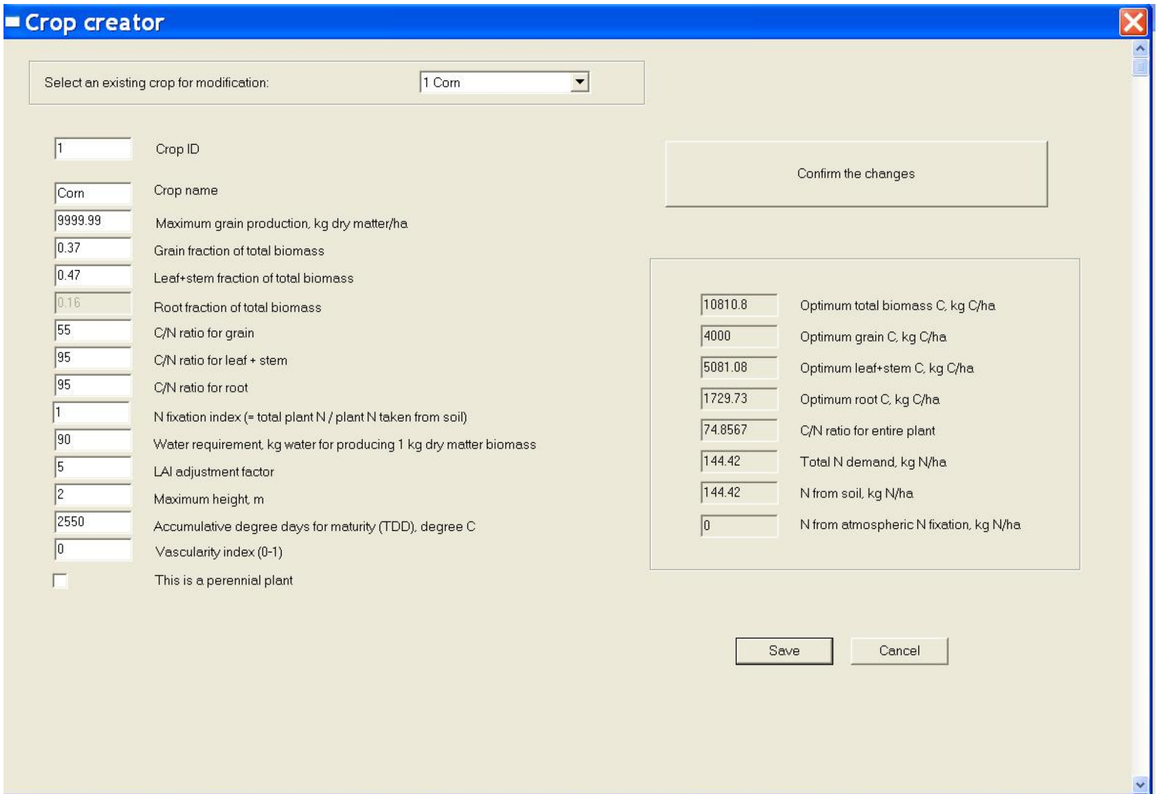


Figure 27. Review and modify crop physiological and phenology parameters

After modifying the above-listed parameters, you can click button "Confirm the changes" to calculate the new crop biomass, C pools, crop C/N ratio, total N demand and other parameters which are routinely reported by the farmers or agronomists. By repeatedly adjust the parameters listed in the left column, you are able to bring the physiological or phenology factors to close to the observations. When you feel satisfied with the new parameter settings, you can click button "Save" to save the new parameters in a corresponding file stored at \DNDC\Library\Lib_crop for future use.

Please note that the names of crops 1-62 have been reserved for DNDC. You can modify the parameter values of the crops but not you are not allowed to change the names. If you want to create a new crop or cultivar that doesn't exist in the crop library, you can use crops 63-79.

Lib_livestock: Default livestock data for each type of livestock

Example file name: Livestock_1 (for dairy cow)

1	AnimalCode
DairyCow	AnimalType
6.68	Default_C_intake_kgC/head/day
0.0575	Milk_C_fraction
0.0091	Meat_C_fraction
0.0219	Urine_C_fraction

0.2798	Dung_C_fraction
0.0329	Enteric_CH4_C_fraction
0.5988	Respiration_C_fraction
0.3340	Default_N_intake_kgN/head/day
0.2500	Milk_N_fraction
0.0500	Meat_N_fraction
0.3497	Urine_N_fraction
0.3497	Dung_N_fraction
0.0006	Enteric_N2O_N_fraction

The above-described library files for soil and crop are provided as defaults in DNDC, which can be modified by the users based on their own data.

2.4. Initiation of Regional Simulation

When the GIS and climate library files have been prepared and located at the right directories, you should be ready to conduct the regional simulations. To initiate a regional run, you need to click the "Input" button by the "Region" sign to select the target region and set relevant input information.

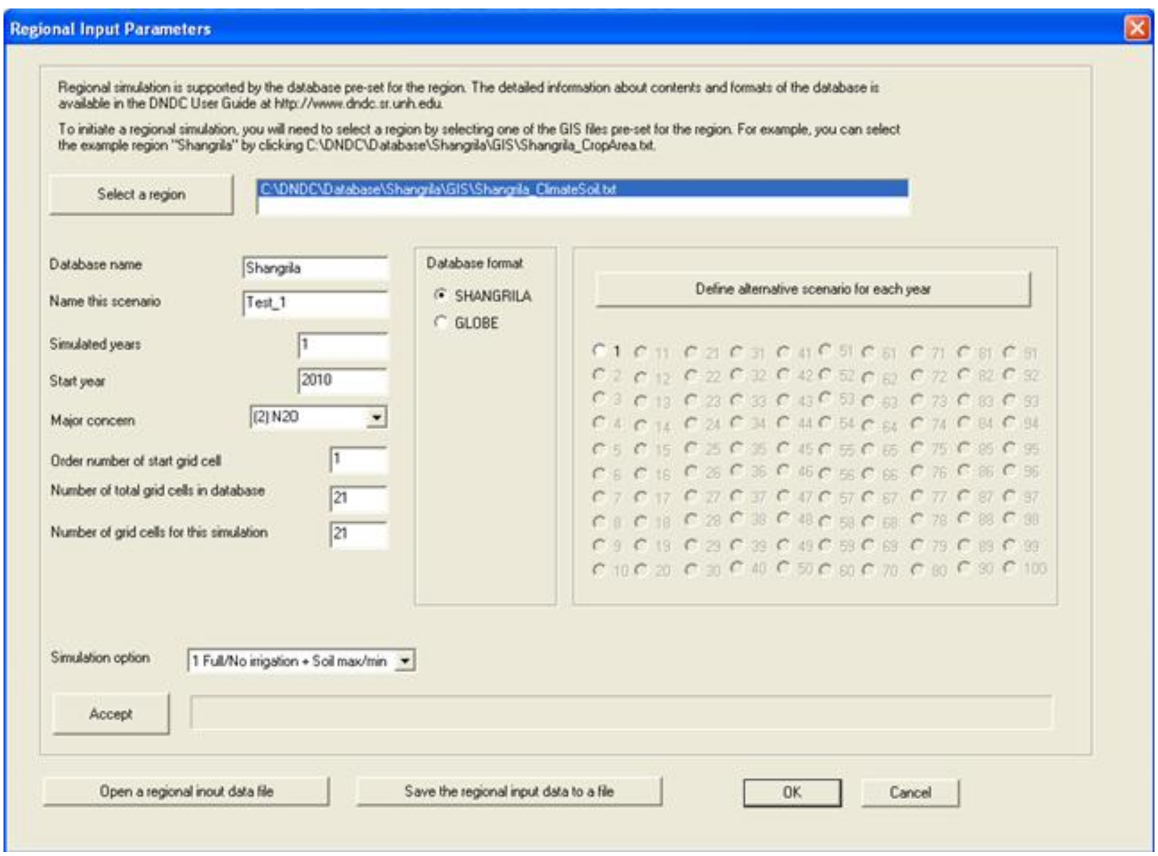


Figure 28. Page for region selection and scenario setting

Let's use "Shangrila" as an example to show how to select the region. By clicking button [***Select a region***], you will be asked to select a GIS file. Let's go to \DNDC\Database\Shangrila\GIS, and select the first file Shangrila_ClimateSoil.txt.

When you click the [***Database name***] box, "Shangrila" will automatically show up. That means DNDC has learnt your target region is Shangrila, and will read out the necessary input information from the Shangrila-relevant directories for use during the model runs. Now, you can further set several input parameters to specify the regional simulation.

[***Name this scenario***]: Give a string (no space is allowed) to name this simulation. The name will be used to construct the result file names.

[***Simulated years***]: Number of years for the regional simulation.

[***Start year***]: An integer (e.g., 2000) for the first simulated year that totally depends on your climate library files.

[***Major concern for this simulation***]: Select one from five options: SOC, CO2, N2O, CH4, NH3 and N leaching.

[***Order number of start grid cell***]: An integer to define the first grid cell to be simulated. This function allows you to skip the grid cells you don't want to simulate.

[***Number of total grid cells in database***]: Number of all the grid cells in the selected database.

[***Number of grid cells for this simulation***]: Number of the grid cells that will be simulated in the run.

[***Simulation option***]: There are four options to implement the regional simulation: (1) four runs for each grid cell with combinations of MaximumSoil+irrigation, MaximumSoil+no-irrigation, MinimumSoil+irrigation, MinimumSoil+no-irrigation, (2) two runs for each grid cell with combinations of AverageSoil+irrigation, AveragySoil+no-irrigation, (3) two runs for each grid cell with combinations of MiximumSoil+no-irrigation, MinimumSoil+no-irrigation, and (4) one run for each grid cell with AverageSoil+no-irrigation. The options provide flexibility to the users based on their concerns about uncertainty quantification and computing time.

[***GIS database format***]: "Shangrila" provides an example format which should be applicable for most regions. However, the users can add their own data in a new format for simulation although that will require a special effort to modify the source code of DNDC.

Clicking [***Define alternative climate or management for each year***] will open a new page that will allow you to systematically alter some input parameters provided by the preset regional database.

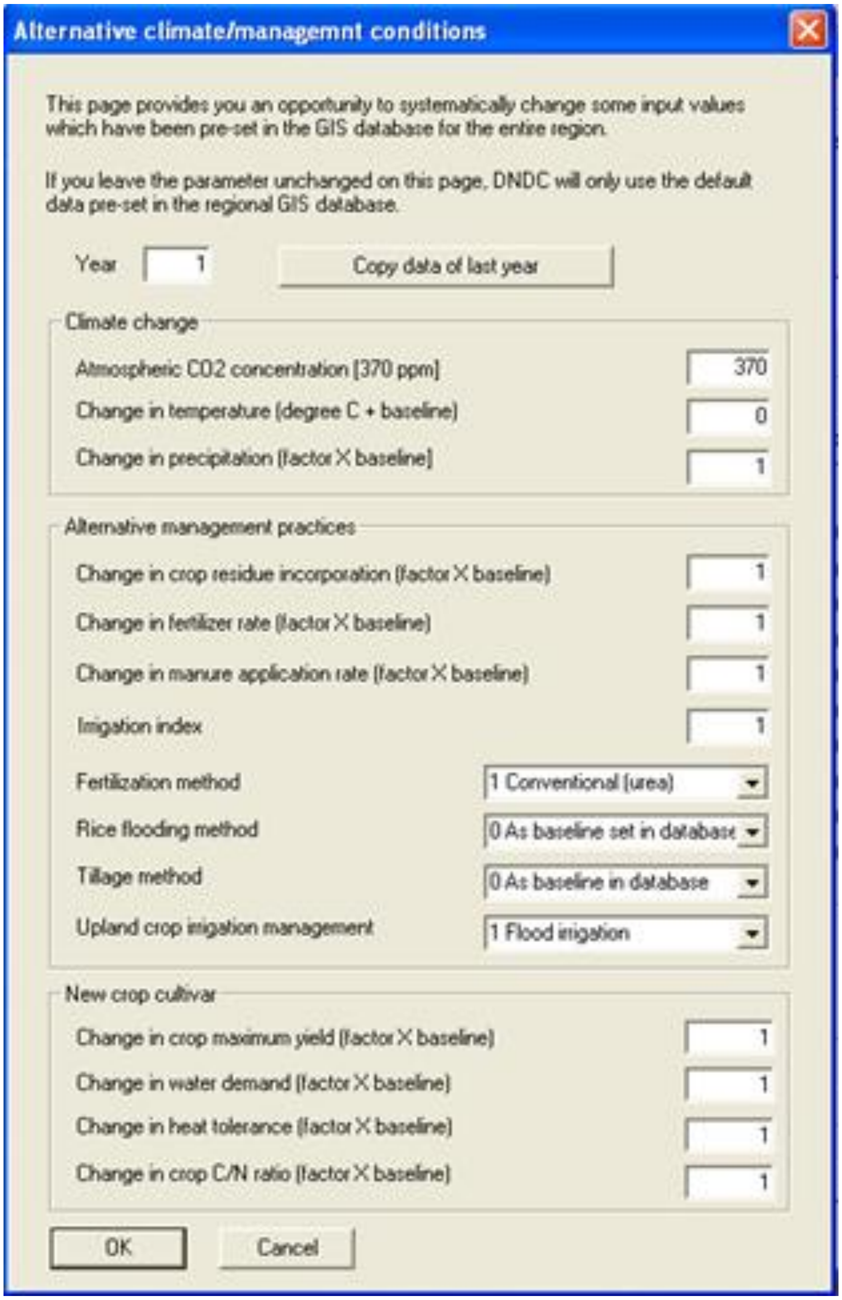


Figure 29. Systematically modifying climate and/or management conditions for regional simulation

