

# Digging In

## A Nutrient Management Course for Farmers



Northwest Crops and Soils Program  
Dr. Heather Darby

AGRONOMIST AND NUTRIENT MANAGEMENT SPECIALIST



This training manual has been developed by University of Vermont Extension to facilitate the instruction of a nutrient management course for livestock farmers. During the course, farmers learn to develop and implement their own nutrient management plans, and gain an understanding of how their plans were put together, and the importance of nutrient management planning from both economic and environmental perspectives.

The course aims to provide a comfortable, small-group, learning opportunity for the farmers. Once the course is finished, class participants will have generated nutrient management plans following Vermont's Natural Resources Conservation Service (NRCS) 590 Nutrient Management Standard. A multi-agency educational team conducts the program. The course is taught over a six-week period with participants attending a three-hour session each week. The farmers will spend approximately eighteen hours in classroom instruction and activities to estimate annual animal manure quantities, document and plan crop rotations, identify fields with manure spreading restrictions, analyze soil test reports, and calculate on-farm nutrient credits for animal manure and legumes. Farmers will also spend an estimated twenty hours at home writing their nutrient management plans. This guide is designed to present some of the instruction that is given in the course. In addition, it gives instructions on how to use the UVM Extension Nutrient Management web application, goCrop™ and the accompanying app for record keeping.

# **Digging In**

## **A Nutrient Management Course for Farmers**

**Dr. Heather Darby**

AGRONOMIST AND NUTRIENT MANAGEMENT SPECIALIST



The University  
of Vermont

---

EXTENSION

Copyright ©2009 by University of Vermont Extension

Issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, in cooperation with the United States Department of Agriculture. University of Vermont Extension, Burlington, Vermont. University of Vermont Extension, and U.S. Department of Agriculture, cooperating, offer education and employment to everyone without regard to race, color, national origin, gender, religion, age, disability, political beliefs, sexual orientation, and marital or familial status.

This material is based upon work supported in part by the Cooperative State Research, Education, and Extension Service, U.S. Department of Agriculture, under Agreement No. 2008-51130-19504.

Every effort has been made to make this publication as complete and accurate as possible. This text is only a guide, however, and should be used in conjunction with other information sources on crop, soil and farm management. The editors, authors and publisher disclaim any liability, loss, or risk, personal or otherwise, which is incurred as a consequence, directly or indirectly, of the use and application of any of the contents of this publication.

Any reference to commercial products, trade names, or brand names is for information only, and no endorsement or approval is intended.

Revised December 2017

### **Acknowledgements**

These training materials were partially funded through a grant provided by the Vermont Agency of Agriculture, Foods and Markets. We would also like to acknowledge the following individuals for their roles in developing this publication: Karen Hills, Initial layout and manual development, Dr. Wendy Sue Harper for contributions to Session III and reviewing text; Joanne Yousten for worksheet development, photographs, and reviewing text; Amanda Gervais for revisions, worksheet development and illustrations; and Dr. Joel Tilley for worksheet development. Additional illustrations and photographs by Dr. William Jokela, David Heleba, and Ben Gabos. Additional reviewing was done by Elaine Burnor, Debra Heleba, Dr. William Jokela, Dr. Fred Magdoff, and Dr. Eric Young. Cover illustration by Amanda Gervais.

# Contents

Getting Ready for the Course .....	5
<b>SESSION I: Getting Started .....</b>	<b>7</b>
LESSON I-1: Nutrient Management .....	8
LESSON I-2: Navigating the Course Binder .....	11
EXERCISE I-1: Farm Description.....	12
LESSON I-3: Maps and Soil Fact Sheets.....	14
EXERCISE I-2: Map and Soil Fact Sheets Checklist.....	21
LESSON I-4: Soil Sampling.....	22
EXERCISE I-3: Soil Test Schedule .....	23
EXERCISE I-4: Organizing Your Soil Test Results .....	23
LESSON I-5: Soil Erosion, RUSLE2, and Choosing a Rotation .....	24
EXERCISE I-5: Choosing Rotations that Meet T.....	26
EXERCISE I-6: Creating a Field Inventory .....	27
EXERCISE I-7: Manure Application Schedule.....	29
EXERCISE I-8: Checklist .....	30
 <b>SESSION II: Understanding Soil Nutrients .....</b>	 <b>31</b>
LESSON II-1: The Dirt on Soil .....	32
LESSON II-2: The Nitrogen Cycle .....	36
EXERCISE II-1: Calculating Nutrient Availability in Manure .....	40
LESSON II-3: The Phosphorus Cycle .....	48
LESSON II-4: The P-Index.....	52
EXERCISE II-2: P-Index Worksheet.....	53
EXERCISE II-3: Checklist .....	55

