Dairy-CropSyst

User Manual



**Biological Systems Engineering**

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# Acknowledgement

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# Introduction

Dairy confined animal feeding operations (CAFOs) may have deleterious effects on the environment by concentrating nutrients and emitting high amounts of greenhouse gasses (GHG). To reduce these effects in the United States, CAFOs are required to implement plans to minimize the natural resource contamination and to report GHG and ammonia emissions that exceed EPA guidelines.

The IPCC protocol for GHG emission lack farm level resolution, similarly the use of constant emission factors has proven insufficient for quantifying the gaseous emission from livestock operations. Use of modelling tools may aid in planning and evaluating farm scale mitigation efforts. A model that accommodates the impact of existing and emerging manure treatments on emissions and nutrient fate would provide more comprehensive simulation for whole-farm nutrient cycle.

# Model Description

Dairy-CropSyst is a decision support tool for researchers, extensionists, and CAFO managers. It could be used to evaluate the effects of different manure treatment options including anaerobic digestion, nutrient recovery, and solid separation on net GHG emission and manure nutrient fate from a whole-farm perspective from the barn to crop land application. The model integrates established models, performance parameters of different manure treatments, and a cropping systems model, CropSyst, to predict the soil nutrient budget and carbon footprint.

At various stages on a dairy facility manure nutrients undergo different chemical reactions driven by environmental factors. The mass balance of these nutrients in organic and inorganic form is modeled as they pass from one stage to another on a daily time step. An animal sub-model based on feed intake, milk production, and body weight simulates the CO2 and CH4 emission during respiration and enteric fermentation, manure production, and manure nutrient composition from a single lactating cow. Manure excreted by the animal is received on the barn floor and stays there for 6-12 hrs depending on the frequency of manure scrape/flush. The main process occurring during this time is the urea hydrolysis to total ammonium nitrogen (TAN) and subsequent NH3 volatilization. A small fraction of C and N is also mineralized from manure in the barn. Dairy-CropSyst uses an empirical model to estimate CO2 and CH4, while N2O emission from the barn floor is estimated using an emission factor. In the lagoon, manure stays for a prolonged time until field conditions allow manure application. During lagoon storage, the manure organic matter decomposes releasing CO2 and CH4. This process is simulated using a three-pool first order decay model corrected for temperature and dissolved oxygen concentration. During decomposition, the organic N in the lagoon is converted into inorganic form. This ammonification is estimated using the C:N ratio of manure and the N is added to the existing TAN pool. Major N losses from the lagoon are in the form of NH3 volatilization, however some N is also mineralized during nitrification and denitrification. The manure is pumped out periodically to cropland for fertigation. A fertigation event is generated for a cropping systems model. But the manure gets treated for GHG reduction and nutrient recovery before it is stored in the lagoon. Dairy-CropSyst allows the user to select manure treatment options including AD, fiber separation, fine solids removal, and TAN recovery. Model default solids reduction and nutrient recovery factors for these treatments are based on published values and industry data. The field component of the simulation is handled by CropSyst, a well-known, tested model that is used to study the effect of cropping systems management on productivity and the environment. CropSyst simulates the soil water budget, soil-plant nitrogen budget, biomass production, crop yield, and carbon footprint.

# Model Architecture and System Requirement

Dairy-CropSyst consists of three independent executables that communicate through a common database (**Figure 2**). The user interface (Client.exe) is a Windows Presentation Foundation application coded in C# using the Model-view-viewmodel design pattern. The user interface runs on the Microsoft .NET 4.5 framework. The dairy model and associated file input and output logic (scenario\_run.exe) are contained in a Windows console application and were coded in C++. The field model, CropSyst (CropSyst\_4.exe), is a Windows console application coded in C++. The database consists of a series of text-based and binary files located on the user’s hard drive.

