Feed Nutrient Management Planning Economics (FNMP$) …

Connecting Feed Decisions with Crop Nutrient Management Plans

Software Instructions

This tool estimates:

1) manure volume and nutrient content
2) land requirements for agronomic utilization of the manure
3) labor and land application equipment time requirements and travel distance of manure hauling
4) the costs associated with land application
5) the potential nitrogen and phosphorus nutrient value of manure
5) costs associated with feed changes

List of Tables

Introduction

With the ability to integrate feed management decisions and animal performance measures into the nutrient planning processes, this software tool has been developed to aide producers and their advisors. The primary purpose of Feed Nutrient Management Planning Economics (FNMP$) is to estimate the impact of feed-program decisions on the crop nutrient program. Feeding crude protein and phosphorus above minimum animal requirements produces manure with additional nutrients. Feeding decisions will influence a nutrient plan's land access requirements, labor and equipment needs, costs associated with land application as well as value of the manure. Decisions to include phytase in a swine or poultry ration, or to replace corn with distillers grains in a dairy or beef ration, have far ranging implications. This tool will help quantify the resulting changes.

In addition, this tool helps determine the overall cost and benefit of manure application including the impact that animal feed program will have. FNMP$ estimates: 1) excreted and crop available manure nutrients in manure; 2) land requirements for agronomic utilization of the manure; 3) labor and land application equipment time requirements; 4) the costs associated with land application and; 5) costs associated with feed changes**.**

FNMP$ provides additional value as it evaluates the impact of various manure management decisions on economic considerations. For example, with the recent implementation of a P Index risk assessment on Concentrated Animal Feeding Operations (CAFOs), fields are being identified that must receive manure at a P-based rate. P-based rates are typically lower than N-based rates, requiring additional land access and time for manure applications. FNMP$ can be used to evaluate the economic, time, and land consequences of this, and other, decisions.

Thanks to an improved ability to provide accurate and farm-specific estimates of nutrient excretion, FNMP$ takes a more comprehensive evaluation of the costs and benefits associated with manure application. Integration of this new tool – for estimating excretion with existing procedures for estimating land requirements and evaluating economic factors – provides a unique opportunity to integrate feed management decisions into the comprehensive nutrient management planning (CNMP) process. As one of the six components of a CNMP, feed management provides an important opportunity to improve the environmental and financial performance of an animal feeding operation (AFO).

The FNMP$ program is one component of a suite of tools that enables users to integrate feed management decisions into the CNMP planning process. The other tools analyze opportunities for adjusting the feed program as part of a CNMP, while FNMP$ assists in determining the economic impacts of such adjustments.

The software generates individualized data as it estimates excretion, based on operation-specific feed rations and animal performance. Generalized data contained in the program can be modified by the user for maximum customization and, in return, maximum benefit.

Overview of the Five-step Process

The software consists of four unique software modules for completing an analysis of manure nutrient excretion, harvested and crop available manure nutrients, land requirements and distance traveled, and time and costs associated with land application of manure. The general organization of this software is illustrated below.

5 Steps of FNMP$

Step 1. Manure Management Facility/ System

Each manure management system is chosen to best match the operation's facilities. Each facility is associated with nutrient and solid retention factors. These factors can be altered at later steps to better fit the specific operations conditions. The manure systems are determined first so that animal groups can be associated with a specific system if more than one facility is available.

Step 2. Animal Characteristics

Diet, production, feed costs, and bedding information is entered for each animal group. More than one type of species can be included: beef, dairy, swine, poultry layers or broilers, or horses. This information is used to determine an estimate of manure nitrogen, phosphorus, and potassium excretion as well the mass and volume of manure produced. The beef, swine, and poultry work groups used an animal mass balance approach, where excretion is estimated as a difference between intake and retention in body mass or animal products (eggs or meat). Dry matter excretion was based on estimates of feed dry matter digestibility, with adjustments based upon research literature for solids in urine.

The horse work groups used existing data sets, to which equations were fitted. The horse work group chose to publish separate equations for exercised and sedentary horses.

The dairy section provides two options for estimating excretion for lactating cows, a Mass Balance Estimate and equations based upon existing data sets (Regression Equation Estimate). The dairy work group also proposed equations for dry cows and heifers.

Step 3. Manure Management

Manure management factors (nutrient and solids retention) can be updated or defaults can be used to determine harvested manure (manure nutrients and solids after storage and housing losses). Other factors including bedding additions and manure moisture can be updated.

Step 4. Crop System

Depending on the operation's crop system or user's preferences, one of two options for the crop system is chosen: simple or comprehensive. Manure application methods, field description, crop types, and additional nutrient credits can be entered. This information is used to determine crop available nutrients, acres needed to spread manure at agronomic rates, distance traveled and detailed crop information.

Step 5. Time & Economics

An estimate of: 1) equipment and labor time for completing manure application; 2) annualized costs (including fixed and variable costs) associated with land application only; and 3) approximate value of the crop-available nutrients in manure.
The user selects equipment from a preset list of options and can change default values – for inputs like speed, swath width, and prices – for various inputs.

The machinery and labor time and expense estimates follow the recommendations of the North Central Farm Machinery Task Force. Manure-supplied nutrients are valued at commercial fertilizer prices for the nutrients needed for crop production (e.g. nitrogen is valued for crops requiring nitrogen fertilizer but is not assigned a value when applied to legume crops) and are modifiable by the user.

Table 1.Summary of key user inputs and outputs of individual modules within FNMP$.

Module	Primary User Inputs	Module Outputs
Excretion	Number and weights of animals	Total nitrogen excreted
	Ration nutrient concentration	Total phosphorus excreted
	Feed intake	Excreted solids mass and concentration
	Animal performance (e.g. weight gain, days on feed)	Fertilizer value of excreted manure
	Facility housing animals	
Nutrient Availability	Manure housing/storage type	Crop available nitrogen
	Nutrient retention in storage (optional)	Crop available phosphorus
	Crop availability of nutrients (optional)	Harvested manure mass (dry and liquid systems) and volume (liquid systems only)
	Manure moisture and ash concentrations	
Cropping system	Crops, yield, and crops receiving manure	Manure nutrient concentration
	Crop nutrient requirements (optional) and credits from non-manure sources	Land application rate
	Basis for application rate	Land requirements
	Average field size	Average and maximum travel distance
	Land availability	Excess/ deficient nutrients applied
	Value of nutrients.	
Economics	Application and nurse tank/truck equipment	Application time for spreading equipment and nurse tank/truck
	Application equipment operating characteristics	Total annual costs for manure application
	Operating costs (optional)	Nutrient value of manure
		Total annual costs of feed
		Net costs of manure application
Summary	Summary of conditions	Excreted and crop available N and P2O5
		Land required per year
		Transportation distances
		Application time by activity
		Nutrient value estimates
		Application cost estimates
		Net value estimates

Setup Instructions

Installing Software from a CD

1) Insert CD
2) Copy setup folder to hard drive
3) Open setup folder and then open Setup.exe
4) Follow further setup instructions

Note: if your computer is not current with Microsoft updates, it may be necessary to manually update with the following programs found in the setup folder-

Dotnetfx
ReportViewer
WindowsInstaller3_1

Starting the Program

A shortcut will automatically be placed on your desktop. You can also start the program from the Start menu listed under programs.

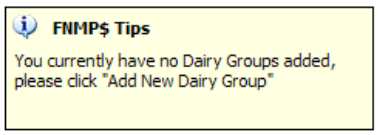
General considerations

- Saving Data – all entered data is automatically saved unless "cancel" is selected on data entering pages

- Messages:

Warning: data is missing

Information: drag mouse over "i" and instructions will appear in a message window

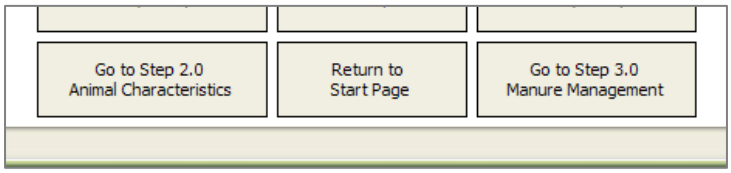


FNMP$ Tips: helpful reminders and tips as you enter data

- Navigation

Tool bar:

Navigation Buttons

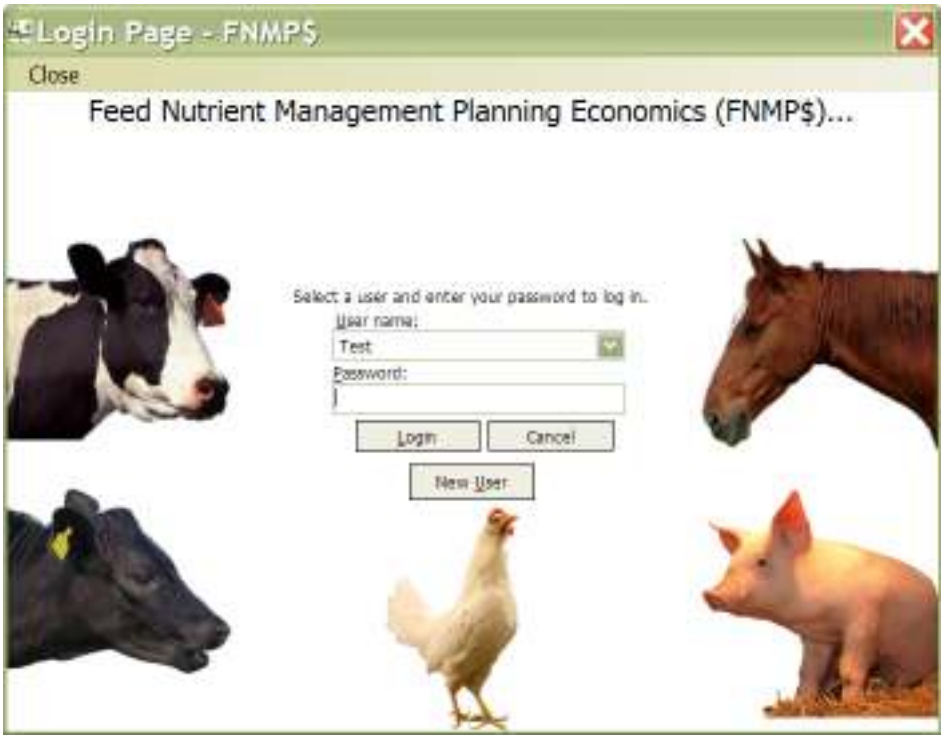


- Defaults

  Defaults will appear in grey boxes to the right of data entry boxes. They are based on the most current information but changing this information will allow the user to make the information more specific and relevant to the operation.

Adding users

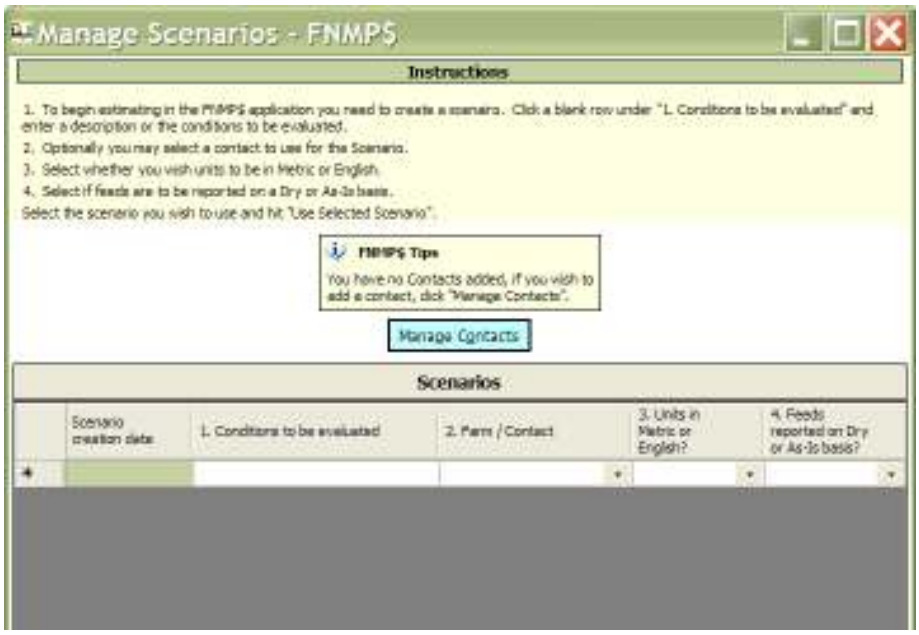
Click on 'New User' on the login page. Follow instructions to create users.
Note: passwords are OPTIONAL



Starting Scenarios

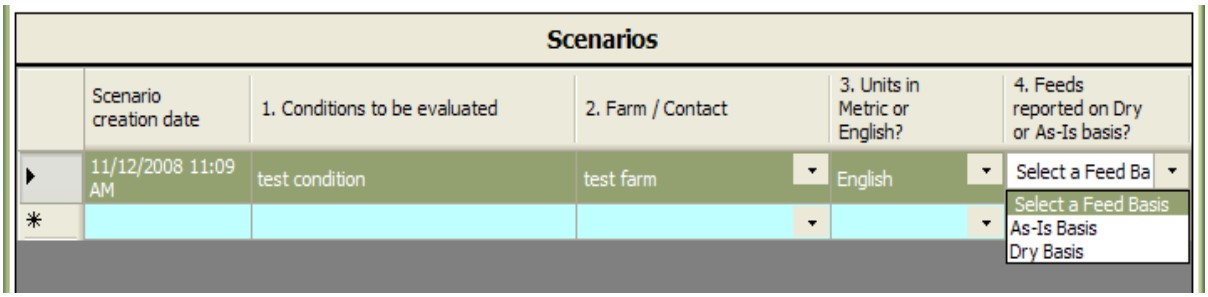
Manage Scenarios

Before starting a scenario, you can add a farm or business contact by clicking on “Manage Contacts”. This allows the user to keep records but entering this information is optional. Only a farm or business name is required.



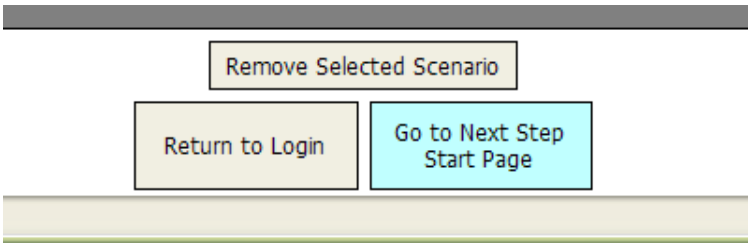
Creating Scenario

By clicking on a scenario line, today's date will automatically appear.
1. Enter the "conditions to be evaluated". These are user defined and can be any description.
   Examples: 'low P diet', 'ration with soybean meal', 'increased corn silage acres'
2. Select farm/ business contact from the drop down menu
3. Choose English or Metric units
4. Choose how feeds will be reported: "dry basis" or "as-fed basis"



The units chosen will be used through out the program. If at anytime you wish to change the units, you can return to 'manage scenarios' from the start page (see next).

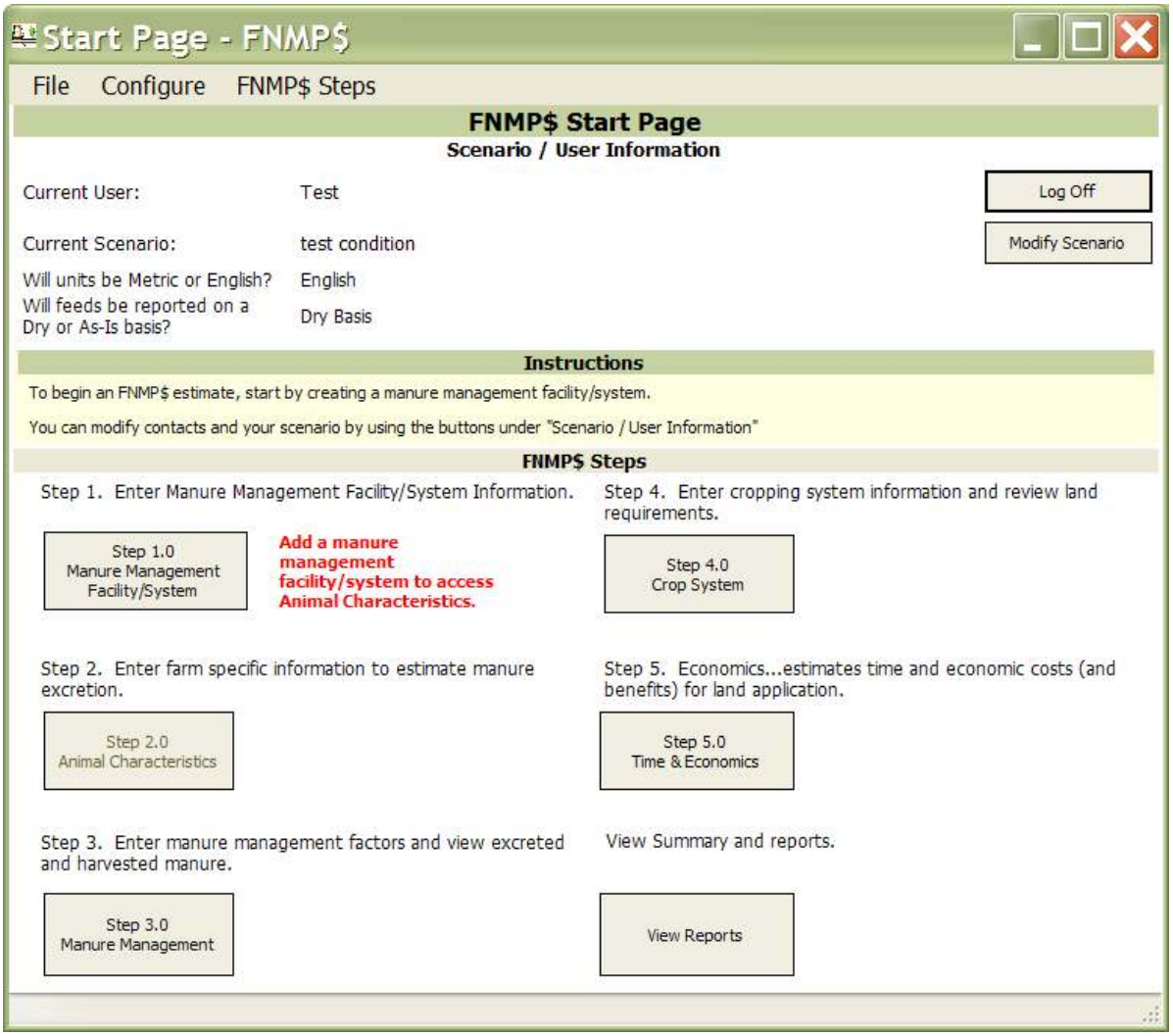
If multiple scenarios are entered, make sure the scenarios you wish to work with is highlighted before continuing on by clicking on "Go to Next Step Start Page". If a scenario is not highlighted, clicking on "Go to Next Step Start Page", will not work.