<b>SESSION III: Managing Soil Nutrients.....</b>	<b>57</b>
LESSON III-1: Managing the Plant and Soil Ecosystem .....	58
EXERCISE III-1: Farm Nutrient Balance .....	65
LESSON III-2: Potential Environmental Risks on Your Farm.....	67
EXERCISE III-2: Risk Assessment .....	68
LESSON III-3: N- or P-Based Management and Manure Spreading Restrictions .....	70
EXERCISE III-3: Checklist.....	72
 <b>SESSION IV: Putting it All Together.....</b>	 <b>73</b>
LESSON IV-1: Understanding Potassium .....	74
LESSON IV-2: Secondary Nutrients and Micronutrients .....	77
LESSON IV-3: Understanding Nutrient Recommendations .....	80
EXERCISE IV-1: Field Plan Recommendation Worksheet.....	86
EXERCISE IV-2: Checklist .....	93
 <b>SESSION V: Future Success.....</b>	 <b>95</b>
LESSON V-1: Making Use of Your Plan .....	96
LESSON V-2: Recordkeeping.....	99
LESSON V-3: Reporting to State and Federal Agencies .....	101
LESSON V-4: Updating the Plan .....	103
EXERCISE V-1: Checklist .....	105

## Getting Ready For the Course

**I**t is very important that you communicate with various agencies well in advance of the course so that you have all of the necessary materials on the first day of class. It can take as long as six months to collect all of the information listed below. Make sure that you allow yourself plenty of time before the course to gather the materials needed to complete your Nutrient Management Plan (NMP).

You will need to have the following pieces of information for Session I:

### Current Soil Test Results

Soil test results must be no more than three years old. Samples must have been analyzed at the UVM Agricultural and Environmental Testing Lab or at another lab that uses the modified Morgan extractant. It is best to have soil test results from all farm fields at the time of the class. An individual soil test should not represent more than 20 acres of land.

### Current Manure Analyses

A manure sample needs to be taken from each manure storage facility every year. Therefore, if you have two manure storage facilities, each one should be sampled at least once per year. This is a requirement because the nutrient content of manure varies widely between different storage facilities, farms, and even between different seasons.

### Manure Production Information

This is a calculation of how many gallons or tons of manure, bedding waste, and waste water are produced on your farm each year. This number should be calculated by a Natural Resources Conservation Service (NRCS) employee or a land treatment planner (LTP) using the Vermont manure screening tool. The amount of waste produced should be calculated separately for each manure storage facility.

### WHAT IS A LAND TREATMENT PLANNER?

**A** land treatment planner is someone who helps develop maps, crop rotations, and other important pieces of a nutrient management plan. In Vermont, they work for the local conservation districts. Get to know your local land treatment planner!

### Maps

Several different types of maps are required to complete a NMP. These maps are usually created by an LTP or NRCS soil conservationist. A NMP must have each of the following types of maps for all land included in the plan.

**Proximity.** This map shows the location of the farmstead in relation to all tracts and includes roads and towns.

**Watershed.** Includes the 12 digit hydrologic code, surface waters and impaired watersheds.

**Land Use.** This map gives acreage and Farm Service Agency (FSA) tract and field numbers for each field, and erodibility and wetland determinations (if they are available).

**Soil.** This map shows the location of different types of soil on the farm.

**Environmental Concerns.** This map shows the location of wetlands, streams, wells, and other sensitive areas.

**Buffers and setbacks.** This map identifies vegetative buffers and labels nutrient application setbacks.

**Nitrate Leaching.** This map shows the level of risk for nitrates to leach through the soil to groundwater.

**Topographic.** This map shows landscape features and slope.

**Planned Practices.** This map identifies and labels all land treatment practices.

**Field Stack Map.** This map identifies vetted areas for field stacking manure.

**Frequently Flooded Soils Map.** This map identifies frequently flooded soils. The winter manure spreading ban is extended from October 16- April 14 for these fields. Only tracts of land that contain frequently flooded soils will have this map.

## RUSLE2 Calculations

RUSLE2 is a computer program that is used to predict soil loss or erosion from your farm fields. The amount of potential soil loss from each field is based on a variety of soil and management factors. Erosion rates are calculated by year and over the course of the cropping cycle that is used by the farmer. The erosion rate for each field must be at or below the tolerable soil loss (T) level for that particular soil type. These calculations will be completed in collaboration with a NRCS employee or a land treatment planner.