Figure 1 illustrates the program architecture, the user enters information using client.exe which writes the data to the database as a Dairy-Cropsyst scenario file, and, if a farm field is to be simulated, writes to a CropSyst scenario file. Next, the user invokes client.exe to run the model at which point scenario\_run.exe is executed by client.exe. Then, scenario\_run.exe reads the scenario and weather data from the database and runs the necessary dairy models and writes emission and nutrient data. If a farm field simulation is specified, scenario\_run.exe writes fertigation and management information to the database and executes CropSyst\_4.exe. Once the dairy models and, optionally, the field model is completed, scenario\_run.exe aggregates output information and creates a Microsoft Excel file with a summary of the output. Finally, client.exe prompts the user that the simulation has finished and displays the results.

The software requires operating systems with Windows 7 or higher and Microsoft .NET 4.5 Framework, the program requires about 500 MB of hard drive space.



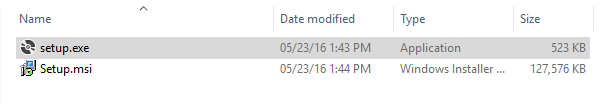
**Figure 1. Relationships among the major components of Dairy-CropSyst. The user interface writes scenario-specific information to the database and executes the diary models and simulation logic, which in turn executes the field model. Each of the three components can run in isolation if the database is configured properly.**

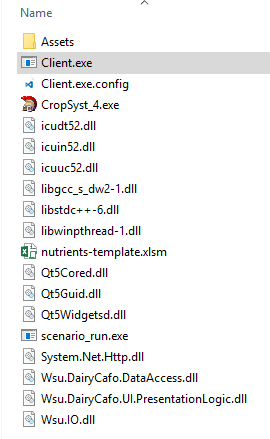
Dairy-CropSyst current version is intended for research and teaching, the weather and soil packaged is for demonstration only and cover part of the Washington and Idaho. The current user interface hides lot of complexity and feature of the model, a Pro version will be package with CS Suit in another version.

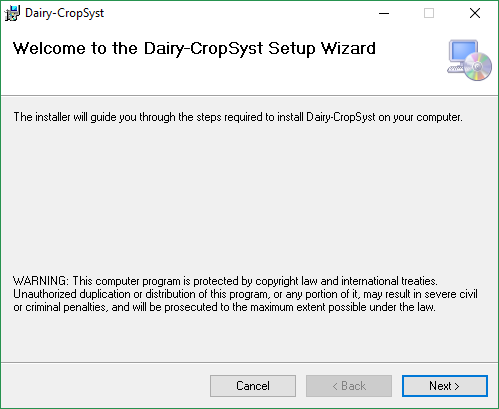
# Installation

Installation files can be found at <http://bsyse.wsu.edu/faculty/stockle/>

Install Dairy-CropSyst by running “setup.exe” and by following the on-screen instructions. The program will be installed to the Dairy-CropSyst directory in your Program Files (x86) folder.



****



# The installation folder and you

After the installation wizard has finished installing Dairy-CropSyst to your computer, browse to the installation directory (default is “C:\Program Files (x86)\DairyCropSyst”).

Do not make any changes to these files unless you know what you’re doing

**Client.exe** - The scenario editor; this is the tool that user likely be interacting with the most

**CropSyst\_4.exe** – The CropSyst model. New versions will likely come out from time to time. You’ll need to overwrite this file (make a backup first!) and not the one in your CropSyst installation directory

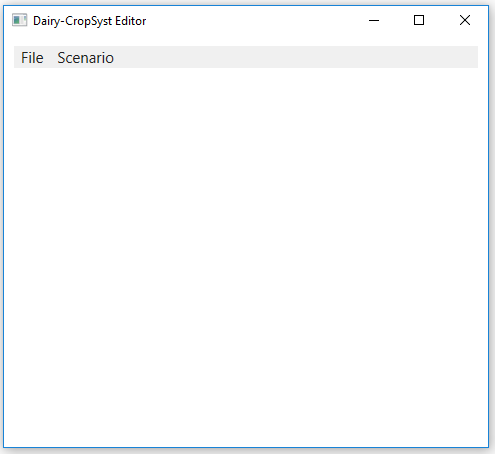
**nutrients-template.xlsm** – This is used to create the excel output if output is enabled