Start Page

All steps of the FMNP$ program are outline on the start page. You can return back to this page at anytime by clicking “Go to Start Page” at the bottom of each window OR selecting the “FNMP$ Steps” from the toolbar menu.

Start with Step 1.0 Manure Management Systems as indicated in the red note.



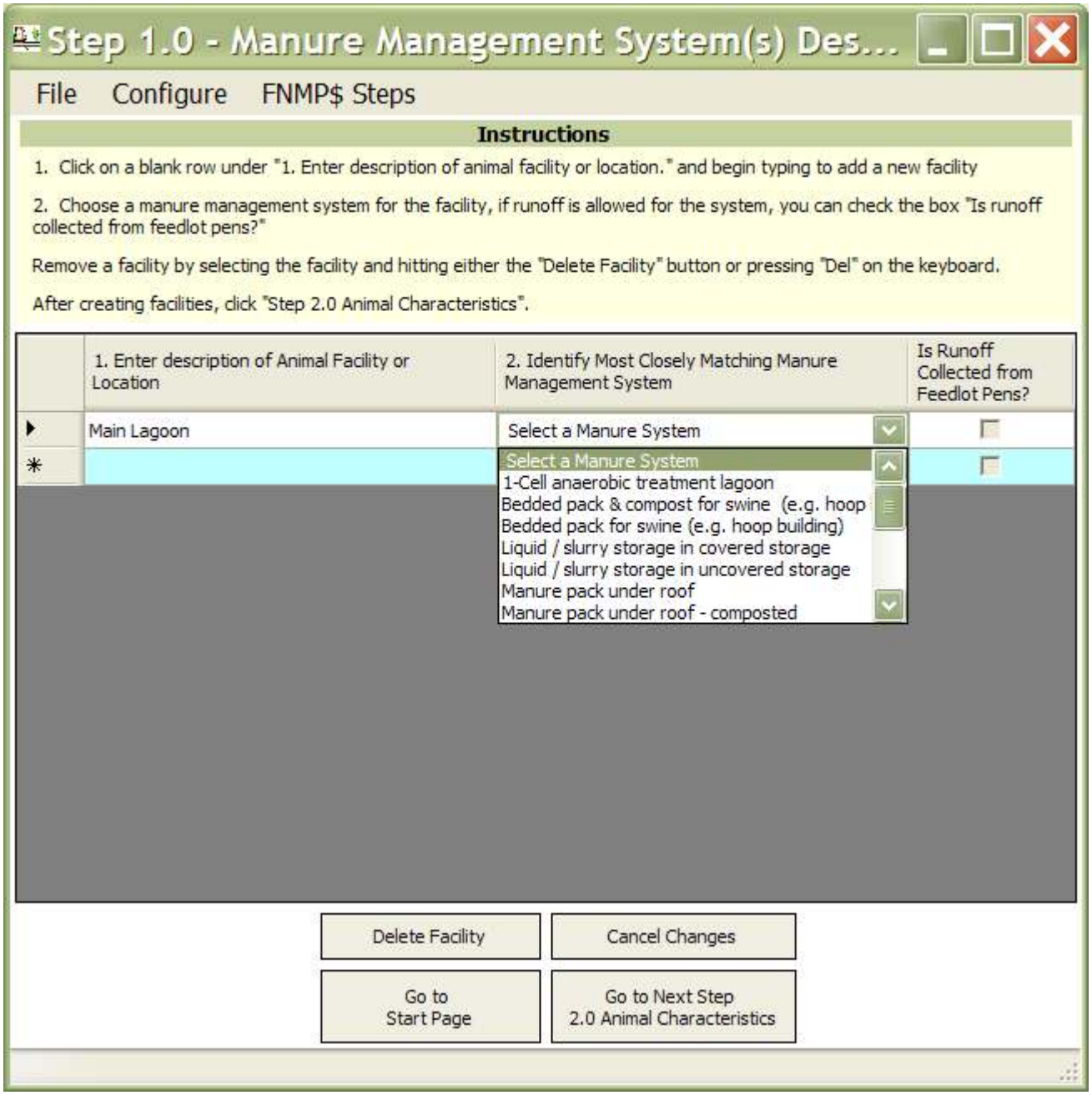
FNMP$ Steps

Step 1.0 Manure Management Systems

1) Pick a manure management system that bests fits the farms' management.
Multiple manure management systems can be entered for one farm.

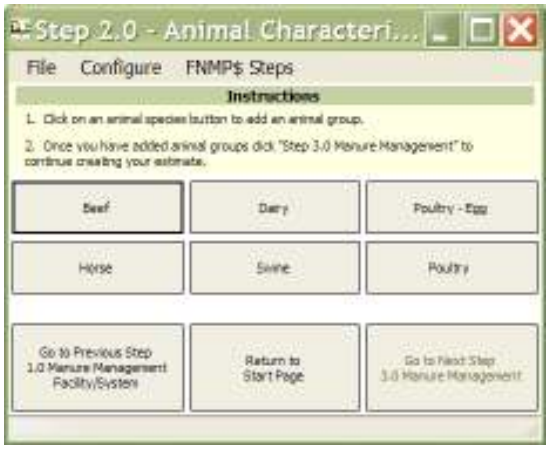
Storage and treatment options are associated with default values for nutrient and solid retention (Table). However, these can be changed at a later step.

2) If a beef feedlot is used, check "is runoff collected from feedlot pens" if applicable.



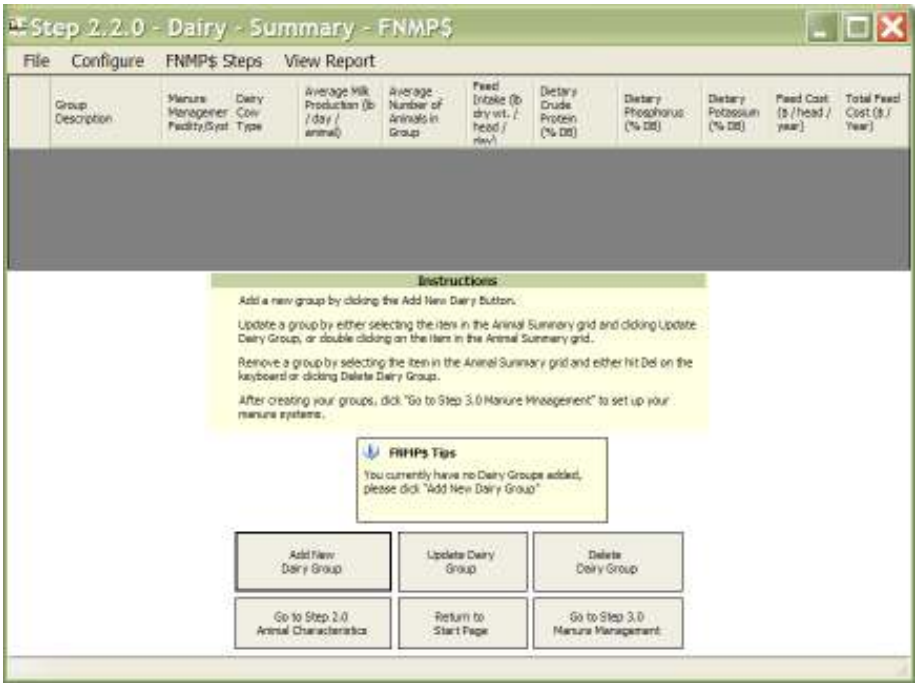
Step 2.0 – Animal Characteristics

Choose the species of animals you would like to work with. Multiple species can be entered for one farm. After entering one species, return to this page from the start page to enter additional species.