Options for climate data change:

[***Atmospheric CO2 concentration (370ppm)***]: The default value is 370 ppm. You can change it to a new number that will affect the modeled crop growth and production as well as other consequential soil biogeochemical processes at the regional scale.

[***Change in temperature change (degree C + baseline)***]: The default value is 0. You can change it to a positive or negative number to systematically alter the daily temperatures provided by the preset climate files.

[***Change in precipitation (factor X baseline)***]: The default value is 1. You can change it to a new number (e.g., 0.5, 0.8, 1.5. 1.8 etc.), with which the new precipitation will be calculated by multiplying the original daily precipitation with the given factor for the entire region.

Options for changing farming management practices:

[***Change in crop residue incorporation (factor X baseline)***]: The default value is 1. It means the incorporated fraction of above-ground crop residue is identical with baseline value defined in the GIS database. You can set a factor to change the default value.

[***Change in fertilizer rates (factor X baseline)***]: The default value is 1. You can change it to a new number, which will be used to multiply the original fertilizer rates provided by the preset database.

[***Change in manure application rate (factor X baseline)***]: The default value is 1. You can change it to a new number, which will be used to multiply the original manure application rates provided by the preset database.

[***Irrigation index***]: The default value is 1 that means 100% of water deficit will be met with sufficient irrigation water if the crop is regarded as irrigated. You can change the Irrigation Index to a number smaller than 1, that will reduce irrigation water to cause insufficient irrigation for the irrigated fields.

[***Irrigation method***]: Seven optional methods: (1) conventional application (urea, surface apply), (2) slow-release fertilizer (lasting for 90 days), (3) nitrification inhibitor use (effective for 120 days), (4) soil-N-adjusted rate (fertilizer rate is automatically calculated based on the crop N demand and soil residue N on the day of planting), (5) precision fertilization (fertilizer is automatically applied at daily time step based on the crop N demand and soil N availability on each day), (6) usease inhibitor use (effective for 120 days), and (7) ammonium sulfate (instead of urea).

[***Rice flooding method***]: Six options: (0) applied as baseline, (1) continuous flooding, (2) midseason drainage, (3) marginal flooding, (4) direct seeding , and (5) dryland rice (instead of paddy rice).

[***Tillage method***]: Four options: (0) applied as baseline, (1) conventional tillage, (2) reduced till, (3) no-till.

[***Upland crop irrigation method***]: Six options (1) flood, (2) sprinkler, (3) drip, (4) drop under film mulch, (5) only film mulch.

Options for new crop cultivars:

[***Change in crop maximum yield (factor X baseline)***]: A factor can be defined to alter the default maximum yield of all the crops in the region. The default value of the factor is 1.

[***Change in crop water demand (factor X baseline)***]: A factor can be defined to alter the default crop water demand for all the crops in the region. The default value of the factor is 1.

[***Change in crop maximum yield (factor X baseline)***]: A factor can be defined to alter the default maximum yield of all the crops in the region. The default value of the factor is 1.

[***Change in crop heat tolerance (factor X baseline)***]: A factor can be defined to alter the default maximum temperature depressing the crop growth for all the crops in the region. The default value of the factor is 1.

[***Change in crop C/N ratio (factor X baseline)***]: A factor can be defined to alter the default crop C/N ratio to change the crop N demand for maintaining optimum yield for all the crops in the region. The default value of the factor is 1.

The above-listed parameters can be reset for each specific year by selecting the year number. The button "Show data of last year" enables you to copy the entire set of the parameter values defined for the last year to the current year.

When you finish the regional input procedure, please click "OK" to transfer all the input information into computer's memory. At this moment, you are ready to execute the regional simulation.

2.5. Run DNDC for Region

After completing the input procedure, click the "Run" button to start the regional simulation. During the regional simulations, DNDC runs for each cropping system in each grid cell for the defined years four times with the maximum and minimum values of the most sensitive soil factors depending on the user-defined "major concern" combined with irrigation and non-irrigation options. DNDC continuously runs cell by cell until reaching the end of the database. A regional simulation produces four files to record a same group of items (e.g., C, N or water pools or annual fluxes) but predicted with the four different soil-irrigation combination scenarios. The four files are stored at \DNDC\Result\Record\Region\RegionName\RunNmae\. All the result files are in a plain text format, so they can be reprocessed with any computing program, word processor, or spreadsheet software (e.g., Excel etc.).

IV. MODELED RESULTS REVIEW

1. Results from Site Runs

During simulations in site mode, daily weather, soil climate, soil C and N pools/fluxes, crop growth, and field management are automatically recorded in eight files with names as follows:

Day_Climate_year.csv,
Day_FieldCrop_year.csv,
Day_FieldManage_year.csv,
Day_Graze_year.csv,
Day_SoilClimate_year.csv,
Day_SoilC_year.csv,
Day_SoilN_year.csv,
Day_SoilP_year.csv,
Day_SoilWater_year.csv.

The contents of daily files are listed as follows:

Day_Climate_year.csv:

Day – Julian day;
Temp. (C) - Air temperature in °C;
Prec.(mm) – Precipitation in mm;
WindSpeed(m/s) – Wind speed in m/s;
Radiation(MJ/m2/d) – Radiation in MJ/m2/day;
Humidity – Relative humidity in %;
PET(mm) – Potential evapo-transpiration in mm/day;
Actual_ET(mm) – Actual evapo-transpiration in mm/day;
Evap(mm) – Actual evaporation in mm/day;
Trans(mm) – Actual transpiration in mm/day.

Day_FieldCrop_year.csv:

LeafC – Crop leaf biomass in kg C/ha;
StemC – Crop stem biomass in kg C/ha;
RootC – Crop root biomass in kg C/ha;
GrainC – Crop grain biomass in kg C/ha;
TDD – Crop accumulative temperature in °C;
GrowthIndex – Crop growth index;
Water_demand – Crop water demand in mm/day;
Water_stress – Daily crop water stress (0-1);
N_demand – Crop N demand in kg N/ha/day;
N_stress – Daily N stress;
LAI – Crop leaf area index;

N_from_soil – Crop N taken from soil in kg N/ha/day;
N_from_air_NH3 – Crop N taken from N dry deposition in kg N/ha/day;
N_fixation – Crop N through biological N fixation in kg N/ha/day;
Day_N_increase – Daily increment of crop N in kg N/ha/day;
TotalCropN – Crop accumulative N content in kg N/ha;
DailyCropGrowth – Daily increment of crop biomass in kg C/ha;
DayShootGrowth – Daily increment of crop leaf and stem in kg C/ha;
DayRootGrowth – Daily increment of crop root biomass in kg C/ha;
DayGrainGrowth – Daily increment of crop grain biomass in kg C/ha;
DayShootSenes – Daily crop shoot senescence in kg C/ha;
DayRootSenes – Daily crop root senescence in kg C/ha;
DayGrainSenes – Daily crop grain senescence in kg C/ha;
LeafN – Daily increment of crop leaf N in kg N/ha/day;
StemN – Daily increment of crop stem N in kg N/ha/day;
RootN – Daily increment of crop root N in kg N/ha/day;
GrainN – Daily increment of crop grain N in kg N/ha/day.

Day_FieldManage_year.csv:

Irrigation (mm) – Daily irrigation water in mm/day;
Fertilizer (kgN/ha) – Daily N fertilizer application rate in kg N/ha;
Fertilizer (kgP/ha) – Daily P fertilizer application rate in kg P/ha;
Manure (kgN/ha) – Daily manure N application rate in kg N/ha;
Manure (kgP/ha) – Daily manure P application rate in kg P/ha;
Plant_cut (kg C/ha) – Daily plant cut in kg C/ha.

Day_Graze_year.csv:

Grass shoot-C – Grass shoot biomass in kg C/ha;
Dairy – Dairy cow population in head;
Beef – Beef cow population in head;
Pig – Swine population in head;
Sheep – Sheep or goat population in head;
Horse – Horse population in head;
Hours – Hours for animals staying in grazing field per day;
Grazed-C – Daily grazed grass biomass in kg C/ha;
Grazed-N – Daily grazed grass biomass in kg N/ha;
Dung-C – Daily production of feces in kg C/ha;
Dung-N – Daily production of feces in kg N/ha;
Urine-C – Daily production of urine in kg C/ha;
Urine-N – Daily production of urine in kg N/ha;
Food deficit – Daily feed deficit.

Day_SoilClimate_year.csv:

Soil_temperature – Soil temperatures (°C) at 1, 5, 10, 20, 30, 40 and 50 cm depth;

Soil_moisture – Soil moisture (water-filled porosity) at 1, 10, 20, 30, 40 and 50 cm depth;
Soil_oxygen – Soil oxygen content (kg O2/layer) at 1,10, 20, 30, 40 and 50 cm depth;
Soil_Eh - Soil redox potentil (mV) at 1, 10, 20, 30, 40 and 50 cm depth;
WT – Water table (mm, minus is below soil surface);
Ice – Soil ice content (wfps) at 1, 10, 20, 30, 40 and 50 cm depth;
Ice – Soil profile (0-50 cm) ice content (mm);
Snowpack – Snow pack (mm water);
SoilWater – Total water content in soil profile (mm water in 0-50 cm);
DeepWater – Water content (mm) below 50 cm;
Soil_pH – Soil pH.

Day_SoilC_year.csv:

Very labile litter – Soil very labile litter content (kg C/ha);
Labile litter – Soil labile litter content (kg C/ha);
Resistant litter – Soil resistant litter content (kg C/ha);
Microbe – Soil living microbial content (kg C/ha);
Humads – Soil humads (active humus) content (kg C/ha);
Humus – Soil passive humus content (kg C/ha);
CharC – Soil chark content (kg C/ha);
SOC – Soil total organic C content (kg C/ha);
dSOC – Daily change in SOC content (kg C/ha/day);
DOC – Soil dissolved organic C content (kg C/ha);
Photosynthesis – Plant photosynthesis rate (kg C/ha/day);
Shoot-respiration – Plant shoot autotrophic respiration rate (kg C/ha/day);
Root-respiration – Plant root autotrophic respiration rate (kg C/ha/day);
NPP – Plant net primary production rate (kg C/ha/day);
Soil-heterotrophic-respiration – Soil microbial heterotrophic respiration rate (kg C/ha/day);
Eco-respiration – Ecosystem respiration rate (kg C/ha/day);
NEE – Net ecosystem C exchange rate (kg C/ha/day);
Stub – Plant stub standing on ground (kg C/ha);
CH4-DOC – DOC available for methanogens (kg C/ha);
CH4-prod. - Daily methane production (kg C/ha/day);
CH4-oxid. - Daily methane oxidation (kg C/ha/day);
CH4-flux - Daily methane flux (kg C/ha/day);
CH4-pool - Methane content in soil profile (kg C/ha);
DOC-leach - Daily DOC loss through leaching flow (kg C/ha/day);
Litter-C - Daily litter incorporation (kg C/ha/day);
Manure-C - Daily manure incorporation (kg C/ha/day).