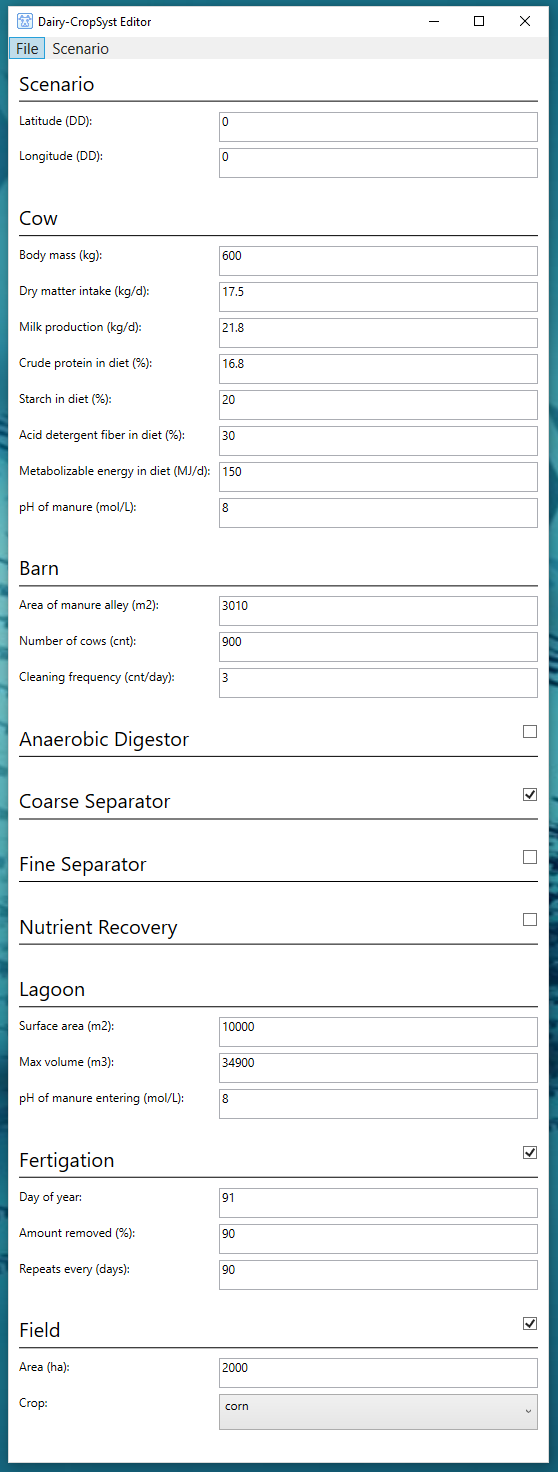
**scenario\_run.exe** – The dairy model. If you manually edit dairy scenario files, you’ll want to run this program from the command window or by using a bat file.

**Assets** – This is where template CropSyst scenarios reside as well as weather and soil files.

# Meet your new Editor

* Double click on client.exe opens the user interface.



Click on File tab to opens a new or existing scenario.

Enter the coordinates of location, the user interface automatically load soil and weather info from the database

Build your virtual farm

To include crop field emission and nutrients fate check field and select a CropSyst scenario from drop down.

Save Scenario by clicking of file tab and save.

The saved scenario can be also edited in Notepad++

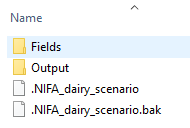
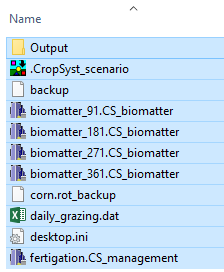
Run simulation by clicking on Scenario tab

# Running your own scenarios

By default, Dairy-CropSyst only allows users to choose between two field types; alfalfa and corn. Both simulate monocropping … [*template scenarios have not been created, will describe in details once we make some decisions*].