## Soil Fact Sheets

Each type of soil present on the farm should have a corresponding fact sheet that lists characteristics of that soil. These fact sheets can be obtained from NRCS or a land treatment planner.



## SESSION I

...

# Getting Started

*What will be covered in Session I:*

### Introduction to Nutrient Management Lessons

LESSON 1: Nutrient Management

LESSON 2: Navigating the Course Binder

LESSON 3: Maps and Soil Fact Sheets

LESSON 4: Soil Sampling

LESSON 5: Soil Erosion, RUSLE2, and Choosing a Rotation

### Terms to Learn

- nutrient management plan
- NRCS 590 Nutrient Management Standard
- Farm Service Agency land tract and field numbers
- T or tolerable soil loss
- RUSLE2

### Exercises

1. Farm Description
2. Map and Soil Fact Sheets Checklist
3. Soil Test Schedule
4. Organizing Your Soil Tests
5. Choosing Rotations that Meet T
6. Field Inventory Worksheet
7. Manure Application Schedule
8. Checklist

## LESSON I-1

### Nutrient Management

**Y**ou are here to develop a sound NMP for your farm. Nutrient management planning is a mixture of best management practices that aim to optimize crop yield and quality, minimize fertilizer input costs, and protect our natural resources. The basic principles of nutrient management are to apply the right amount of fertilizer in the right form, in the right place, and at the right time. If these principles are followed, crops will be productive, production costs will be minimized, and water resources will be protected. At the end of this course, you will have a NMP that satisfies state and federal regulations as dictated by the NRCS 590 Nutrient Management Standard. In addition to meeting regulations, NMPs can provide many benefits to both your farm and the environment.

#### Nutrient Management Can Make Your Farm Money

A NMP can save you money. By accurately accounting for the nutrients from your manure applications and from legumes and other crops in your rotation, you can reduce the amount of commercial fertilizer you need to purchase. Often this reduction is significant. The bottom line is that following a NMP often saves farmers money.

The amount of the savings depends on your current level of nutrient crediting. See the sidebar to the right for an example of the nitrogen (N) fertilizer value of the manure and legumes generated on a 100 cow dairy farm.

#### Nutrient Management Can Protect the Environment

A well-developed NMP will help you to farm within the needs and limitations of the environment. The driving force behind regulatory nutrient management programs is environmental concerns — specifically, water quality protection. Two of the most crucial nutrients in farming, nitrogen and phosphorus, can be harmful to the environment if they are applied without a proper under-

standing of their potential impact on water resources. In addition, excessive nutrients occur in soil when they are applied to a crop beyond what is needed for optimum growth. The results of excessive nutrient application are not beneficial to the crop and can be detrimental to the environment through nutrient losses to air, surface water, and ground water. Nitrogen is a mobile nutrient and is not easily retained in soils. Nitrogen that is not utilized by plants or tied up in the soil (immobilized) can be lost to the air, lost to groundwater, or carried in runoff to lakes and streams. Nitrogen is readily lost

#### SAVING MONEY WITH NUTRIENT MANAGEMENT

100 cow dairy (N = \$ 0.40/lb.)

Alfalfa N = \$ 2,400

(50 acres/year @ 120 lbs. N/acre)

Manure N = \$ 5,400

(27 tons/cow/year @ 5 lbs. N/ton)

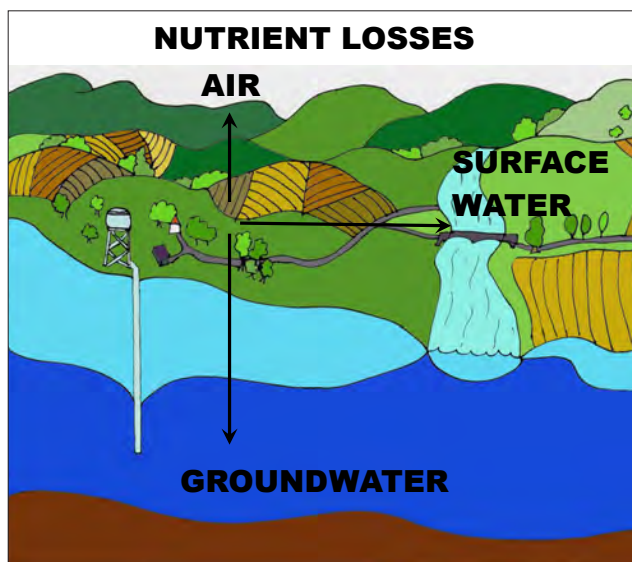
TOTAL on farm N value = \$7,800

#### Assumptions:

- 50 acres of hay is rotated annually. Stand density is 30 to 70% at time of plow-down.  
N credit = 120 lbs. N/acre.
- Manure is from milking cows only. Each cow produces 27 tons of manure per year. Manure is surface applied, therefore N content is 5 lbs. N/ton.
- The value of N is \$0.40/lb.
- If you currently credit N for manure and plow-downs, you may NOT save money by following a nutrient management plan.
- If you don't currently credit N, you can potentially save a substantial amount on fertilizer purchases.