Day_SoilN_year.csv:

Crop – Daily crop N uptake in kg N/ha;
Urea – Soil urea content in kg N/ha;
NH4+ – Soil ammonium content in 0-10, 10-20, 20-30, 30-40, and 40-50 cm in kg N/ha;

NO3- – Soil nitrate content in 0-10, 10-20, 20-30, 30-40, and 40-50 cm in kg N/ha;
exchengeable-NH4 – Soil exchangeable ammonium content in 0-10, 10-20, 20-30, 30-40, and 40-50 cm in kg N/ha;
NH3 – Ammonia content in soil profile in kg N/ha;
N2O-flux – Daily nitrous oxide emission rate in kg N/ha/day;
NO-flux – Daily nitric oxide emission rate in kg N/ha/day;
N2-flux – Daily dinitrogen emission rate in kg N/ha/day;
NH3-flux – Daily ammonia emission rate in kg N/ha/day;
NO3-leach – Daily nitrate loss through leaching flow in kg N/ha/day;
Urea-leach – Daily urea loss through leaching flow in kg N/ha/day;
Gross N mineralization – Daily gross N mineralization rate in kg N/ha/day;
N assimilation – Daily microbial N assimilation rate in kg N/ha/day;
Ice_DOC – DOC trapped in soil ice (kg C/ha);
Ice_N – Available N trapped in soil ice (kg N/ha);
Ice_N2O – N2O trapped in soil ice (kg N/ha);
Ice_N2 – N2 trapped in soil ice (kg N/ha);
Nitrification – Daily nitrification rate (kg N/ha/day);
Denitrification – Daily denitrification rate (kg N/ha/day);
N_fixation – Daily soil N fixation rate (kg N/ha/day);
Litter_N – Daily litter incorporation N (kg N/ha/day).

Day_SoilP_year.csv:

OrganicP – Organic phosphorous content in soil profile (kg P/ha);
LabileP – Labile inorganic phosphorous content in soil profile (kg P/ha);
SorbedP – Adsorbed phosphorous content in soil profile (kg P/ha);
ComplexP – Complex phosphorous content in soil profile (kg P/ha);
CropDemandP – Daily crop demand for phosphorous (kg P/ha/day);
DayUptakeP – Daily crop uptake of phosphorous (kg P/ha/day);
CropP – Crop P content (kg P/ha);
Leach_P – Daily P loss through leaching flow (kg N/ha/day);

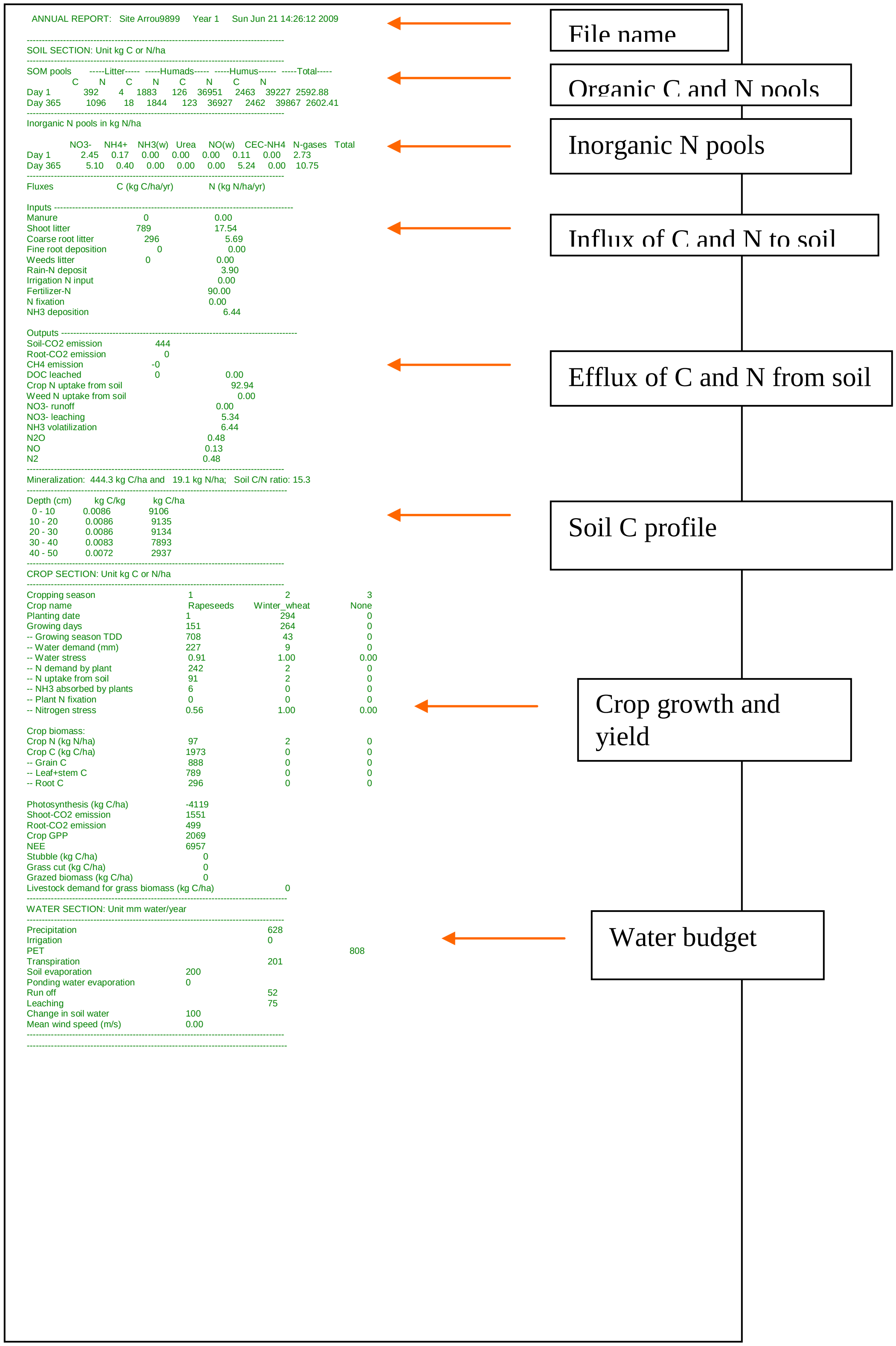
Day_SoilWater_year.csv:

IniSoilWater – Daily initial soil water content (mm);
EndSoilWater – Daily soil water content at end of each day (mm);
FreeWater – Soil liquid water content (mm);
SoilIce – Daily ice water content (mm);
IniDeepWater – Daily initial soil water content below 50 cm (mm);
EndDeepWater – Daily end soil water content below 50 cm (mm);
Precipitation – Daily precipitation (mm/day);
Irrigation – Daily irrigated water (mm/day);
Ponding – Ponding water on soil surface (mm);
SnowPack – Snow pack water content (mm);
Evaporation – Daily soil water loss through evaporation (mm/day);
Transpiration – Daily soil water loss through transpiration (mm/day);

SurfaceWaterEV – Daily water loss through ponding water evaporation (mm/day);
Leaching – Daily soil water loss through leaching flow (mm/day);
Runoff – Daily water loss through surface runoff flow (mm/day);
dSoilWater – Daily change in soil water storage in profile (mm/day);
DayInFlow – Daily total water influx to soil (mm/day);
DayOutFlow – Daily total water efflux from soil (mm/day);
Error – Error in water balance (mm/day);
SedimentYield – Daily soil erosion rate (kg/day);
SOC_loss – Daily SOC loss due to soil erosion (kg C/day);
ION_loss – Daily soil inorganic N loss due to soil erosion (kg N/day);
OrgP_loss – Daily organic P loss due to soil erosion (kg P/day);
AdsP_loss – Daily adsorbed P loss due to soil erosion (kg P/day);
LabP_loss – Daily labile P loss due to soil erosion (kg P/day).

Besides the daily reports, DNDC produces an annual report at the end of each simulated year to summarize the crop growth/yield, soil C and N pools/fluxes and water balance for the simulated site. This file provides condensed information for assessing annual C, N and water dynamics. Below-listed is an example file for the annual report:

An example annual report:


```
 ANNUAL REPORT:   Site Arrou9899    Year 1    Sun Jun 21 14:26:12 2009

--------------------------------------------------------------------------------
SOIL SECTION: Unit kg C or N/ha
--------------------------------------------------------------------------------
SOM pools       -----Litter-----  -----Humads-----  -----Humus------  -----Total-----
                 C       N       C       N       C       N       C       N
Day 1           392      4    1883     126    36951    2463    39227  2592.88
Day 365         1096     18    1844     123    36927    2462    39867  2602.41
--------------------------------------------------------------------------------
Inorganic N pools in kg N/ha

                NO3-    NH4+    NH3(w)   Urea    NO(w)   CEC-NH4   N-gases   Total
Day 1           2.45    0.17    0.00    0.00    0.00    0.11    0.00    2.73
Day 365          5.10    0.40    0.00    0.00    0.00    5.24    0.00   10.75
--------------------------------------------------------------------------------
Fluxes                      C (kg C/ha/yr)          N (kg N/ha/yr)

Inputs --------------------------------------------------------------------------
Manure                           0                     0.00
Shoot litter                   789                     17.54
Coarse root litter               296                      5.69
Fine root deposition                0                      0.00
Weeds litter                     0                     0.00
Rain-N deposit                                           3.90
Irrigation N input                                       0.00
Fertilizer-N                                           90.00
N fixation                                              0.00
NH3 deposition                                             6.44

Outputs --------------------------------------------------------------------------
Soil-CO2 emission                  444
Root-CO2 emission                    0
CH4 emission                      -0
DOC leached                        0                      0.00
Crop N uptake from soil                                     92.94
Weed N uptake from soil                                       0.00
NO3- runoff                                              0.00
NO3- leaching                                              5.34
NH3 volatilization                                         6.44
N2O                                                    0.48
NO                                                     0.13
N2                                                    0.48
--------------------------------------------------------------------------------
Mineralization:  444.3 kg C/ha and   19.1 kg N/ha;   Soil C/N ratio: 15.3
--------------------------------------------------------------------------------
Depth (cm)        kg C/kg          kg C/ha
  0 - 10        0.0086           9106
 10 - 20         0.0086           9135
 20 - 30         0.0086           9134
 30 - 40         0.0083           7893
 40 - 50         0.0072           2937
--------------------------------------------------------------------------------
CROP SECTION: Unit kg C or N/ha
--------------------------------------------------------------------------------
Cropping season                              1                    2                   3
Crop name                                    Rapeseeds      Winter_wheat            None
Planting date                               1                    294                   0
Growing days                                151                  264                   0
-- Growing season TDD                       708                   43                   0
-- Water demand (mm)                        227                    9                   0
-- Water stress                              0.91                 1.00                0.00
-- N demand by plant                         242                    2                   0
-- N uptake from soil                        91                    2                   0
-- NH3 absorbed by plants                    6                     0                   0
-- Plant N fixation                          0                     0                   0
-- Nitrogen stress                          0.56                 1.00                0.00

Crop biomass:
Crop N (kg N/ha)                             97                    2                   0
Crop C (kg C/ha)                            1973                   0                   0
-- Grain C                                   888                   0                   0
-- Leaf+stem C                              789                    0                   0
-- Root C                                    296                   0                   0

Photosynthesis (kg C/ha)                    -4119
Shoot-CO2 emission                          1551
Root-CO2 emission                           499
Crop GPP                                    2069
NEE                                         6957
Stubble (kg C/ha)                                0
Grass cut (kg C/ha)                              0
Grazed biomass (kg C/ha)                         0
Livestock demand for grass biomass (kg C/ha)                       0
--------------------------------------------------------------------------------
WATER SECTION: Unit mm water/year
--------------------------------------------------------------------------------
Precipitation                                                628
Irrigation                                                   0
PET                                                                             808
Transpiration                                                201
Soil evaporation                            200
Ponding water evaporation                   0
Run off                                                      52
Leaching                                                     75
Change in soil water                        100
Mean wind speed (m/s)                       0.00
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
```

Both the daily and annual result data files are recorded at \DNDC\Result\Record\Site.