If you wish to create a custom field simulation, then follow these steps:

1) Browse to a Dairy-CropSyst scenario directory, open the Fields directory. You should see a folder named either “corn” or “alfalfa”. [*NOTE: Do not edit the name of the folder – if you do there is a chance the Editor will overwrite your custom scenario*] Open the folder. This is the CropSyst scenario directory.

 ->  -> 

2) Select all the files and delete them

3) Copy the files from your custom CropSyst scenario into this directory

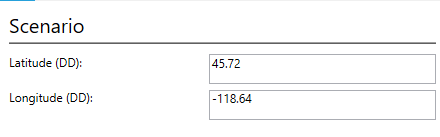
You are now ready to run the custom scenario from the Editor.

[*NOTE: You may need to update the area of the field and enable the field in the Editor*]

[*NOTE: If you wish to use custom soil and weather then do not save the Dairy-CropSyst scenario via the Editor – this will overwrite soil and weather and set them to be the same geo-coordinates as the Dairy. You may run the scenario using the Editor but do not save it (alternatively, run the scenario using scenario\_run.exe). Make sure to specify the area of the field in the CropSyst Scenario Editor or by adding “size=xxx” in the “[field]” section of the scenario file.*]

# Weather and Soil Data

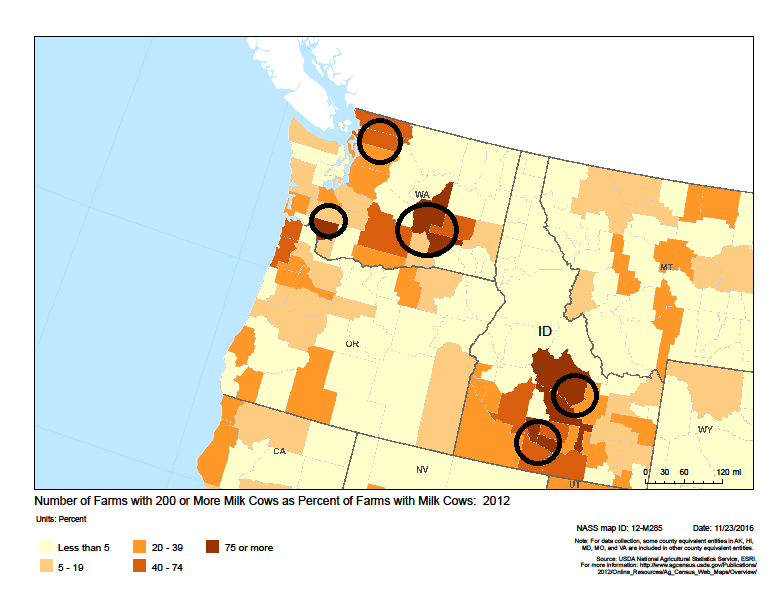
Weather and soil parameter files are chosen by the Editor based on the latitude and longitude specified.



When the scenario is saved, the files in the Assets\Database\{Soil/Weather} directory of the installation directory are parsed and the nearest location to the specified geo-coordinates is chosen. [*NOTE: A location will always be chosen, even if it’s thousands of miles away, so be careful.*]

# Building up virtual farm and linking soil and weather files

The existing data base cover only the location in States of Washington and parts of Southern Idaho where most of the state’s dairy operations exists. These tentative locations are highlighted in the map below with circle, the exact coordinates are provided in appendix 2.