to the air when it is changed from a liquid to a gas through the process of volatilization or denitrification. Greenhouse gas emissions from agriculture such as nitrogen gaseous emissions from manure, fertilizers, and other sources are linked to ozone depletion, acid rain and climate change as a whole. The main concern with N losses is the leaching (downward movement) of nitrates through the soil into groundwater. This problem is amplified when N applications exceed crop removal rates. Excess nitrate in drinking water is a human health concern. Water high in nitrates can inhibit an infant's ability to utilize oxygen. Livestock can also be adversely affected by elevated nitrate levels in drinking water. The health standard for drinking water is 10 ppm nitrate-N.

Phosphorus is the major nutrient promoting algae and aquatic weed growth in lakes and streams. Phosphorus bound to sediments and in surface water runoff can lead to algae blooms and oxygen depletion in fresh-



Nutrient losses can occur through volatilization into the air, runoff into surface waters, or leaching into groundwater.

water environments, such as Lake Champlain and in salt water environments, such as the Gulf of Mexico.

## Nutrient Management Can Improve Public Relations

Chances are, you have neighbors who don't know much about agriculture. Farmers need to be concerned with the image of agriculture held by the non-farming public. A NMP is the ideal jumping-off point for better public



Algae blooms can turn parts of Lake Champlain green during the summer months.

relations between your farm and the community. Efforts to do this will begin with good manure storage, handling, and application. Such efforts will help you spread manure to minimize odor, road spillage, and traffic hazards or delays. This also applies to water contamination from cattle standing in bodies of water.

By completing a NMP and implementing best management practices, you and your neighbors will know that your farm complies with state regulations and upholds the highest standards possible to keep the environment safe and clean.



What happened here? Maybe the tractor wouldn't start this day. An honest mistake like this can be bad for public relations.

## Following the Standard

In this class we will develop our NMPs based on the NRCS 590 Nutrient Management Standard. What does this mean? This standard is a very specific set of rules developed by the USDA NRCS that outlines the information that must be included in a NMP. The “590” is a code number that NRCS has assigned to this collection of rules and requirements. When a farmer uses soil tests to make decisions about applying fertilizer, he or she is practicing a nutrient management strategy. But the farmer may not be taking into account the many environmental factors that affect the transport of nutrients, such as soil type, slope, and distance to a nearby stream. A NMP meets the highest standard of excellence — the NRCS 590 Standard.

The NRCS 590 Standard requires information such as:

- Basic information about the farm, such as area, number of animals, and contact information
- Current soil and manure analyses
- Crop rotations, cover cropping, and tillage practices
- Quantity of manure produced and nutrient content of the manure
- Manure and fertilizer application to each field (timing, amount, method)
- Characteristics of the soils present on the farm
- Detailed maps of environmentally sensitive areas
- Environmental factors that affect nutrient transport
- Field by field plan for meeting the nutrient needs of the crop while minimizing movement of nutrients from the field

This class will provide the tools for creating a plan that meets the NRCS 590 Standard. A complete copy of the NRCS 590 Standard can be found in your class materials. As we go through each session we will continually refer to the 590 Standard. You should take the time to read the standard. Plans meeting this stringent standard have taken into account many factors specific to a farm and demonstrate the highest level of stewardship of the environment.

## LESSON I-2

### Navigating the Course Binder

**I**n this class you have been provided with a Land Treatment Plan and goCrop™, a web application to start creating your very own NMP. The LTP will provide you with the required documents that help to fill in each section. The remaining information is entered into goCrop™ and once completed it will be printed to complete your plan. The binder is divided into sections to help you navigate through the class and keep your plan organized. There is a wealth of information contained in this binder. To use it successfully, familiarize yourself with information included in each section. We will go through the binder and describe what pieces of information you will find in each section. During the six sessions you will be filling out all the forms on the web application.

#### Binder Sections

**Farm Information.** This first section is where you will enter all of the background information about your farm.

**Maps.** Here you will place the different types of maps created for your farm fields. Take a minute to look through the maps to make sure that they are all there and to organize them in a way that makes sense to you.

**Soil Information.** Behind this tab you will place the soil fact sheets describing each of the soil types that are present on your farm.