All the result files are in a plain text format so that they can be reprocesses with any word processor or spreadsheet software.

When a multi-year simulation is conducted, a multi-year result file recorded by DNDC will become handy for quick reviewing the major annual pools or fluxes across the simulated years. The Items reported in the multi-year files are listed as follows:

Year – Year number;
GrainC1 – Grain production for crop 1 (kg C/ha);
LeafStemC1 – Leaf and stem production for crop 1 (kg C/ha);
RootC1 – Root production for crop 1 (kg C/ha);
GrainC2 – Grain production for crop 2 (kg C/ha);
LeafStemC2 – Leaf and stem production for crop 2 (kg C/ha);
RootC2 – Root production for crop 2 (kg C/ha);
GrainC3 – Grain production for crop 3 (kg C/ha);
LeafStemC3 – Leaf and stem production for crop 3 (kg C/ha);
RootC3 – Root production for crop 3 (kg C/ha);
SOC – SOC content in 0-10, 0-20, 0-30cm (kg C/ha);
Ini_SOC – Initial SOC content at beginning of a year (kg C/ha);
End_SOC – SOC content at the end of a year (kg C/ha);
dSOC – Annual change in SOC content (kg C/ha/yr);
LitterC_input – Annual litter C input (kg C/ha/yr);
RootC_input – Annual root C input (kg C/ha/yr);
ManureC_input – Annual manure C input (kg C/ha/yr);
Soil-CO2 – Annual soil CO2 emission (kg C/ha/yr);
CH4 – Annual methane emission (kg C/ha/yr);
Ini_SON – Initial soil organic N content at beginning of a year (kg N/ha);
Ini_SIN – Initial soil inorganic N content at beginning of a year (kg N/ha);
End_SON – End soil organic N content at end of a year (kg N/ha);
End_SIN – End soil inorganic N content at end of a year (kg N/ha);
dSN – Annual change in soil total N content (kg N/ha/yr);
Atmo_N_input – Annual atmospheric N deposition (kg N/ha/yr);
Fertilizer_N_input – Annual fertilizer N application (kg N/ha/yr);
Manure_N_input – Annual manure N application (kg N/ha/yr);
Litter_N_input – Annual litter N incorporation (kg N/ha/yr);
N_fixation – Annual biotic N fixation (kg N/ha/yr);
Crop_N_uptake – Annual crop N uptake (kg N/ha/yr);
N_leach – Annual soil N loss through subsurface leaching (kg N/ha/yr);
N_runoff – Annual soil N loss through surface runoff (kg N/ha/yr);
N2O_flux – Annual soil N2O emission (kg N/ha/yr);
NO_flux – Annual soil NO emission (kg N/ha/yr);
N2_flux – Annual soil N2 emission (kg N/ha/yr);
NH3_flux – Annual NH3 emission (kg N/ha/yr);

exchengeable-NH4 – Soil exchangeable ammonium content at the end of a year (kg N/ha);
PET – Annual potential evapotranspiration (mm);
Transpiration – Annual transpiration (mm);
Evaporation – Annual evaporation (mm);
WaterLeach – Annual water leaching flow (mm);
Runoff – Annual surface runoff water flow (mm);
Irrigation – Annual irrigated water (mm);
Precipitation – Annual precipitation (mm);
MeanT – Annual mean temperature (°C);
WindSpeed – Annual average wind speed (m/s);
ColdStress – Annual average plant coldness stress;
WaterStress – Annual average plant water stress;
N_Stress – Annual average plant N stress;
Cut_CropC – Annual grass cut (kg C/ha).

2. Results from Regional Runs

The simulated results for a region are recorded in a group of four files stored at \DNDC\Result\Record\Region\RegionName\RunName\. The files contain simulated annual C, N and water pools/fluxes for each cropping system in each grid cell. The four files contain same items but produced from different scenarios, which are maximum and minimum most sensitive soil factors combined with full irrigation and non-irrigation. For example, the modeled results for "Shangrila" are recorded in four files as follows:

- Shangrila_FullIrri_max_rate_1.txt;
- Shangrila_FullIrri_min_rate_1.txt;
- Shangrila_ZeroIrri_max_rate_1.txt; and
- Shangrila_FullIrri_min_rate_1.txt.

The four files provide annual rates of changes in the C, N and water pools or fluxes for each cropping system in each grid cell. The items reported in the files are list as follows:

Grid_ID	System_ID	SystemName	Area ha	Year	SOC kgC/ha	dSOC kgC/ha
230101	2	Corn	15	1	61194	5521
230101	3	W_wheat	758	1	57929	2256
230101	4	Soybean	89	1	56280	607
230101	11	Peanut	4	1	56552	880
230101	15	Beans	3385	1	56195	522
230101	17	wwt/cor	2976	1	61194	5521
230101	18	wwt/rap	207	1	61176	5504
230101	20	wwt/veg	710	1	57085	1413
230101	29	po/v/v	627	1	57963	2290
230101	30	r/r/ve	2993	1	57089	1416

CH4 kgC/ha	GrainC kgC/ha	ShootC kgC/ha	RootC kgC/ha	ManureC kgC/ha	LitterC kgC/ha	N2O kgN/ha
-0.442	5986	7603	2588	134	7217	0.559

-0.335	3337	2818	1261	134	2486	0.309
-0.4	587	754	335	134	663	0.46
-0.417	867	1164	446	134	952	0.215
-0.457	525	671	263	134	554	0.162
-0.442	5986	7603	2588	134	7217	0.559
-0.292	3190	9571	1110	134	7963	0.663
-0.274	4986	2301	384	134	1763	0.582
-0.191	8729	4029	671	134	3084	0.69
2.117	7300	3369	562	134	2446	0.788

NO kgN/ha	N2 kgN/ha	NH3 kgN/ha	UptakeN kgN/ha	LeachN kgN/ha	DepositN kgN/ha	FixedN kgN/ha
2.239	1.776	32.499	263.65	39.37	5.42	0
1.403	0.93	4.349	168.31	23.06	9.87	0
0.1	1.676	2.39	89.41	51.17	8.53	80.47
0.185	0.716	3.367	83.56	17.34	6.8	0
0.037	0.498	2.483	84.93	11.63	4.79	15.86
2.239	1.776	32.499	263.65	39.37	5.42	0
1.929	2.307	27.452	227.23	54.9	11.13	0
3.458	2.49	24.703	251.03	61.87	11.21	0
3.184	2.018	14.363	377.51	49.25	11	0
1.875	98.658	26.608	457.2	52.89	214.49	0

Miner_N kgN/ha	Fert_N kgN/ha	ManureN kgN/ha	dSON kgN/ha	dSIN kgN/ha	H2Otran mm	H2Oevap mm
5.03	277	8.93	78.4	-30.06	504	403
5.05	156	8.93	36.29	-26.68	1019	66
5.24	47	8.93	22.7	-0.94	704	307
5.03	61	8.93	25.37	-28.34	598	345
4.86	43	8.93	18.01	-28.17	272	336
5.03	277	8.93	78.4	-30.06	504	403
9.93	262	8.93	174.04	-23.79	1331	52
6.11	298	8.93	54.71	-27.07	1330	52
8.27	397	8.93	93.86	-25.39	1593	28
3.95	388	8.93	50.56	10.73	2064	35

H2Orunof mm	H2Oleach mm	H2Oirri mm	H2Oprec mm	dSoilH2O mm	CountryID
0	442	572	684	-93	0
0	525	836	684	-90	0
0	476	709	684	-94	0
0	462	629	684	-92	0
0	426	273	684	-77	0
0	442	572	684	-93	0
0	538	1124	684	-113	0
0	538	1123	684	-112	0
0	547	1353	684	-131	0
0	345	607	684	-1154	0

Utilizing the recorded data in the files in conjunction with the acreage data in the regional GIS input file (e.g., Shangrila_CropArea.txt), the total pools or fluxes can be calculated for a cropping system, a grid cell, or the entire region. This post-simulation calculation can be accomplished with spreadsheet software or the user-created programs.

Provision of the same items but simulated with four different soil-irrigation combination scenarios is to provide the opportunity for users to (1) quantify the uncertainty induced from the upscaling simulations and (2) estimate effects of irrigation on crop yields or soil biogeochemistry at regional scale.

V. UNCERTAINTY ANALYSIS

Modeling simulations produce predictions with uncertainties. The uncertainties could come from both the model itself and the input data driving the model runs. The defects in scientific basis, structure or algorithms embedded in a model can be detected through an adequate amount of validation tests against datasets observed from field or laboratory experiments with well documented input information. However, even with a well validated model, a simulation could still produce large uncertainties with insufficient or inaccurate input information no matter at site or regional scale. DNDC provides tools to quantify the uncertainties for site or regional simulations.

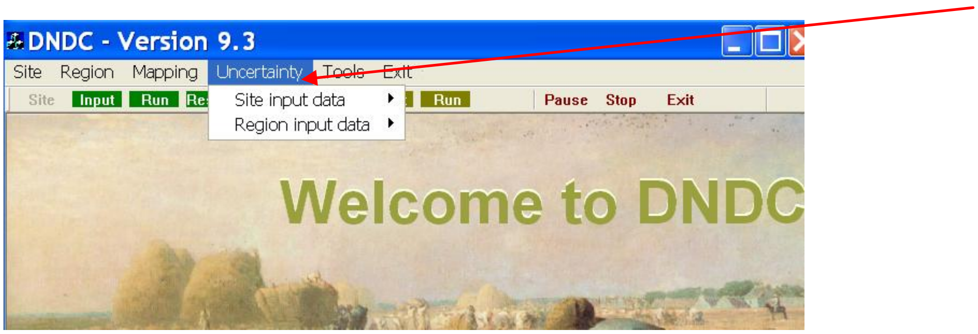


Figure 30. Open uncertainty analysis

By clicking “Uncertainty” on the top of the main menu, you will have two choices to conduct an uncertainty analysis by using input information from a site run or from an existing regional database built up in the Shangrila format.

Let’s select “Site input data”. At first, we’ll see a notice as follows:

“This Monte Carlo test is for a specific site case. All the input parameters for the case must have been set in advance with the regular input procedure. If you have done so, please click OK to continue.”