The supplied soil and weather databases can be supplemented to expand the spatial reach of the model or to use custom datasets. The files need to be in the following pattern following CropSyst UED format:

xx.xxxx{N/S}\_xxx.xxxx{W/E}.UED and xx.xxxx{N/S}\_xxx.xxxx{W/E}.CS\_soil

where x is a number and {N/S} is either the character N or S and {W/E} is either the character W or E. For example, the following is for the weather file at the coordinates 48.9832, -122.4680:

48.9832N\_122.4680W.UED

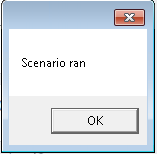
The weather and soil file should be saved at following locations, the program will extract them by entering the coordinates

C:\ProgramData\DairyCropSyst\Database\Weather

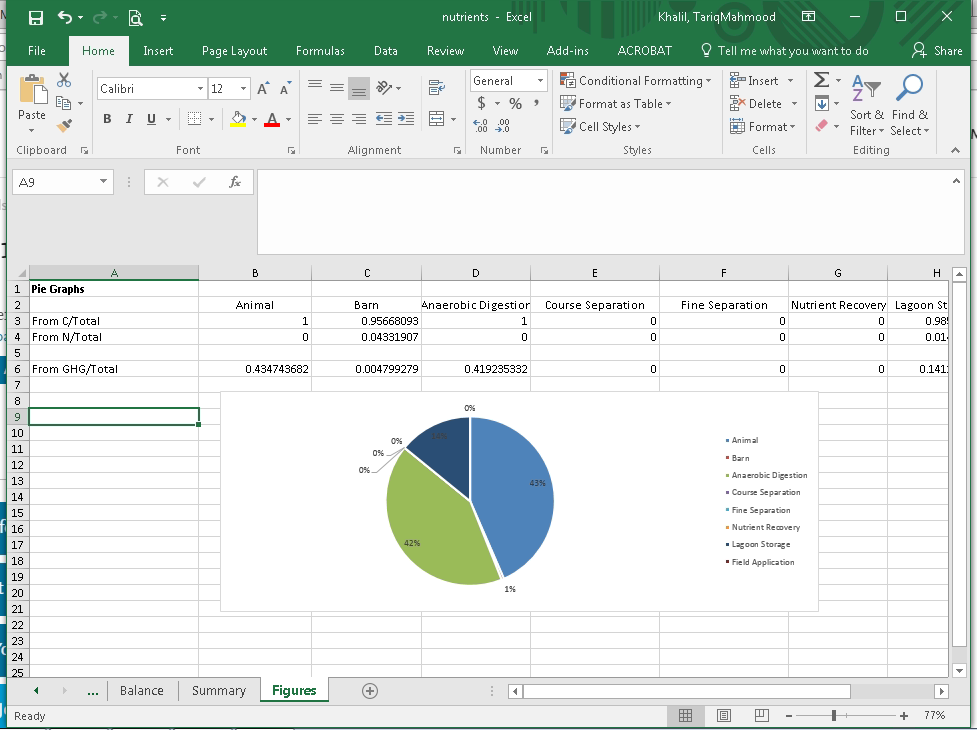
C:\ProgramData\DairyCropSyst\Database\Soil