Step 2.2.0 Dairy Summary

This page will show a summary of the Dairy animals entered. To add groups, select “Add New Dairy Group”.



Step 2.2.1 – Dairy Cattle Animal & Feed Management Characteristics

1) Enter animal group information. To use defaults, select “Use Default Values”
By selecting “Return to Dairy Summary”, all data will be saved.
2) If shavings/ sawdust or straw is used for bedding, this can be entered on this page for each group. If sand is used, that can be entered at the next step. See note below for bedding use. This is only applicable if a solids separation system is NOT used.
3) After entering data for lactating animals, choose the type of nutrient excretion estimate: mass balance or regression. See below for further explanation.

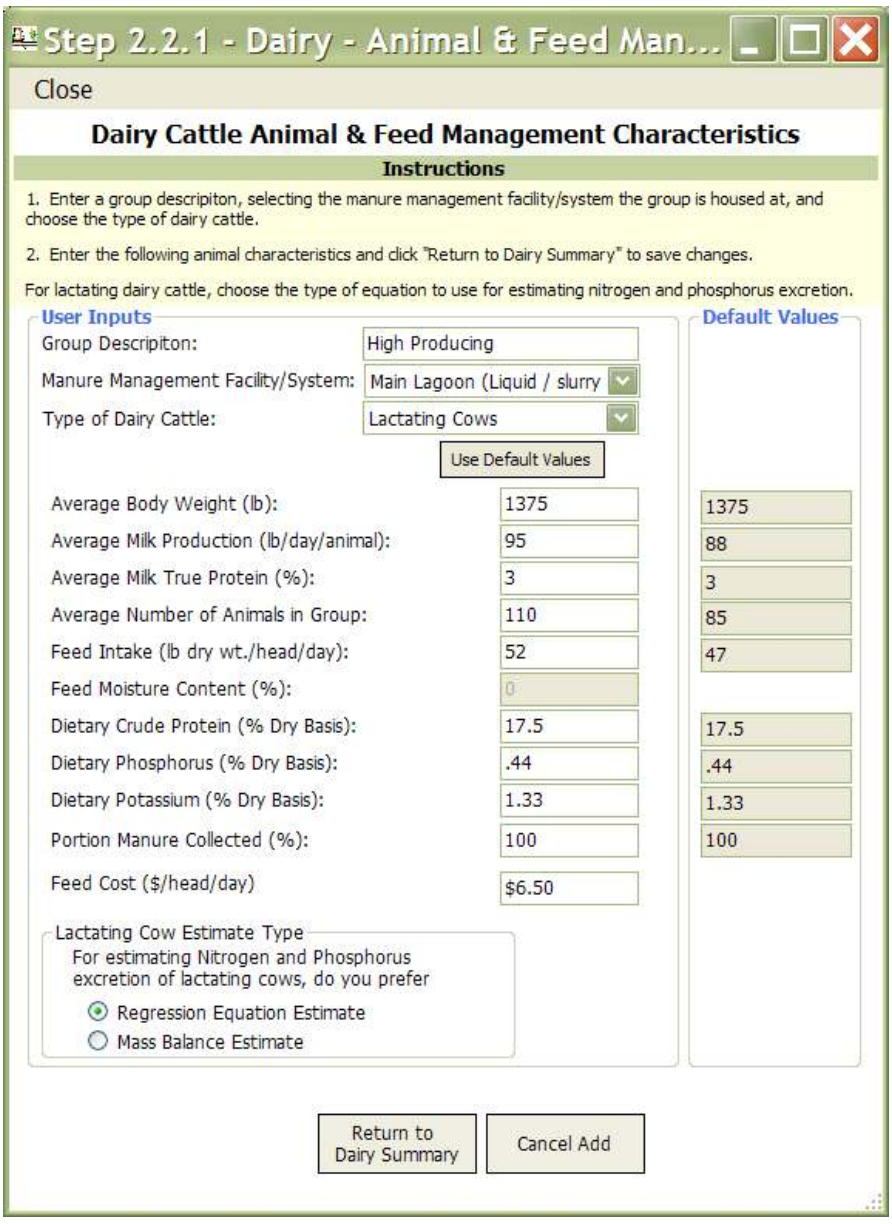


Table 2. Example data collection from FMP Template.

A) Dairy Cattle:	**Group 1**
Define Groups	High
(i.e. production level, dry, heifers)	
Group Animal Data:	
Average weight	1335
Average Milk True Protein %	3.0
Average Milk Production lbs	97
Average Number of animals in group	200
% Manure collected	100
Group Ration Information:	
Indicate how the following information will be reported -Wet or Dry basis?	DM
If Wet basis, what is the diet DM?	
Feed intake lbs/ cow/ day	56.1
Dietary %CP	16.8
Dietary %P	0.34
Dietary %K	1.3
Ration cost ($/hd/day)	$6.70

Note: Lactating Cow Estimate Type

Mass Balance vs. Regression Equations for determining nutrient excretion from lactating cows

Mass balance: Nutrient excretion is estimated as a difference between nutrient intake and nutrient retention in milk.

Nitrogen retention is calculated using true protein concentration of milk:

N retention = MY x Milk CP%[1] / 6.38

[1]Milk TP% is converted to Milk CP% by a conversion factor of 0.9345 (Mackle et al., 1999).

Phosphorus retention assumes a milk P concentration of 0.1%.
Potassium retention assumes a milk K concentration of 0.14%.

Regression equations: Nutrient excretion is estimated using equations from the ASAE Standard (2005).

Table 3. Mass balance and regression equations for nutrients excreted for lactating dairy cattle.

Nutrients Excreted:	**Nitrogen**
Regression Equation *(ASAE, 2005)*	$N_{Excreted}$ (kg)= [(Milk x 2.303) + (DIM* x 0.159) + (DMI x Dietary CP x 70.138) + (BW x 0.193) – 56.632] / 1000 Residual error = 102.71; inter-study error = 53.07 *DIM is assumed to be 150 days unless user defines
Mass Balance Equation	$N_{Excreted}$ (kg) = Intake N (DMI x Dietary CP/6.25) - Retained N (MY x Milk CP*/6.38) *Milk true protein (MTP) values were converted to CP by a factor of 0.9345 (Mackle et al., 1999)
	Phosphorus
Regression Equation *(Nennich et al., 2005)*	$P_{Excreted}$ (kg) = [(DMI × Dietary P × 560.7)+ 21.1] / 1000 Residual error = 9.7; inter-study error = 9.2
Mass Balance Equation	$P_{Excreted}$ (kg) = Intake P (DMI x Dietary P) – Retained P (MY x 0.001)
	Potassium
Regression Equation *(Nennich et al., 2005)*	$K_{Excreted}$ (kg) = [((DMI × 7.21) + (Dietary K × 15944)) − 164.5] / 1000 Residual error = 36.9; inter-study error = 2.7
Mass Balance Equation	$K_{Excreted}$ (kg) = Intake K (DMI x Dietary K) – Retained K (MY x 0.0014)