Let’s assume we just finished a one-year simulation so that all the input data for the case have been stored in the computer’s memory. After clicking the OK, we’ll see a new page as follows:

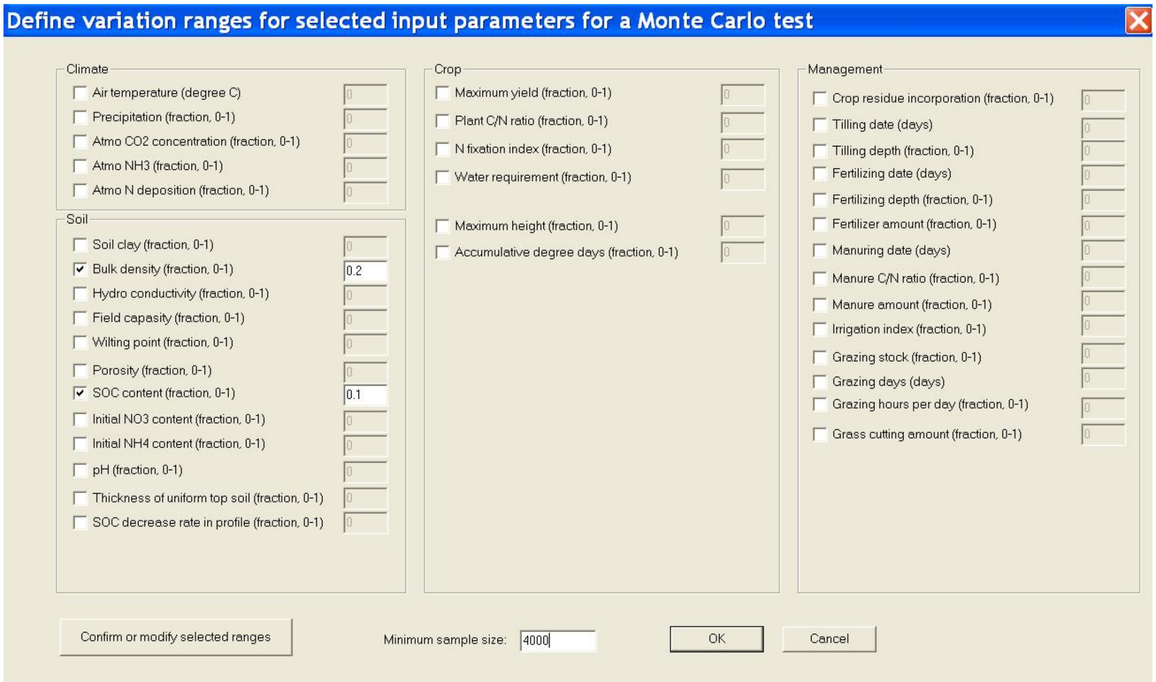


Figure 31. Define ranges of variation of selected input parameters

On this page, a single or several input items can be selected to test the impact of their variations on several major output items including annual change in soil organic carbon content (dSOC) and annual fluxes of methane (CH4), nitrous oxide (N2O), nitric oxide (NO), dinitrogen (N2), ammonia (NH3) and nitrate leaching loss for the modeled site. After selecting one or more concerned input items from the categories of climate, soil, crop or management, please click "Confirm or modify selected ranges" to see the default range for each of the selected input items. The units of range for most of the input items are fractions of the input data you originally set during the case simulation. After the click, you will also see a suggested sample size at window "Minimum sample size". The users can modify the default settings. In general, the larger the sample size the smoother the obtained curve of the frequency distribution. In DNDC, each range of the input item is fixedly divided into eight equal sections, and the middle values of the sections will be randomly selected and combined to run DNDC. A lowest number, 4000, is suggested to conduct a Monte Carlo run with a single varied input item. If the number of tested items increases, the required sample size will increase exponentially.

After the Monte Carlo simulations for the site is accomplished, a file will be recorded at \DNDC\Result\Record\MonteCarlo to summarize the modeled results. The following is an example showing the top part of the Monte Carlo simulated results with two variable input parameters, soil bulk density (Dens) and SOC content (SOC). The numbers in column Dens or SOC indicate the varied fraction of the original input bulk density or SOC value for each run.

Results of Monte Carlo test

		Output Parameters							Input Parameters				
No.	Year	dSOC	CH4	N2O	NO	N2	NH3	N_leaching	Dens	SOC	None	None	None
		kgC/ha	kgC/ha	kgN/ha	kgN/ha	kgN/ha	kgN/ha	kgN/ha					

1	1	2183	-0.645	0.6537	0.3115	0.0949	0.0049	1.4395	-0.2	-0.043	0	0	0
2	1	2140	-0.68	0.732	0.3189	0.1035	0.005	1.4535	0.1429	0.0143	0	0	0
3	1	2105	-0.702	0.773	0.3206	0.1084	0.005	1.4608	-0.086	0.0429	0	0	0
4	1	2213	-0.623	0.617	0.3096	0.0911	0.0049	1.4324	-0.143	-0.071	0	0	0
5	1	2140	-0.68	0.732	0.3189	0.1035	0.005	1.4535	0.1429	0.0143	0	0	0
6	1	2059	-0.735	0.866	0.3287	0.1201	0.005	1.4754	0.2	0.1	0	0	0
7	1	2183	-0.645	0.6537	0.3115	0.0949	0.0049	1.4395	-0.2	-0.043	0	0	0
8	1	2158	-0.664	0.6928	0.3145	0.0995	0.0049	1.4465	-0.143	-0.014	0	0	0
9	1	2249	-0.597	0.5828	0.3085	0.0883	0.0049	1.4252	0.0857	-0.1	0	0	0
10	1	2058	-0.736	0.8666	0.3284	0.1213	0.005	1.4754	0.1429	0.1	0	0	0

Due to the large amount of simulation runs for Monte Carlo analysis, the method is only applicable for site scale in DNDC. For regional simulations, uncertainty is quantified with a Most Sensitive Factor (MSF) method which was developed to specially serve uncertainty analysis with DNDC regional predictions. In this method, the spatial heterogeneity of soil properties as well as irrigation are regarded as the major source of uncertainty. To bring the uncertainty under control, during regional simulation runs, DNDC always runs four times for each grid cell with the maximum and minimum values of the most sensitive soil factors combined with and without irrigation. The most sensitive factors are automatically determined by DNDC based on the user-defined major concern for the simulation. For example, if the major concern is N2O emission or SOC change, DNDC will determine the most sensitive factor for the target flux is the initial SOC content based on a large amount of sensitivity tests done during the development of DNDC; and then DNDC will run twice with the maximum and minimum initial SOC contents for a grid cell to produce a pair of N2O fluxes or SOC changes for the cell. The pair of modeled fluxes will form a range, which should be wide enough to include the “real” N2O flux or SOC change with a high probability. The MSF method has been compared with the Monte Carlo method with encouraging results. The major goal of adopting the MSF method is to save the computing time.

In summary, with the Monte Carlo approach at site and with the MSF method at regional scale, the users have the opportunity to quantify uncertainties produced from the model simulations.

VI. Case Studies

Modeling soil C sequestration, trace gas emissions or nitrate leaching is a task including simulating plant production, soil climate and soil biogeochemistry under given climatic and management conditions. The subordinate relation among the simulated processes is apparent. The plant growth drives the soil climate in conjunction with the weather conditions, determines the soil nutrient profiles through the nutrient absorption, and affects soil C dynamics by depositing the litter into the soil. The soil temperature, moisture, redox potential and nutrient profiles dominate the microbial activities in the soil, and hence determine a series of biogeochemical reactions including decomposition, nitrification, denitrification, fermentation etc. So any discrepancy occurring in the upstream (e.g., crop growth) simulation will inherently cause errors for the downstream (e.g., N2O fluxes) simulations. A successful simulation is built upon the decent simulations for all the processes. A matrix of external parameters, which can be set or modified by the users, have been built in DNDC to provide adequate flexibilities to allow the users to obtain reasonable results without any model alterations at code level.

Five case studies are provided in the User's Guide to demonstrate how to correctly model crop growth, soil climate, C sequestration and trace gas emissions. For each case there are four components, namely Site Description, Input Settings, DNDC Simulation and Key Notes, which explicitly explain how each run is set and what the key issues are for each simulation.

Case 1: Annual crop simulation: Maize growth in Iowa, USA

Site Description: A field experiment focusing on crop development, growth and yield was conducted by Changsheng Li and his colleagues (University of New Hampshire) at a maize field (41°33' N, 90°59' W) in Muscatine County in Iowa, the U.S. in 1997. Total crop biomass and its partitions in the leaves, stems, roots and grain were measured at weekly time step. The plant samples were analyzed for their water, C and N contents. Daily weather data of 1997 was collected from the closest climatic station, IA Observatory, in Iowa City. Soil data were obtained from the local soil survey records.

Input Settings: The climate, soil and management input data were set as follows:

Input parameter	Value	Unit
Climate		
Latitude	41.5	°
Weather station	IA Observatory, Iowa City	
N in rainfall	1	mg N/l
Air NH_3 concentration	0.06	μg N/m^3
Atmospheric CO_2 concentration	350	ppm
Soil		
Land-use type	Upland cropland	
Texture	loam	

Bulk density	1.3	g/cm^3
pH	6.5	
SOC content (0-10 cm)	0.015	g C/g soil
Management		
Number of cropping systems	1	
Span of cropping system 1	1	year
Years in a cycle of cropping system 1	1	year
Farming practices for year 1		
Number of crops planted	1	
Crop 1 (crop type code)	Maize (1)	
Planting date	5/20	
Harvest date	10/20	
Fraction of above-ground residue left as stub	0.1	
Maximum yield	5800	kg C/ha
Grain fraction	0.65	
Leaf+stem fraction	0.23	
Root fraction	0.12	
Grain C/n ratio	60	
Leaf+stem C/N ratio	90	
Root C/N ratio	100	
TDD	2800	°C
Water requirement	100	g water/g dry matter
Maximum LAI	5	
N fixation index	1	
Vascularity	0	
Cover crop	No	
Tilling applications	2	
Tilling application 1: date	5/10	
Tilling application 1: depth	20	cm
Tilling application 2: date	10/25	
Tilling application 2: depth	20	cm
Fertilizer applications	1	
Fertilization 1: date	5/20	
Fertilization 1: rate	150	kg N/ha
Fertilization 1: type	NH4NO3	
Manure applications	0	
Weeding applications	0	
Irrigation applications	0	

DNDC Simulation: All the above-listed input information has been saved in a file named "Iowa_maize_1997.dnd" stored in the package you received. Now you can open the input file on the DNDC user's interface and review all the settings. Please click OK to accept the input data and click "Run" to execute the one-year simulation. Please open file C:\DNDC\Result\Record\Site\Day_FieldCrop_1.csv to review the modeled crop growth. By copying the columns of "LeafC", "StemC", "RootC" and "GrainC" in file "Day_FieldCrop_1.csv " into the provided Excel file "Iowa_field_model_comparison.xls", you can compare the modeled daily crop biomass dynamics with the weekly measured crop data. The result should like the figure as follows:

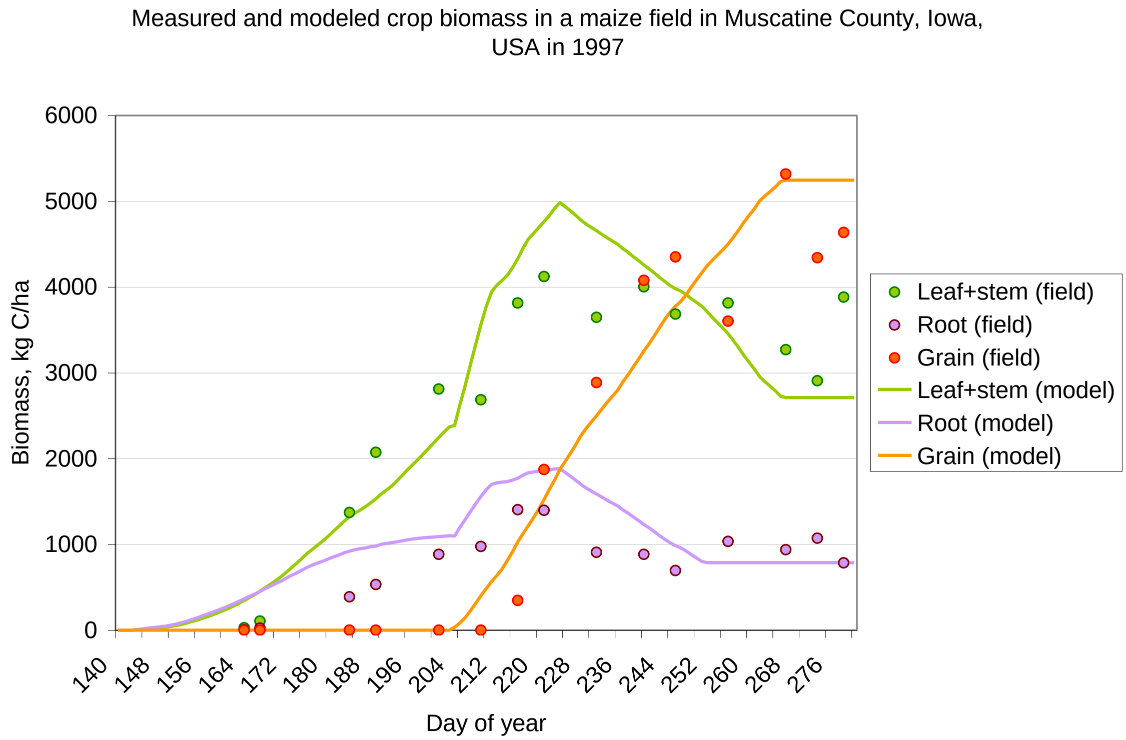


Figure 32. Measured and modeled biomass dynamics of corn growing in Iowa

Key Notes: This practice is aimed to demonstrate how to accurately simulate crop growth and yield by correctly setting the crop parameters. The users are encouraged to change the parameters such maximum yield, biomass partitioning, biomass C/N ratio, accumulative thermal degree days (TDD), water requirement or N fixation index and then observe how these parameters could affect the crop phenology and biomass production under the given climate and soil conditions.