# Getting Simulation Output

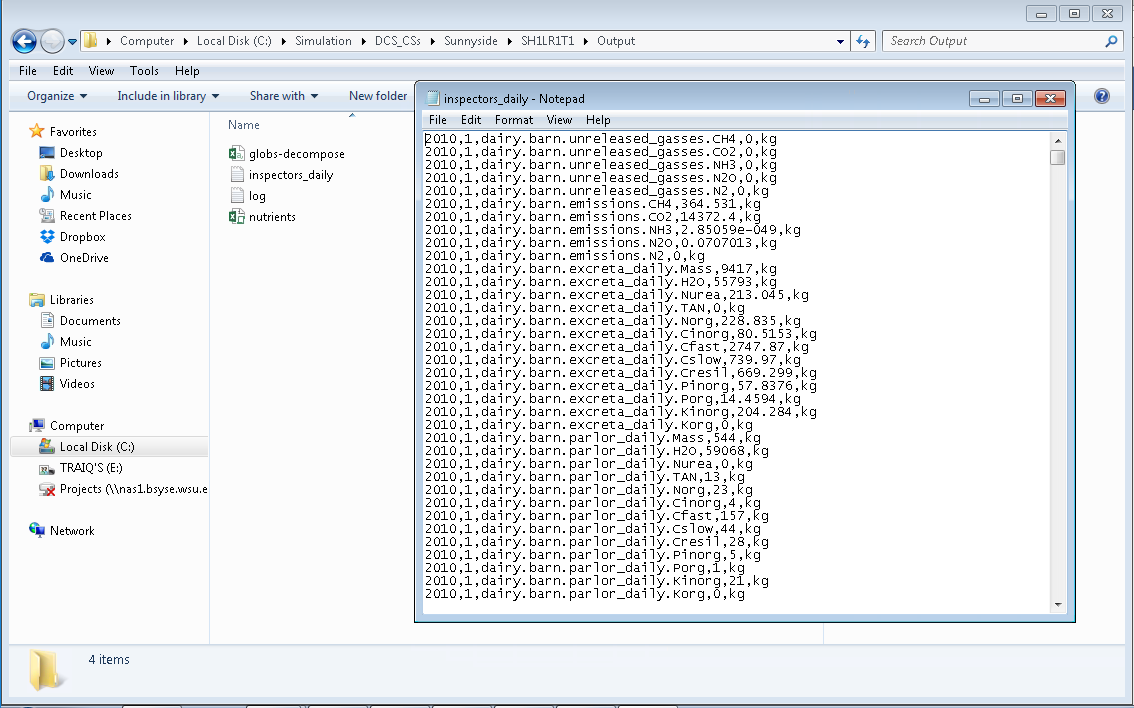
When the scenario runs successfully the program display message.



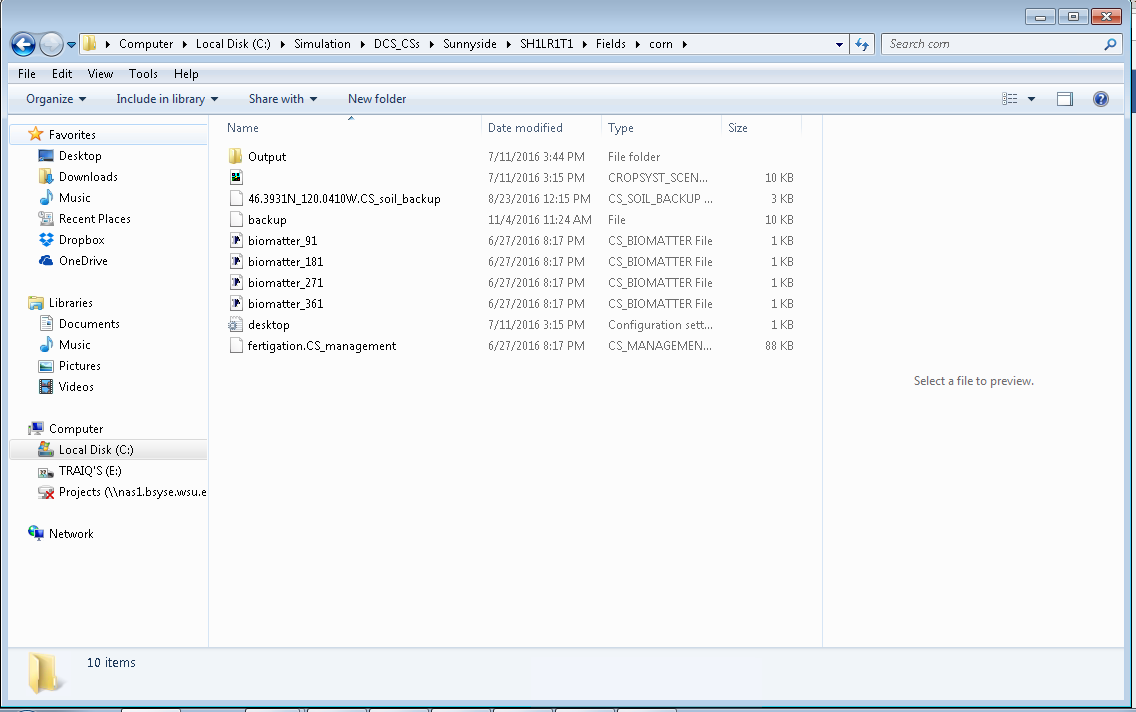
The model generates a common summary for both dairy farm and field crop.