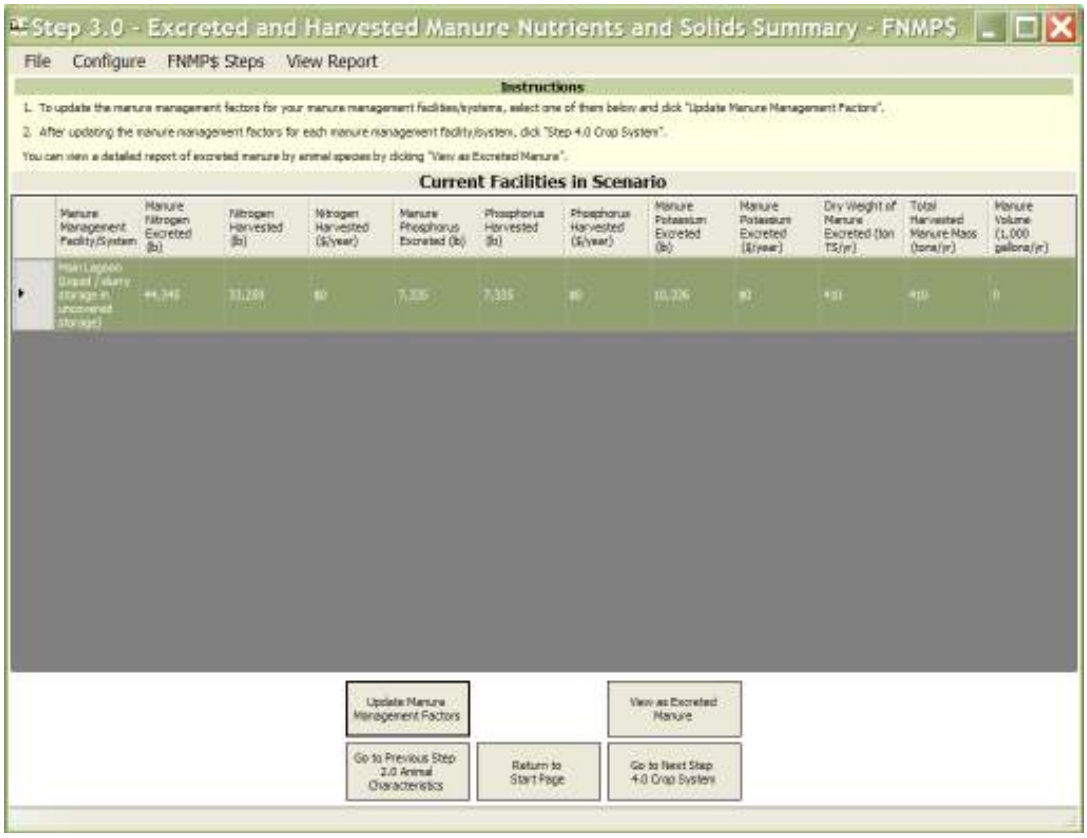
Note: *Bedding use*

Table 4. Daily bedding requirements for dairy cattle. (Table 4-4, AWMFH).

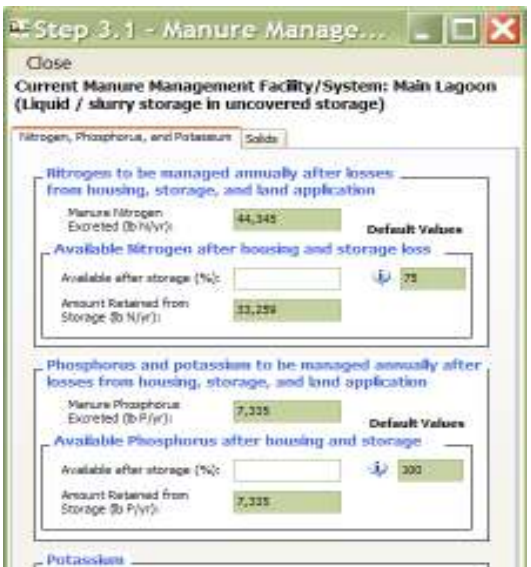
	Barn type		
Material	Stanchion Stall	Free-Stall	Loose housing
	------ lb/d/1000# ------		
Loose hay or straw	5.4		9.3
Chopped hay or straw	5.7	2.7	11
Shavings or sawdust	-	3.1	-
Sand, soil, or limestone	-	1.5	-

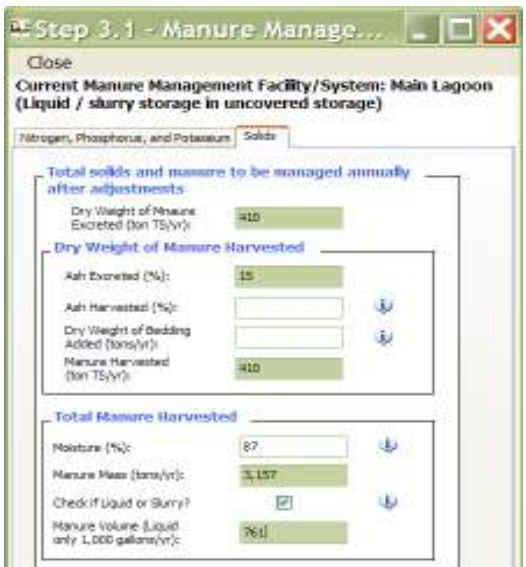
Step 3.0 Excreted and harvested Manure nutrients and solids summary

It is important that you “Update Manure Management Factors”. If the manure source is a liquid or slurry, the volume estimation can not be completed if you do not enter data.

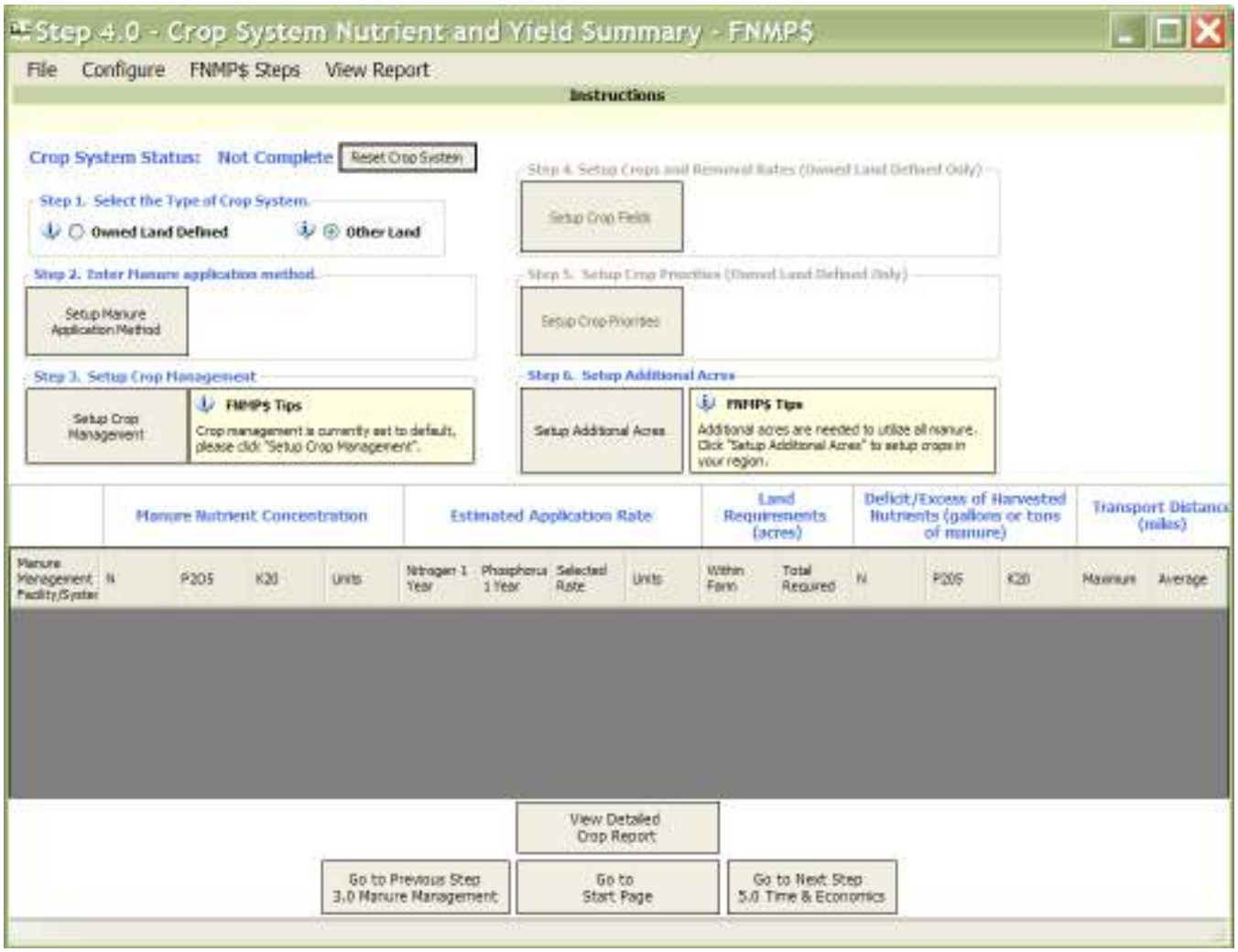


Updating Manure management factors
NPK
1) If you are unsure of the N or P retention, use the default vales by leaving the data field blank.
Solids
2) If Sand bedding is used, increasing the % ash of manure harvested will take this into account. For dairy, if 40#/hd/day of sand is used with 95% recovery in a sand settling basin, increase the ash to 20%.