Case 2: Perennial crop simulation: Sugarcane growth in Hawaii, USA

Site Description: A field experiment focusing on sugarcane growth and yield was conducted by Carl Evensen and his colleagues (University of Hawaii at Manoa) in the Hawaiian Sugar Planters Association Kunia Substation (21°24' N) on the island of Oahu, Hawaii in 1991-1993. Total crop biomass and its components in leaves, stems and roots were periodically measured during the 19-month growing period. Daily weather data of 1991-1993 were obtained from the Honolulu Observatory station. The observed results were published in Evensen et al. (1997, Agronomy Journal 89:638-646).

Input Settings: The climate, soil and management input data were set as follows:

Input parameter	Value	Unit
Climate		
Latitude	21.5	°
Weather station	Honolulu Observatory,	

	Hawaii	
N in rainfall	0.1	mg N/l
Air NH_3 concentration	0.06	µg N/m^3
Atmospheric CO_2 concentration	350	ppm
Soil		
Land-use type	Upland cropland	
Texture	Silty clay loam	
Bulk density	1.25	g/cm^3
pH	7.0	
SOC content (0-10 cm)	0.012	g C/g soil
Management		
Number of cropping systems	1	
Span of cropping system 1	3	year
Years in a cycle of cropping system 1	3	year
Farming practices for year 1		
Number of crops planted	1	
Crop 1 (crop type code)	Sugarcane (7)	
Planting date	5/20	
Harvest date	1/10	
Year of harvest	3	
Fraction of above-ground residue left as stub	0.1	
Maximum yield of grain	150	kg C/ha
Grain fraction	0.01	
Leaf+stem fraction	0.89	
Root fraction	0.10	
Grain C/N ratio	150	
Leaf+stem C/N ratio	100	
Root C/N ratio	150	
TDD	11000	°C
Water requirement	500	g water/g dry matter
Maximum LAI	6	
N fixation index	1	
Vascularity	0	
Cover crop	No	
Tilling applications	0	
Fertilizer applications	4	
Fertilization 1: date	5/20	
Fertilization 1: rate	37	kg N/ha
Fertilization 1: type	Urea	
Fertilization 2: date	8/20	
Fertilization 2: rate	40	kg N/ha
Fertilization 2: type	Urea	
Fertilization 3: date	10/20	
Fertilization 3: rate	40	kg N/ha
Fertilization 3: type	Urea	
Fertilization 4: date	12/20	
Fertilization 4: rate	40	kg N/ha
Fertilization 4: type	Urea	
Manure applications	0	
Weeding applications	0	
Irrigation applications	30	
Farming practices for year 2		
Number of crops planted	0	
Crop 1 (crop type code)	None	

Fertilizer applications	3	
Fertilization 1: date	1/20	
Fertilization 1: rate	40	kg N/ha
Fertilization 1: type	Urea	
Fertilization 2: date	2/20	
Fertilization 2: rate	40	kg N/ha
Fertilization 2: type	Urea	
Fertilization 3: date	3/20	
Fertilization 3: rate	40	kg N/ha
Fertilization 3: type	Urea	
Irrigation applications	32	
Farming practices for year 3		
Number of crops planted	0	
Crop 1 (crop type code)	None	
Fertilizer applications	0	
Irrigation applications	0	

DNDC Simulation: All the above-listed input information has been saved in a file named "Honolulu_sugarcane.dnd" stored in the package you received. Now you can open the input file on the DNDC user's interface and review all the settings. Please click OK to accept the input data and click "Run" to execute the 3-year simulation. Please open file C:\DNDC\Result\Record\Site\Day_FieldCrop_1.csv, Day_FieldCrop_2.csv and Day_FieldCrop_3.csv to review the modeled crop growth. By copying the columns of "LeafC", "StemC", "RootC" and "GrainC" in files into the provided Excel file "Honolulu_comparison.xls", you can compare the modeled daily crop biomass dynamics with the measured data. The result should like the figure as follows:

Observed and Modeled sugarcane biomass in Honolulu, Hawaii in 1990-1992

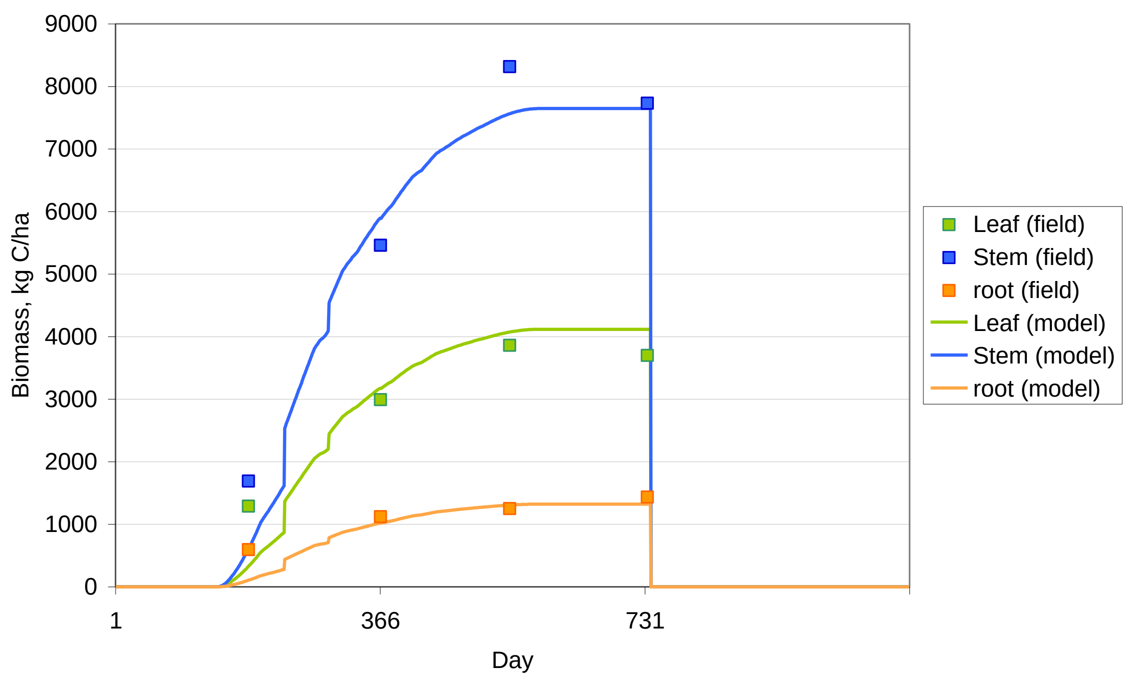


Figure 33. Measured and modeled biomass dynamics of sugarcane growing in Hawaii

Key Notes: This practice is aimed to show how to accurately simulate perennial crop growth by correctly setting the crop parameters for each year. In this case, the crop parameters were set only for the first year by indicating the crop would be harvested in the third year. For the second and third years, it is not necessary to define the crop parameters although all the farming management practices must be specified for each year.

Case 3: Long-term soil organic carbon simulation: 150-year SOC dynamics in a winter wheat field at Rothamsted, the U.K.

Site Description: Long-term observations on soil organic carbon (SOC) have been conducted through the Broadback Continuous Wheat Experiment in the Rothamsted Experimental Station (RES) in the U.K. since 1843. Winter wheat was planted every year except for a period between 1926 and 1967, during which the filed was fallowed 1 year in 5 years. The wheat field consisted of three plots with different fertilizing treatments. Plot 22 was amended with 3.5 tons/ha per year of farmyard manure, which contained 3000 kg C, 225 kg N, 40 kg P and 210 kg K since 1885. Plot 08 received synthetic fertilizer, ammonium sulfate, at rate 144 kg N/ha/yr with 35 kg P, 90 kg K/ha/yr. Plot 02 was a control without any fertilizer applied. During the First World War, yields were low when the weeds got out of control due to the lack of labor for hand weeding. During the period of 1926-1967, all the three plots were fallowed 1 year in 5 years to control the weeds. During 1843-1967, an old variety of winter wheat (Red Rostock) was planted; and in 1968 a new variety, Cappelle-Desprez, was introduced, which was a short-stemmed cultivar with a maximum grain yield 2 times higher than that of the old variety. Soils were sampled and analyzed at irregular intervals, usually every 20 years or so. The crop yields were also measured and reported at a basis of 10-year average. This is a unique case by proving the longest both yield and SOC records in the world. The field data were kindly provided by Dr. D.S. Jenkinson of RES to the DNDC group in University of New Hampshire for modeling tests in 1991.

Input Settings: The following table shows the climate, soil and management input data set for the manure treatment. The fertilizer and control treatments share all the input data except for fertilization.

Input parameter	Value	Unit
Climate		
Latitude	51.0	°
Weather station	Rothamsted, UK	
N in rainfall	2.0	mg N/l
Air NH_3 concentration	0.2	μg N/m^3
Atmospheric CO_2 concentration	350	ppm
Soil		
Land-use type	Upland cropland	
Texture	loam	
Bulk density	1.5	g/cm^3
pH	7.5	
SOC content (0-10 cm)	0.01	g C/g soil

Management

Number of cropping systems	4	
Span of cropping system 1	71	year
Years in a cycle of cropping system 1	1	year
Farming practices for year 1		
Number of crops planted	1	
Crop 1 (crop type code)	Winter wheat (2)	
Planting date	10/1	
Harvest date	8/1	
Fraction of above-ground residue left as stub	0.1	
Maximum yield	1200	kg C/ha
Grain fraction	0.23	
Leaf+stem fraction	0.45	
Root fraction	0.32	
Grain C/N ratio	25	
Leaf+stem C/N ratio	167	
Root C/N ratio	200	
TDD	1500	°C
Water requirement	150	g water/g dry matter
Maximum LAI	3	
N fixation index	1	
Vascularity	0	
Cover crop	No	
Tilling applications	1	
Tilling application 1: date	8/5	
Tilling application 1: depth	30	cm
Fertilizer applications	0	
Manure applications	1	
Manure application 1: date	9/1	
Manure application rate	3000	kg C/ha
Manure C/N ratio	13.3	
Weeding applications	0	
Irrigation applications	0	
Span of cropping system 2	14	year
Years in a cycle of cropping system 2	1	year
Farming practices for year 1		
Number of crops planted	1	
Crop 1 (crop type code)	Winter wheat (2)	
Planting date	10/1	
Harvest date	8/1	
Fraction of above-ground residue left as stub	0.1	
Maximum yield	1200	kg C/ha
Grain fraction	0.23	
Leaf+stem fraction	0.45	
Root fraction	0.32	
Grain C/N ratio	25	
Leaf+stem C/N ratio	167	
Root C/N ratio	200	
TDD	1500	°C
Water requirement	150	g water/g dry matter
Maximum LAI	3	
N fixation index	1	
Vascularity	0	

Cover crop	No	
Tilling applications	1	
Tilling application 1: date	8/5	
Tilling application 1: depth	30	cm
Fertilizer applications	0	
Manure applications	1	
Manure application 1: date	9/1	
Manure application rate	3000	kg C/ha
Manure C/N ratio	13.3	
Weeds problem	Serious (2)	
Weeding date	9/1	
Irrigation applications	0	
Span of cropping system 3	40	year
Years in a cycle of cropping system 3	5	year
Farming practices for year 1		
Number of crops planted	1	
Crop 1 (crop type code)	Fallow (0)	
Planting date	1/1	
Harvest date	12/31	
Fraction of above-ground residue left as stub	0	
Maximum yield	0	kg C/ha
Grain fraction	0	
Leaf+stem fraction	0	
Root fraction	0	
Grain C/N ratio	0	
Leaf+stem C/N ratio	0	
Root C/N ratio	0	
TDD	0	°C
Water requirement	0	g water/g dry matter
Maximum LAI	0	
N fixation index	1	
Vascularity	0	
Cover crop	No	
Tilling applications	0	
Fertilizer applications	0	
Manure applications	0	
Weeding applications	0	
Irrigation applications	0	
Farming practices for year 2, 3, 4 and 5		
Number of crops planted	1	
Crop 1 (crop type code)	Winter wheat (2)	
Planting date	10/1	
Harvest date	8/1	
Fraction of above-ground residue left as stub	0.1	
Maximum yield	1200	kg C/ha
Grain fraction	0.23	
Leaf+stem fraction	0.45	
Root fraction	0.32	
Grain C/N ratio	25	
Leaf+stem C/N ratio	167	
Root C/N ratio	200	
TDD	1500	°C
Water requirement	150	g water/g dry matter