Daily value for dairy component are stored in text file



While the CropSyst output can be accessed from the field folder



# Appendix 1

**Model processes characterizing dairy manure nutrients and emissions.**

|  |  |  |
| --- | --- | --- |
| **Description** | **Equation** | **Reference** |
| **Manure Production**  Manure Excreted | Mexc = manure excreted by dairy cow (kg d-1 cow-1)  MP = Milk production (kg d-1 cow-1) | (ASABE, 2005)  (Nennich et al., 2005) |
| Urine Excreted | Uexc = Urine excreted (kg d-1 cow-1)  BW = Dairy cow body weight (kg) |
| Dry Matter Excreted | DMexc = Dry matter in manure (kg d-1 cow-1)  DMI = Dry matter intake (kg d-1 cow-1) |
| **Manure Nutrients**  Nitrogen Excreted | Nexc =Total nitrogen excreted in manure (kg d-1 cow-1) | (Bannink et al., 1999)  (de Boer et al., 2002)  (NRC, 2001)  (ASABE, 2005)  (Nennich et al., 2005) |
| Urine Nitrogen | Nurine = Nitrogen in urine (kg)  Ndiet = Nitrogen in animal diet (kg)  CPdiet = Crud protein in animal diet (%)  Nmilk= Nitrogen in milk (kg)  (Fresh milk contains about 3.2% of crude protein and 15.7% of it is considered to be nitrogen) |
| Carbon Excreted | Cexc = Carbon excreted in manure (kg d-1 cow-1)  C:N = Carbon nitrogen ratio in fresh manure |
| Phosphorus Excreted | Pexc = Phosphorous excreted in manure (kg d-1 cow-1) |
| Potassium Excreted | Kexc = Potassium excreted in manure (kg d-1 cow-1) |
| **Dairy Barn Emission**  Carbon Dioxide | CO2 resp = Carbon dioxide respired by dairy cow (kg d-1 cow-1)  CO2 floor = Carbon dioxide emitted from manure on barn floor (kg d-1 m-2)  N = Number of dairy cows  A = Area of barn manure alley (m2)  T = Temperature (°C) | (Kirchgessner et al., 1991)  (Rotz and Chianese, 2008) |
| Methane | Emax = 45.98 (MJ CH4 head-1 d-1)  ME = Metabolized energy intake (MJ head-1 d-1)  CH4 resp = Dairy cow enteric fermentation methane emission(kg d-1 cow-1)  CH4 floor = Methane emitted from manure on barn floor (kg d-1 m-2)  Starchf = animal feed starch fraction  ADFf = Acid detergent fiber fraction in feed |
| Urea Hydrolysis | rurea = Urea hydrolysis (kg d-1)  rmax\_urea = 0.162 (kg m-3 min-1)  |Urea| = Urea N concentration (kg N m-3)  Kurea = 0.056 (kg N m-3)  V = volume of manure (m3) | (Monteny et al., 1998) |
| NH3 Volatilization | Φ = ammonia volatilization (kg N d-1)  A = lagoon surface area  k = ammonia mass transfer coefficient (m d-1)  f = fraction of ammonia nitrogen in TAN  TAN = Total ammonium N concentration (kg N m-3)  H = Henry constant |
| **Lagoon Processes and Emission**  Carbon Mineralization | Cmin = Carbon Mineralized (kg d-1)  ft = temperature correction factor  fDO = dissolved oxygen correction factor  k = decomposition rate constant (d-1)  C= Carbon (kg)  Subscript “l” = labile pool  Subscript “s” = slow pool  Subscript “r” = recalcitrant pool  Where  and  +  DO = Dissolved oxygen (mg l-1)  maxDOana = Maximum dissolved oxygen at which anaerobic decomposition stops (i.e. 1 mg l-1)  minDOana = Mimimum dissolved oxygen at which aerobic decomposition stops (i.e. 0.1 mg l-1) | (Paul et al., 1999)  (Schomberg et al., 2002)  (Asaeda et al., 2000) |
| Nitrification | rNitr = nitrification rate (kg N m-3)  |NH4| = ammonium concentration (kg N m-3)  KNH4 = half time ammonium saturation constant (1kg N m-3)  KDO = half time DO saturation constant (2 mg l-1)  CT = Temperature correction factor  CpH = pH correction factor | Kadlec & Knight (1996) |
| Denitrification | rDenit = denitrification rate (kg N d-1)  |NO3| = nitrate concentration (kg N m-3)  V = volume of manure(m3)  Ө = temperature function | Kadlec & Knight (1996) |
| N2O Emission  NH3 Emission | rN2O\_Nitr= N2O emitted during Nitrification (kg N d-1)  rN2O\_Dnitr= N2O emitted during denitrification (kg N d-1)  kDenit\_20C = denitrification rate at 20 °C ( 0.57 d-1)  rDeni = total denitrification (kg N d-1)  RN2/N2O = ratio of di-nitrogen to nitrous oxide  Φ = ammonia volatilization (kgN d-1)  A = lagoon surface area  k = ammonia mass transfer coefficient (m d-1)  f = fraction of ammonia nitrogen in TAN  TAN = Total ammonium N concentration (kgN m-3)  H = Henry constant | (Maag & Vinther, 1996)  (Parton et al., 1996) |
| Volume Balance | es = saturation vapor pressure at the temperature of the water surface (Pa)  ea = vapor pressure of the air (Pa)  Rd = gas constant (287.04 J kg-1 K-1)  Ts = temperature of the surface (K)  Ur = wind speed at 1 m (m s-1)  0.622 = ratio of the molecular weights of water and dry air  Ce = bulk transfer coefficient (dimensionless, 2.8x 10-3)  A = area of the liquid surface (m2)  Ks = saturated hydraulic conductivity (m s-1)  H = waste depth above the bottom of the lagoon (m)  As = areal area of the submerged side embankments (m2).  Ab = areal area of the flat bottom (m2). | (Ham, 2001) |