Step 4.0 Crop System



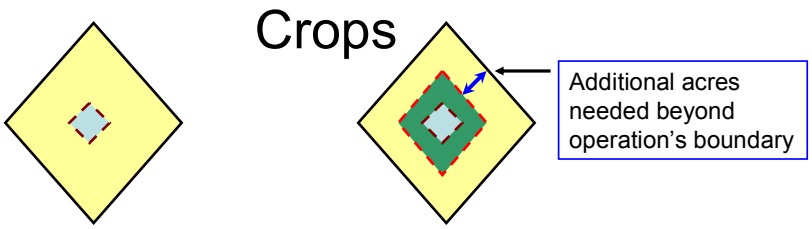
Follow further instructions of each step

1) Choose between simple and comprehensive crop systems approaches
2) Setup Manure Application Method
3) Setup Crop Management
4) Setup Crop Fields (Comprehensive only)
5) Setup Crop Priorities (Comprehensive only)
6) Setup Additional Acres

Crop System Step 1) Choose between simple and comprehensive crop system approaches

Simple: calculates total land base required to utilize the manure nutrients based on typical crops in area, typical field size and percentage of land available to apply manure.

Comprehensive: calculates total land base required to utilize the manure nutrients within currently owned and/or leased land and calculates additional acres beyond owned or leased land needed. This is based on specific field and crop information for currently owned land and additional acres are calculated similar to "simple" approach.



Simple inputs:

- Crops in region
- % of types of crops

Outputs:

- Estimated amount of total acres needed

Comprehensive inputs:

- Defined acreage of each crop type

Outputs:

- Acres needed within and beyond farm's boundaries
- Estimated excess/ deficiency of nutrients

Crop System Step 2) Setup Manure Application Method

For each manure management system, choose a manure application method from the drop down menu that matches the operation's application method as closely as possible.

This will determine the amount of N and P that will be crop available (appendix). The user may override the defaults.

Explanation of crop available nutrients:

Harvested Nitrogen and Phosphorus accounts for losses occurring during storage or treatment.

Harvested N/P = N/P excreted x % N/P retained (based on storage type; appendix)

<u>Crop Nitrogen availability</u> accounts for transformations and forms of N lost during storage and availability based on application type.

Organic N and NH4-N accounts for all harvested nitrogen and the ratio of each depends on the storage type (appendix_). For example, composted N will be 100% in the form of organic N because of NH3 loses and N transformations. The availability of organic-N depends on storage and treatment type and NH4-N availability depends on the application type (appendix_ and _). Applications that involve direct injection will be more available compared to surface application with no incorporation.

Crop available Nitrogen = (N retained x ratio of NH3-N: total N x NH4 availability) + (N retained x organic N availability x ratio of org-N: total N)

☐ Ratio of NH3-N to total N depends on storage type

☐ Organic-N: total N depends on storage type

☐ Organic N availability depends on storage

☐ NH4-N availability depends on application type OR application type and soil conditions and days to incorporation if surface broadcast or dragline surface application is used

Crop Phosphorus Availability is assumed to be 100% unless changed by the user. Phosphorus is converted to P2O5 by multiplying P by 2.29.

3) Setup Crop Management

Simple

a) Average field size, portion of land cropped, and portion of land accessible for applying manure needs to be estimated in order to estimate the distance traveled.

b) Select the manure application rate: N, P, or P 2 or 4 years.

c) Enter fertilizer prices to estimate nutrient value of manure.

Comprehensive

a) Enter total land within the operation's boundaries or leased land. This includes land under water, non-manured fields or other land.

b) Select the manure application rate: N, P, or P 2 or 4 years.

c) Enter fertilizer prices to estimate nutrient value of manure.

4) Setup Crop Fields (Comprehensive only)

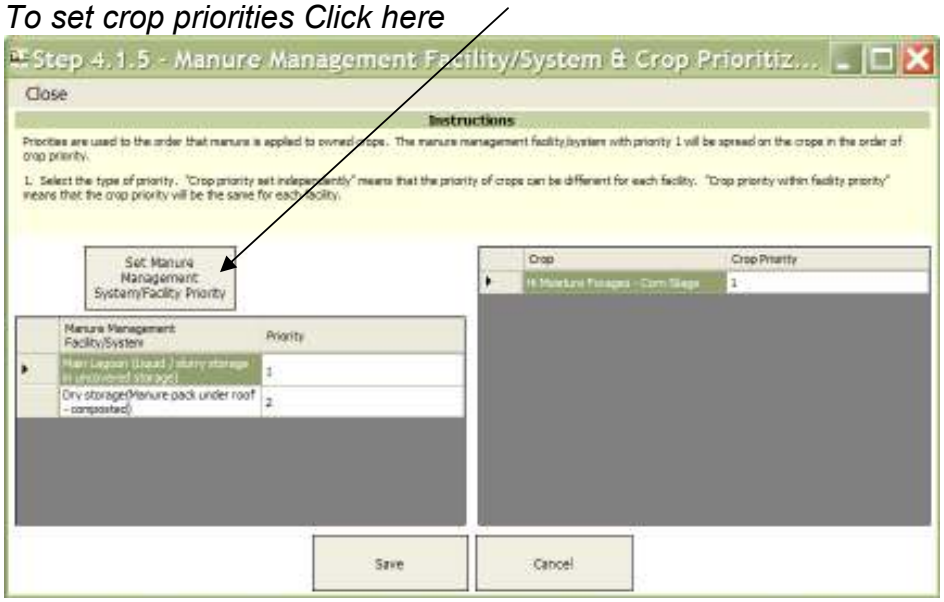
a) Enter all crops manured on owned or leased land.

b) if fertilizer or N credits from a previous crop will contribute to N, enter that value under “Non-manure credits”

5) Setup Crop Priorities (Comprehensive only)

Setting crop priorities

To set crop priorities Click here

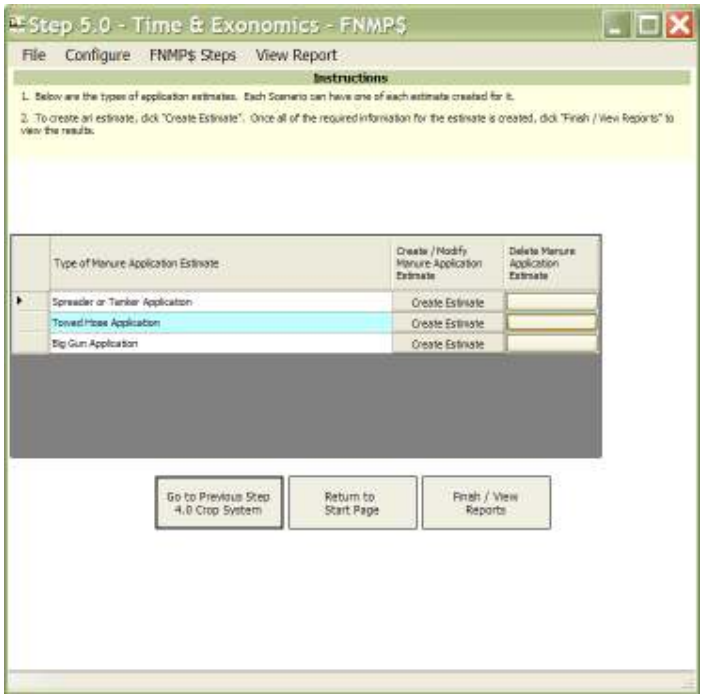


a) If there are more than one manure management system, choose the system that you wish to use first.
b) within that system, choose the crops (if more than one) you wish to manure first or exclude crops if you do not want that manure type to be used on that crop.
c) repeat with each crop system

6) Setup Additional Acres
a) Enter crops in the
b) Determine the percent of each crop relative to total crops in the area. This allows user to define the crop use in the area and manure application rates and land base estimates will be more accurate.

Step 5 Time & economics

Choose the manure application system for each previously determine method by clicking create estimate and then modify estimate



Step 5.1

The left hand table, “User Inputs”, requires data entry, while the right hand table, “Results of Calculations”, showcases the results after the program has completed the appropriate calculations.

Detailed explanation of time and economic inputs

Located under the instructions, first choose from the dropdown menu “Application Rate Limit Set”. The choices include: nitrogen 1 year or phosphorus 1, 2, or 4 years. This entry revises an earlier entry of the same information and provides a convenient means of reviewing different “What if?” scenarios.