Maximum LAI	3	
N fixation index	1	
Vascularity	0	
Cover crop	No	
Tilling applications	1	
Tilling application 1: date	8/5	
Tilling application 1: depth	30	cm
Fertilizer applications	0	
Manure applications	1	
Manure application 1: date	9/1	
Manure application rate	3000	kg C/ha
Manure C/N ratio	13.3	
Weeding applications	0	
Irrigation applications	0	
Years in a cycle of cropping system 4	1	year
Farming practices for year 1		
Number of crops planted	1	
Crop 1 (crop type code)	Winter wheat (2)	
Planting date	10/1	
Harvest date	8/1	
Fraction of above-ground residue left as stub	0.1	
Maximum yield	2800	kg C/ha
Grain fraction	0.37	
Leaf+stem fraction	0.38	
Root fraction	0.25	
Grain C/N ratio	25	
Leaf+stem C/N ratio	316	
Root C/N ratio	210	
TDD	1500	°C
Water requirement	150	g water/g dry matter
Maximum LAI	3	
N fixation index	1	
Vascularity	0	
Cover crop	No	
Tilling applications	1	
Tilling application 1: date	8/5	
Tilling application 1: depth	30	cm
Fertilizer applications	0	
Manure applications	1	
Manure application 1: date	9/1	
Manure application rate	3000	kg C/ha
Manure C/N ratio	13.3	
Weeding applications	0	
Irrigation applications	0	

DNDC Simulation: All input information for the case has been saved in three files named "UK_Rothamsted_manure.dnd", "UK_Rothamsted_fertilizer.dnd" and "UK_Rothamsted_control.dnd" stored in the package you received. Now you can open the input files on the DNDC user's interface and review all the settings. After reviewing, you can click "OK" and "Run" to execute the 150-year simulations for each treatment plot. It takes about 5 minutes for DNDC to accomplish the simulation for each of the three treatment plots. After each simulation, you can open a file named

“Multi_year_summary.csv” stored at C:\DNDC\Result\Record\Site\. By copying the columns of “GrainC_yield” and “SOC 0-20cm, kg C/ha” into the provided Excel file “UK_Rothamsted_wheat_150yr.xls”, you will be able to compare the modeled crop yields and SOC dynamics with the measured data. The results should like the follows:

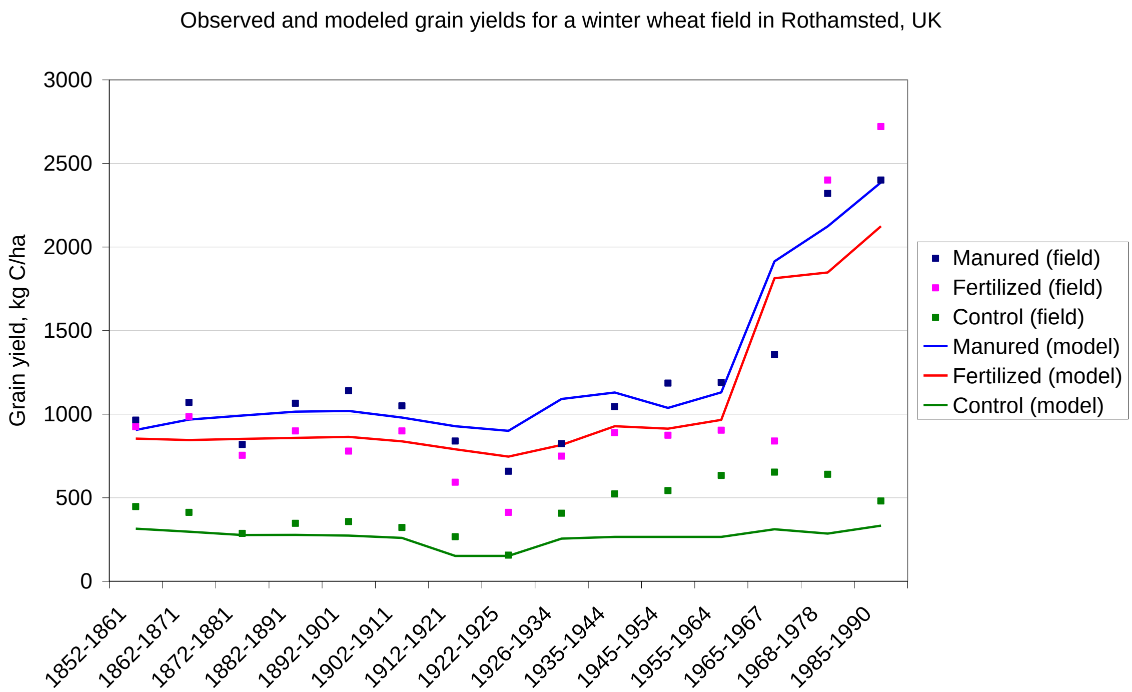


Figure 34. Measured and modeled long-term (150 years) yields of winter wheat in Rothamsted, the U.K.

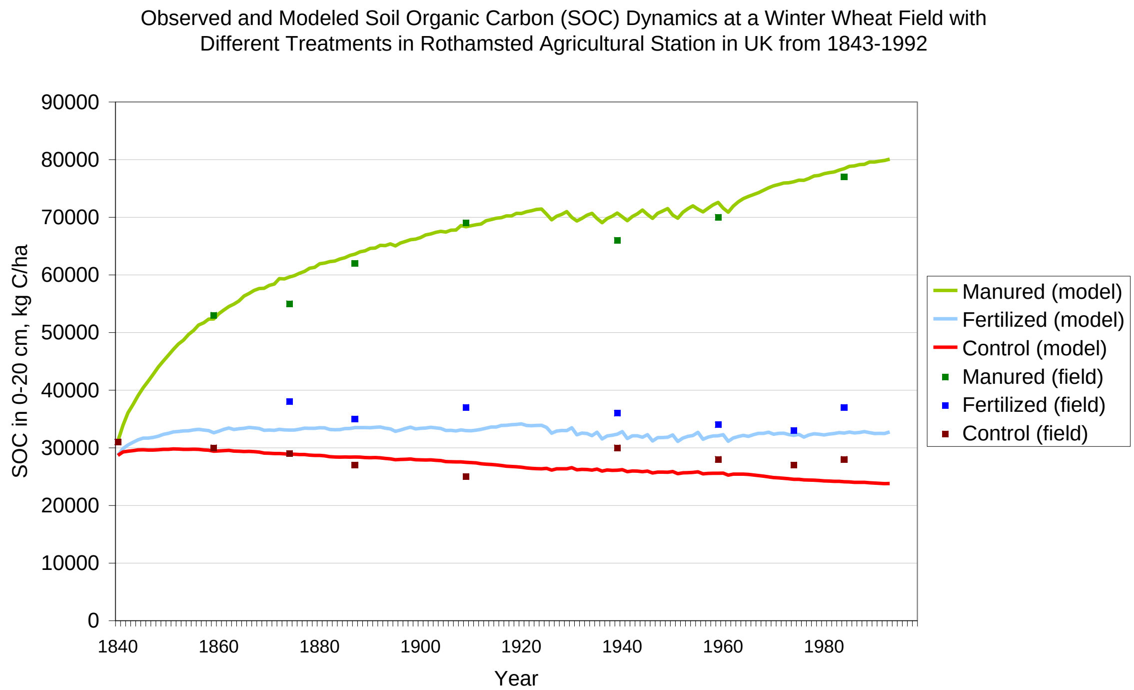


Figure 35. Measured and modeled long-term (150 years) SOC dynamics in a winter wheat field in Rothamsted, the U.K.

Key Notes: This practice is aimed to teach the users how to set a long-term simulation by defining the cropping systems and the cycles within each cropping system. Crop litter incorporation and external organic matter (i.e., manure) amendment dominate SOC dynamics in most agro-ecosystems. It is crucial for modeling SOC dynamics to correctly simulate the crop biomass production. The 150-year observations from the Rothamsted experiment indicate that the soil at the fertilized plot didn't gain much carbon although its crop yields reached the maximum with adequate synthetic fertilizer applied. In contrast, addition of external C source through manure application significantly elevated SOC contents. The users are encouraged to change (1) manure application rate, (2) manure C/N ratio and (3) fraction of above-ground crop residue incorporated to observe how the long-term SOC dynamics can be sensitively affected by the quantity and quality of the organic C additions. If you are interested in C biogeochemistry more than only soil C sequestration, please carefully study on all the C pools and fluxes recorded in the modeled result files (e.g., "Day_SoilC_1.csv" etc.). That would provide you more insights about how soil C is controlled by the climate, soil, vegetation and management conditions.

Case 4: N2O fluxes from a crop field in Arrou, France

Site Description: Experiment focusing on N2O emissions was conducted by Hénault and his colleagues at a crop field (48.1°N, 1.1°W) in Arrou, France in 1998 and 1999 (Hénault, C., Bizouard, F., Laville, P., Gabrielle, B., Nicoullaud, B., Germon, J. C., and Cellier, P., 2005a. Predicting in situ soil N2O emission using NOE algorithm and soil database. Global Change Biology 11, 115–127). Rapeseeds and winter wheat were planted as a typical rotation for the area. Synthetic fertilizer was applied routinely. Crop biomass, inorganic N (i.e., nitrate and ammonium), soil temperature and moisture, and N2O fluxes were measured during the experimental period. High N2O fluxes were measured when the urea and ammonium fertilizer were applied in the warm soil in late March in 1999.

Input Settings: The climate, soil and management input data were set as follows:

Input parameter	Value	Unit
Climate		
Latitude	48.1	°
Weather station	Arrou	
N in rainfall	1	mg N/l
Air NH_3 concentration	0.06	µg N/m^3
Atmospheric CO_2 concentration	350	ppm
Soil		
Land-use type	Upland cropland	
Texture	Silty loam	
Bulk density	1.29	g/cm^3
pH	6.4	
SOC content (0-10 cm)	0.0096	g C/g soil
Management		
Number of cropping systems	1	
Span of cropping system 1	2	year
Years in a cycle of cropping system 1	2	year
Farming practices for year 1		
Number of crops planted	2	
Crop 1 (crop type code)	Rapeseeds (25)	
Planting date	1/1	
Harvest date	6/1	
Fraction of above-ground residue left as stub	1	
Maximum yield	2400	kg C/ha
Grain fraction	0.45	
Leaf+stem fraction	0.4	
Root fraction	0.15	
Grain C/n ratio	12	
Leaf+stem C/N ratio	45	
Root C/N ratio	52	
TDD	700	°C
Water requirement	450	g water/g dry matter
Maximum LAI	4	
N fixation index	1	
Vascularity	0	
Cover crop	No	
Crop 2 (crop type code)	Winter wheat (2)	
Planting date	10/21	
Harvest date	7/12	
Fraction of above-ground residue left as stub	0.5	
Maximum yield	3500	kg C/ha
Grain fraction	0.45	
Leaf+stem fraction	0.38	