# Appendix 2

Geocoordinates of selected dairy sites in WA and ID included in soil and weather download package.

|  |  |
| --- | --- |
| Washington State | Idaho |
| Latitude, Longitude | |
| 48.894667, -122.706556  48.934167, -122.410722  48.991333, -122.278583  48.982444, -122.456750  48.929139, -122.306806  48.867333, -122.461750  46.799972, -123.018972  45.740806, -122.379083  46.274944, -119.028250  46.909111, -119.160083  46.668139, -117.266306  46.274778, -119.120417  46.418722, -120.176667  46.348917, -120.069611  46.194639, -119.934861  48.894667, -122.706556  48.934167, -122.410722  48.991333, -122.278583  48.982444, -122.456750  48.929139, -122.306806  48.867333, -122.461750  46.799972, -123.018972  45.740806, -122.379083  46.274944, -119.028250  46.909111, -119.160083  46.668139, -117.266306  46.274778, -119.120417  46.418722, -120.176667  46.348917, -120.069611  46.194639, -119.934861 | 43.956139, -112.577139  43.497361, -112.085833  43.555028, -114.421611  43.055944, -114.176889  42.743306, -114.446333  43.634139, -112.279167  42.827332, -112.770494  42.073278, -111.842361  42.034932, -111.778339  42.745306, -114.718667  42.459083, -113.656500  43.555738, -116.460523 |