Choose the appropriate application method from the dropdown menu. Depending on the application method chosen, available options include: injection, immediate incorporation, surface broadcast, dragline with injection toolbar, dragline with aerway toolbar, dragline with surface application, or big gun irrigation. This entry also revises an earlier entry of the same information and provides a convenient means of reviewing different “What if?” scenarios.

The average distance to the field has been calculated, and, if so desired, may be overwritten by inputting a new value.

The next category describes the characteristics of the application equipment. First, select the entry most closely matching the user’s application equipment. Several options are incorporated into the dropdown menu.

The next line items relate to swath or spread width, number of passes, length of dragline, supply method, setup time, application rate, and the number of rigs, or guns, used. If the lists of default values appear to be realistic, the user may rely on the default figures. However, he/she may enter customized data, if so desired. Note: Varying significantly from the defaults could affect other specifications, which cannot be changed.

Number of Rigs: Instructions: The total application time listed in the “Results of Calculations” section includes the hours necessary for distributing all manure. For large jobs, multiple application units are often necessary. Check the “Application Duration (hours/rig)” in the right hand table (Results of Calculations) to determine if a producer’s available window for manure application will accommodate the calculated hours per rig. Enter the number of rigs necessary to model realistic application duration.

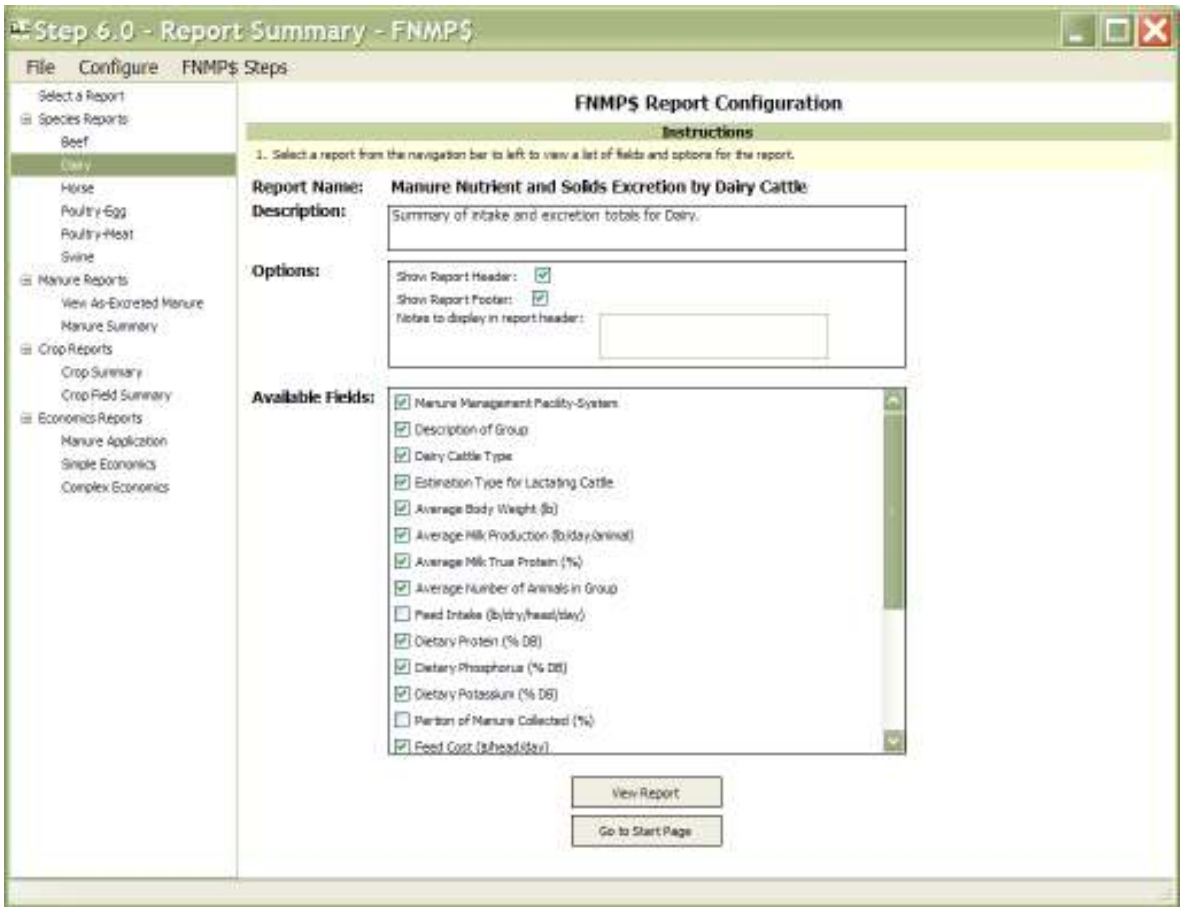
Setup Time per Subfield (for dragline and big gun application methods only).
Instructions: A subfield is a field, or portion of a field, that is covered by a single dragline pull. For example, a 1320-foot drag hose could cover approximately 40 acres in a single setup. Therefore, a 160 acre field would have four subfields. The operator would have to reorganize the drag hose four times to spread manure on the whole field.

Equipment characteristics for either a nurse tank or truck or traveling gun.
Under the “Equipment Operating Characteristics” section, the program displays a calculated discharge rate. A “Calculated Discharge Warning” may appear, suggesting the entries for speeds and/or swath widths are unrealistic. If the discharge rate appears to be out of line for the user’s equipment, change either the entry for speeds or swath widths.

“Costs Assumptions” for fuel, labor, interest, insurance and taxes, lubrication, and equipment costs are provided by the program. These values may be overridden, or left as is.

Reports

Choose the reports and if applicable, chose specific fields you would like to include.



Project Team

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Appendix

Table A 1**. Percent manure moisture of manure management system by species group**.

Manure Management System	% Manure Moisture
Dairy	
Fresh manure	89
Fresh manure stored in covered tank or open storage pond with 30-50% processing water added	92
Bedded manure, unroofed stacking facility	82
Manure stored outside with no bedding; leachate lost	87
Swine	
Fresh Manure	90
Manure stored in covered tank with 50% additional water	93
Ventilated storage pit below slotted floors, diluted 1:1	95
Open lot storage; warm, humid climates	80
Open lot storage; hot, arid climates	40
Broilers and Layers	
Fresh Manure	75
Layer manure stored in shallow pit; cleaned every 3 months	65
Layer manure stored in deep pit; cleaned yearly	50
Broiler manure on sawdust or shavings	25
Beef	
Fresh manure	86
Manure stored in covered tank	86
Bedded manure pack under roof	80
Open lot storage; cold, humid climates	70
Open lot storage; warm, semi-arid climate	30
Open lot storage; hot, arid climates	20

Table A 2. Manure management systems' default values for organic-N, ammonium-N, organic-N availability, and solids and nutrient retentions.

Manure Management System	Organic-N : Total N	NH3-N : Total N	Organic N Availability	Solids Retention	Nutrient Retention		
					N	P2O5	K2O
Open lot or feedlot - scraped or stockpiled solids	0.8	0.2	50%	100%	50%	95%	95%
Open lot or feedlot - composted solids	1	0	50%	60%	35%	90%	90%
Runoff Collection System from Open Lot	0.1	0.9	70%	5%	n/a	n/a	n/a
Manure pack under roof	0.8	0.2	50%	100%	70%	100%	100%
Manure pack under roof -composted	1	0	50%	60%	50%	95%	95%
Bedded pack for swine (e.g. hoop building)1	0.8	0.2	50%	100%	50%	100%	100%
Bedded pack & compost for swine1 (e.g. hoop building)	1	0	50%	60%	35%	100%	100%
Solid/semi-solid manure & bedding held in roofed storage	0.8	0.2	50%	100%	75%	100%	100%
Solid/semi-solid manure & bedding held in unroofed storage	0.8	0.2	50%	100%	65%	95%	95%
Liquid/slurry storage in covered storage	0.8	0.2	70%	100%	90%	100%	100%
Liquid/slurry storage in uncovered storage	0.4	0.6	70%	100%	75%	100%	100%
Storage (pit beneath slatted floor)	0.4	0.6	70%	100%	85%	100%	100%
Poultry manure stored in pit beneath slatted floor	0.5	0.5	70%	100%	85%	100%	100%
Poultry manure on shavings or sawdust held in housing	0.8	0.2	60%	100%	70%	100%	100%
Poultry manure on shavings or sawdust held in housing - composted	1	0	50%	60%	50%	95%	95%
1-Cell anaerobic treatment lagoon	0.2	0.8	70%	40%	20%	35%	60%
Multi-cell anaerobic treatment lagoon	0.2	0.8	70%	40%	10%	35%	60%
Lagoon, solids removed annually for Dairy	0.2	0.8	70%	100%	65%	100%	100%

Table A 3. Manure excretion equations.