Root fraction	0.17	
Grain C/n ratio	30	
Leaf+stem C/N ratio	45	
Root C/N ratio	70	
TDD	1300	°C
Water requirement	180	g water/g dry matter
Maximum LAI	3	
N fixation index	1	
Vascularity	0	
Cover crop	No	
Tilling applications	1	
Tilling application 1: date	6/2	
Tilling application 1: depth	45	cm
Fertilizer applications	1	
Fertilization 1: date	1/1	
Fertilization 1: rate	90	kg N/ha
Fertilization 1: type	NH4NO3	
Manure applications	0	
Weeding applications	0	
Irrigation applications	0	
Farming practices for year 2		
Number of crops planted	2	
Crop 1 (crop type code)	Fallow (0)	
Cover crop	No	
Tilling applications	1	
Tilling application 1: date	7/13	
Tilling application 1: depth	45	cm
Fertilizer applications	3	
Fertilization 1: date	2/6	
Fertilization 1: rate	58	kg N/ha
Fertilization 1: type	NH4NO3	
Fertilization 2: date	3/12	
Fertilization 2: rate	83	kg N/ha
Fertilization 2: type	NH4NO3, urea	
Fertilization 3: date	3/27	
Fertilization 3: rate	40	kg N/ha
Fertilization 3: type	NH4NO3, urea	
Manure applications	0	
Weeding applications	0	
Irrigation applications	0	

DNDC Simulation: All the above-listed input information has been saved in a file named "Arrou_9899.dnd" stored in the package you received. Now you can open the input file on the DNDC user's interface and review all the settings. After the simulation, please open files Day_FieldCrop_1.csv and Day_FieldCrop_2.csv at C:\DNDC\Result\Record\Site\ to review the modeled crop biomass for year 1998 and 1999, respectively. By copying the columns of "LeafC", "StemC", "RootC" and "GrainC" in the files into the Excel file "Arrou_comparison.xls" provided in the training package, you can compare the modeled daily crop biomass dynamics with the measured crop data. To view the modeled soil N profiles and N2O fluxes, you will need to open files Day_SoilN_1.csv and Day_SoilN_2.csv. By copying the columns "Urea", "NH4+", "NO3-" and

“Exchangeable-NH4” of 0-20 cm to file “Arrou_comparison.xls” to compare the measured and modeled soil N dynamics. Copying column “N2O” in the modeled files to “Arrou_comparison.xls” will allow you to compare the modeled N2O fluxes with the measured N2O data. The result should look as follows:

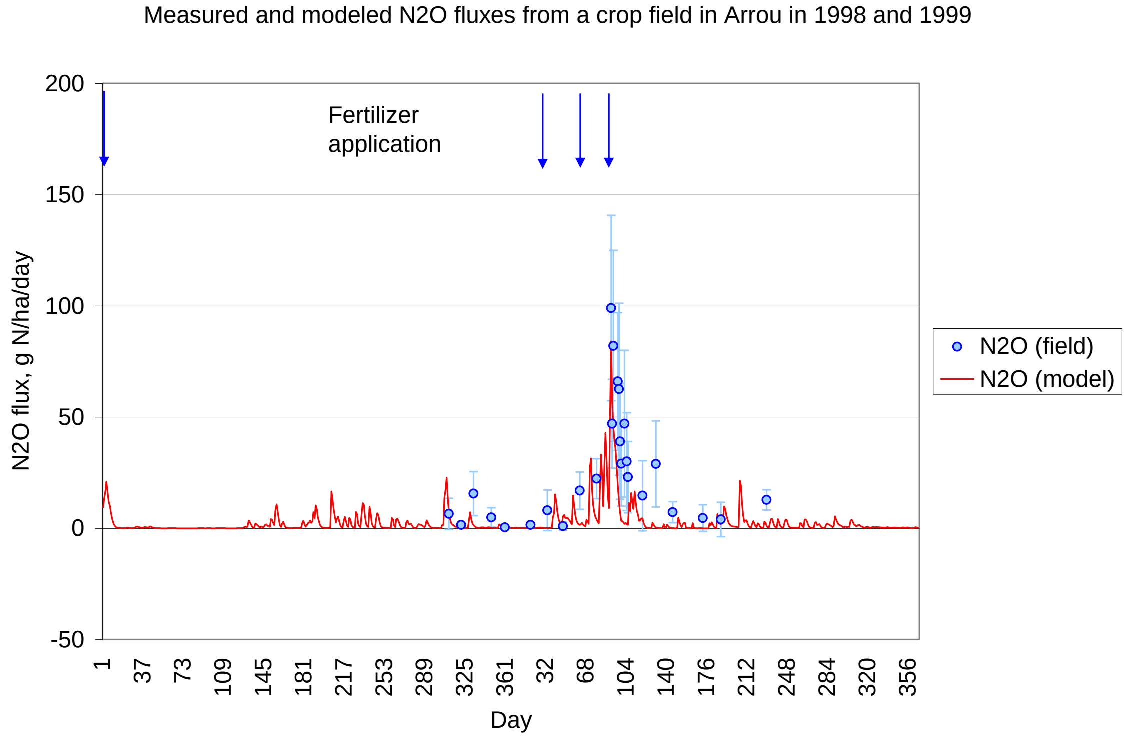


Figure 36. Measured and modeled N2O emissions from a crop field in France

Key Notes: This practice is aimed to demonstrate how to compare measured and modeled soil N fluxes including N2O emissions. The soil N status is controlled by the N input, mainly from fertilization for this case, and the N uptake by crops. Accurately simulating crop growth will ensure you to get correct N contents in the soil profile that will finally help with N gas prediction. N gas emission is sensitive to the fertilizer type, application rate, application depth, N release rate from the fertilizer, and the use of nitrification inhibitor (for urea and ammonium fertilizers). Please try varying (1) fertilizer type, (2) application rate, (3) application depth, (4) using slow-release fertilizer, and (5) using nitrification inhibitor to observe their impacts on N2O and other N gas emissions from the tested site. If you are interested in N biogeochemistry more than only N gases, please carefully study on all the N pools and fluxes recorded in the modeled result files (e.g., “Day_SoilN_1.csv” etc.). That would provide you more insights about how soil N is controlled by the climate, soil and management conditions.

Case 5: Methane fluxes from a paddy rice field in Texas, USA

Site Description: Ronald Sass and his colleagues measured methane (CH4) emissions from a paddy rice field at Texas A&M University Agricultural Center (30.2°N, 93.4°W) near Beaumont in 1994. The variety of rice was Mars with a relatively long growth period, which was planted in early April and harvested in middle August. During the rice growing season, the field was drained once. It was observed by the researchers that the mid-season drainage dramatically diminished the CH4 emission.

Input Settings: The climate, soil and management input data for the site simulation were set as follows:

Input parameter	Value	Unit
Climate		
Latitude	30.2	°N
Weather station	Beaumont	
N in rainfall	2	mg N/l
Air NH_3 concentration	0.06	µg N/m^3
Atmospheric CO_2 concentration	350	ppm
Soil		
Land-use type	Upland cropland	
Texture	Sandy clay loam	
Bulk density	1.3	g/cm^3
pH	6.5	
SOC content (0-10 cm)	0.035	g C/g soil
Management		
Number of cropping systems	1	
Span of cropping system 1	1	year
Years in a cycle of cropping system 1	1	year
Farming practices for year 1		
Number of crops planted	1	
Crop 1 (crop type code)	Paddy rice (20)	
Planting date	4/5	
Harvest date	8/11	
Fraction of above-ground residue left as stub	0.9	
Maximum yield	6400	kg C/ha
Grain fraction	0.41	
Leaf+stem fraction	0.54	
Root fraction	0.05	
Grain C/n ratio	27	
Leaf+stem C/N ratio	45	
Root C/N ratio	55	
TDD	2800	°C
Water requirement	500	g water/g dry matter
Maximum LAI	6	
N fixation index	1	
Vascularity	1	
Cover crop	No	
Tilling applications	2	
Tilling application 1: date	4/1	
Tilling application 1: depth	30	cm
Tilling application 2: date	8/15	
Tilling application 2: depth	30	cm
Fertilizer applications	3	
Fertilization 1: date	4/5	

Fertilization 1: rate	56	kg N/ha
Fertilization 1: type	Urea	
Fertilization 2: date	5/10	
Fertilization 2: rate	78	kg N/ha
Fertilization 2: type	Urea	
Fertilization 3: date	6/10	
Fertilization 3: rate	50	kg N/ha
Fertilization 3: type	Urea	
Manure applications	0	
Flooding applications	2	
Flooding 1: date	5/17	
Draining 1: date	6/16	
Flooding 2: date	6/21	
Draining 2: date	7/27	
Irrigation applications	0	

DNDC Simulation: All the above-listed input information has been saved in a file named "Texas_Beaumont_CH4.dnd" stored in the package you received. By running DNDC with this input file, you will obtain a file named "Day_SoilC_1.csv" at C:\DNDC\Result\Record\Site\. By copying the columns of "CH4-flux" in the file into the Excel file "Txas_Mars_1.xls" provided in the training package, you can compare the modeled daily CH4 fluxes with the measured data. The result should look like as follows:

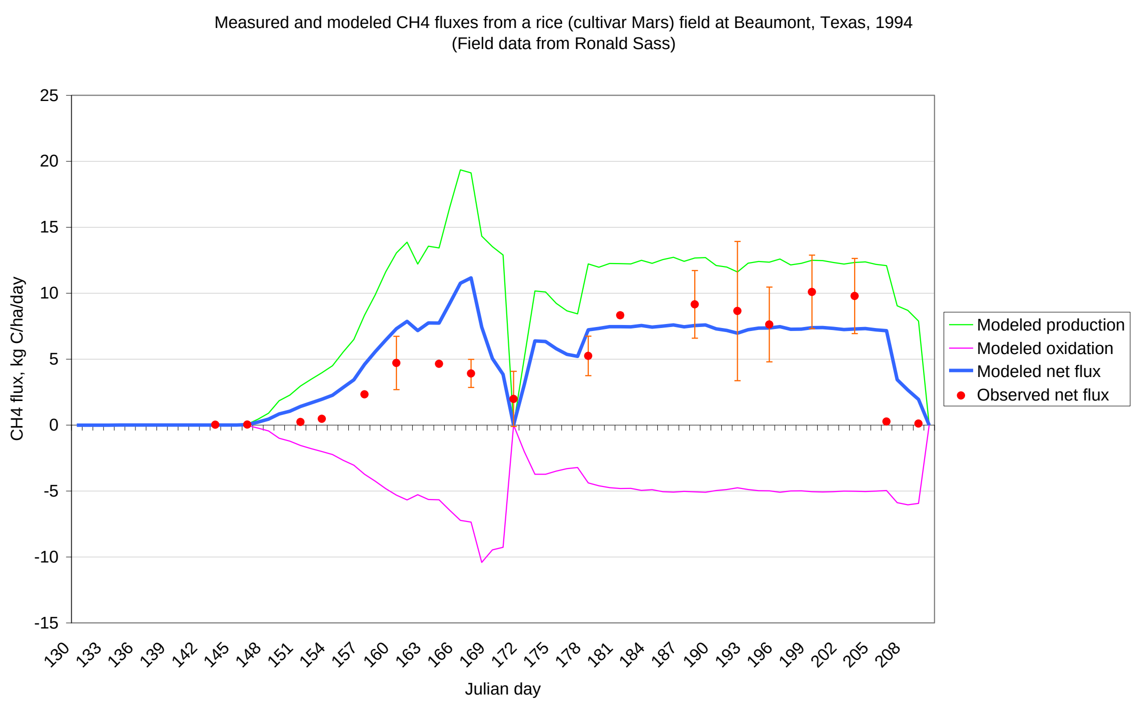


Figure 37. Measured and modeled CH4 emissions from a paddy rice field in Texas, he U.S.

Key Notes: This practice is aimed to demonstrate how to simulate wetland biogeochemistry. What that makes the wetland different from the upland biogeochemistry is the high water table (WT). DNDC provides four options to define WT dynamics, which include (1) specifying flooding start and end dates; (2) defining rainfed with rain-water collecting index; (3) using observed WT data; and (4) adopting a group of hydrological factors empirically induced from historical WT observations. In this case, we utilized option 1 that should be applicable for most irrigated rice fields. With CH_4 emission as a major concern of the ecosystem services of wetlands, you may be interested in exploring how you can enhance the greenhouse gas mitigation by altering the water management, rice biomass production, straw amendment and other management practices for this case.

VII. RELEVANT PUBLICATIONS

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