Production Level	Nutrients Excreted:	
		Nitrogen
Lactating Cow	Regression Equation *(ASAE, 2005)*	$N_{Excreted}$ (kg)= [(Milk x 2.303) + (DIM* x 0.159) + (DMI x Dietary CP x 70.138) + (BW x 0.193) – 56.632] / 1000 Residual error = 102.71; inter-study error = 53.07 *DIM is assumed to be 150 days unless user defines
	Mass Balance Equation	NExcreted(kg) = Intake N (DMI x Dietary CP/6.25) - Retained N (MY x Milk CP*/6.38) *Milk true protein (MTP) values were converted to CP by a factor of 0.9345 (Mackle et al., 1999)
Dry Cow	*(ASAE, 2005)*	NExcreted (kg) = [(DMI x 12.747) +(Dietary CP x 1606.290) - 117.500] / 1000 Residual error = 45.51
Heifer	*(ASAE, 2005)*	NExcreted (kg) = [(DMI x Dietary CP x 78.390) + 51.350] / 1000 Residual error = 10.76; inter-study error = 24.47
		Phosphorus
Lactating Cow	Regression Equation *(Nennich et al., 2005)*	$P_{Excreted}$ (kg) = [(DMI × Dietary P × 560.7)+ 21.1] / 1000 Residual error = 9.7; inter-study error = 9.2
	Mass Balance Equation	$P_{Excreted}$ (kg) = Intake P (DMI x Dietary P) – Retained P (MY x 0.001)
Dry Cow	*(ASAE, 2005)*	PE (kg) = [((DMI x 1000) x Dietary P x dry period) - 264.386) / Dry Period*] / 1000 *Assumes a 60 day Dry Period
Heifer	*(ASAE, 2005)*	PE (kg) = (DMI x 1000) x Dietary
		Potassium
Lactating Cow	Regression Equation *(Nennich et al., 2005)*	$K_{Excreted}$ (kg) = [((DMI × 7.21) + (Dietary K × 15944)) − 164.5] / 1000 Residual error = 36.9; inter-study error = 2.7
	Mass Balance Equation	$K_{Excreted}$ (kg) = Intake K (DMI x Dietary K) – Retained K (MY x 0.0014)
Dry Cow and Heifer	*(ASAE, 2005)*	KE = (DMI x 1000) x Dietary K
		Solids
Lactating Cow	*(ASAE, 2005)*	Manure Solids (kg) = (DMI x 0.35) + 1.017 Inter-study error = 1.13; Residual error = 0.76
Dry Cow	*(ASAE, 2005)*	Manure Solids (kg) = (DMI x 0.178) +2.733 Inter-study error = 0.74; Residual error = 0.45
Heifer	(Nennich et al., 2005)	Manure Excretion (kg) = (DMI × 4.158) − (BW × 0.0246) x 0.17* Residual error = 2.6; Inter-study error = 5.6 *assumes 83% DM

Table A 4. Ammonia nitrogen availability by application type

Application type	Ammonia-N Availability Assumption
Injection	0.95
Immediate Incorporation	0.95
Big Gun Irrigation	0.5
Flood Irrigation	0.95
Sprinkler Including Pivot	0.5
Dragline with Injection Toolbar	0.95
Dragline with Aerway toolbar	0.8
Surface Broadcast and Dragline[1]	= 1/2^ (days to incorporation / 1/2 life)

Soil Condition	[1]Assumed Half Life of NH3-N in Days
Warm, Dry Soils	1
Warm, Wet Soils	4
Cool Soils	14

Table A 5. Comprehensive crop system haul distance equations.

Condition	Facility	Equations estimating: Average Distance	Maximum Distance
Primary Facility Closest to Source	Primary Facility	((((Primary Total Land Required/2) * 1 / (% Manured) / % Cropped / 1280) ^ .5) - ((AvgFieldSize/ 640) ^ .5)))	((((Primary Total Land Required) * 1 / (% Manured) / % Cropped / 1280) ^ .5) - ((AvgFieldSize/ 640) ^ .5)))
	Secondary Facility	(((((Primary Total Land Required + Secondary Total Land Required / 2)) / % Manured / % Cropped / 1280) ^ .5) - ((AvgFieldSize/ 640) ^ .5)))	(((((Primary Total Land Required + Secondary Total Land Required)) / % Manured / % Cropped / 1280) ^ .5) - ((AvgFieldSize/ 640) ^ .5)))
Secondary Closest to Source	Primary Facility	(((((Secondary Total Land Required + Primary Total Land Required / 2)) / % Manured / % Cropped / 1280) ^ .5) - ((AvgFieldSize/ 640) ^ .5)))	(((((Primary Total Land Required + Secondary Total Land Required)) / % Manured / % Cropped / 1280) ^ .5) - ((AvgFieldSize/ 640) ^ .5)))
	Secondary Facility	((((Secondary Total Land Required/2) * 1 / (% Manured) / % Cropped / 1280) ^ .5) - ((AvgFieldSize/ 640) ^ .5)))	((((Secondary Total Land Required) * 1 / (% Manured) / % Cropped / 1280) ^ .5) - ((AvgFieldSize/ 640) ^ .5)))
Equal Distance	Primary Facility and Secondary Facility	((((Secondary Total Land + Primary Total Land) / 2 / % Manured / % Cropped / 1280) ^ .5) - ((AvgFieldSize/ 640) ^ .5))	((((Secondary Total Land + Primary Total Land) / % Manured / % Cropped / 1280) ^ .5) - ((AvgFieldSize/ 640) ^ .5))

Table A 6. Simple crop system haul distance equations.

Condition	Facility	Equations estimating: Average Distance	Maximum Distance
Owned or Leased Land	Primary Facility	((((acres in crops manured by primary facility/2) * 1 / (total acres in cropped/total land owned) / 1 / 1280) ^ .5) - ((AvgFieldSize / 640) ^ .5)))	((((acres in crops manured by primary facility) * 1 / (total acres in cropped/total land owned) / 1 / 1280) ^ .5) - ((AvgFieldSize / 640) ^ .5)))
	Secondary Facility	((((acres in crops manured by primary facility + acres in crops manured by secondary facility/2) * 1 / (total acres in cropped/total land owned) / 1 / 1280) ^ .5) - ((AvgFieldSize / 640) ^ .5)))	((((acres in crops manured by primary facility + acres in crops manured by secondary facility) * 1 / (total acres in cropped/total land owned) / 1 / 1280) ^ .5) - ((AvgFieldSize / 640) ^ .5)))
Additional Acres Needed Primary Closest to Source	Primary Facility	((((Total owned land + Primary Total Land Required/2) * 1 / (% Manured) / % Cropped / 1280) ^ .5) - ((AvgFieldSize/ 640) ^ .5)))	((((Total owned land + Primary Total Land Required) * 1 / (% Manured) / % Cropped / 1280) ^ .5) - ((AvgFieldSize/ 640) ^ .5)))
	Secondary Facility	(((((Total owned land + Primary Total Land Required + Secondary Total Land Required / 2)) / % Manured / % Cropped / 1280) ^ .5) - ((AvgFieldSize/ 640) ^ .5)))	(((((Total owned land + Primary Total Land Required + Secondary Total Land Required)) / % Manured / % Cropped / 1280) ^ .5) - ((AvgFieldSize/ 640) ^ .5)))
Additional Acres Needed Secondary Closest to Source	Primary Facility	(((((Total owned land + Secondary Total Land Required + Primary Total Land Required / 2)) / % Manured / % Cropped / 1280) ^ .5) - ((AvgFieldSize/ 640) ^ .5)))	(((((Total owned land + Primary Total Land Required + Secondary Total Land Required)) / % Manured / % Cropped / 1280) ^ .5) - ((AvgFieldSize/ 640) ^ .5)))
	Secondary Facility	((((Total owned land + Secondary Total Land Required/2) * 1 / (% Manured) / % Cropped / 1280) ^ .5) - ((AvgFieldSize/ 640) ^ .5)))	((((Total owned land + Secondary Total Land Required) * 1 / (% Manured) / % Cropped / 1280) ^ .5) - ((AvgFieldSize/ 640) ^ .5)))
Additional Acres Needed Equal Distance	Primary Facility and Secondary Facility	((((Total owned land + Secondary Total Land + Primary Total Land) / 2 / % Manured / % Cropped / 1280) ^ .5) - ((AvgFieldSize/ 640) ^ .5))	((((Total owned land + Secondary Total Land + Primary Total Land) / % Manured / % Cropped / 1280) ^ .5) - ((AvgFieldSize/ 640) ^ .5))