**Soil Analysis.** Your soil test results go here. In addition, there are instructions for taking a good soil sample, a soil test interpretation worksheet, and a soil test schedule.

**Manure Production.** This section contains descriptive information on the farm's manure handling system and manure and other waste production calculations. If

you export or import manure, you will need to fill out a special form in this section.

**Manure Analysis.** This is where you will find everything relating to manure nutrients. There are instructions on how to take a good sample of manure for analysis, instructions for calibrating your manure spreader, and worksheets that will help you calculate the quantity of nutrients that are in your farm's manure.

**Field Information.** In this section, you will list your crop rotations, current crop to be grown and yield goals. Crop nutrient removal rates for the farm will be calculated.

**Risk Assessment.** By using the Vermont Phosphorus Index, the Revised Universal Soil Loss Equation version 2 (RUSLE2), Nitrate Leaching Index and completing the environmental concerns risk assessment, you will be determining the potential risk for nutrient loss to groundwater and surface water.

**Field by Field Planning.** Using your soil test

results, you will be determining nutrient needs for your crops and planning how to meet those nutrient needs with manure or fertilizer. Through this process, you will allocate all of the manure produced on your farm to your farm fields.

**Recordkeeping.** An important part of a NMP is keeping records of what happens on your farm, including manure and fertilizer applications, crop yields, and any unexpected changes that you

had to make to your plan.

**References.** Here you'll find a checklist of all the components necessary for completing your NMP. In this section you can also read the NRCS 590 Standard.



A former Nutrient Management class participant keeps his binder handy so he can easily refer to it.

As you can see, there is a lot to be done in the next six weeks. This process may seem overwhelming at first because there is so much information and paperwork, but don't worry. We will be taking it one step at a time. More than one hundred and fifty farmers have already gone through this class and 95% of them have

completed their plans. You can do it too!

## EXERCISE I-1

### Farm Description

The first step in creating your NMP is to create a new farm plan. This is done by completing a series of forms found under the FARM TAB. The forms include, Details, Watershed, Land, Livestock, Manure Management and Fertilizers. The goal of this form is to help you describe your farming operation, capturing herd inventory, land use characteristics, agronomic practices, and farm goals. Here you will provide some basic information about your farm, like in the example (page 13). Fill out the information to reflect the management practices on your farm.



The screenshot shows the 'New Farm' form in the goCrop application. The form is titled 'New Farm' and is divided into two main sections: 'Details' and 'Location'. The 'Details' section includes fields for 'Name\*', 'Email\*', and 'Phone\*'. The 'Location' section includes fields for 'Address 1\*', 'Address 2', 'Town\*', 'State\*', 'Zip Code\*', 'Country\*' (with 'USA' selected), and 'County\*'. At the bottom right of the form, there are two buttons: 'Cancel' and 'Create Farm'.



Farm Information							
Farm Name	Bedrock Farm			Plan Date	2016-10-04	Crop Year	2016
Farm Manager	Fred Flintstone			Planner	Heather Darby		
Farm Address	Bedrock Farm 1611 Harbor Road Shelburne, VT 05482			Planner	Heather Darby 278 South Main St St. Albans, VT 05478		
County	Chittenden			Planner Phone	802-524-6501		
Phone No	4138241440			Planner Email	cropsoilvt@gmail.com		
Email	gocrop@uvm.edu						
Years Farming	9						
Describe your farm and plans for the future: Organic dairy farm with focus on producing high quality milk.				Talk about any anticipated major changes such as changes to herd size, structures being built or additional acreage being bought. If you anticipate that things will stay the same, then say so.			
Land Inventory (acres)				Watershed Lake Champlain Direct Northeast Arm			
	Owned	Leased		Hydrologic Unit & Code	041504061201		
Total	147	20		Impaired Watershed	Yes		
Tillable	0	0		Impairment Reason	303d listed watershed		
Permanent Hayland	25	20		Each watershed has a name and a code assigned to it. Look on your watershed map for the code for your watershed.			
Permanent Pasture	70	0					
Woodland	65	0					
Typical Rotation (Crops and Sequence): Perennial hay is currently the only crop produced.							
Tillage Operation/Equipment (Type, Timing, Depth, and Sequence): Not currently applicable.							
Primary	N/A						
Secondary	N/A						
Livestock Inventory				Breed:	Other		
				Rolling Herd Avg: 15000 lbs/cow/year			
Type/Breed	Present Number	Maximum Number	Weight (lbs)	Avg Milk Production (lbs/head/day)	Always Confined?	Grazing Type	Stocking Rate (head/ac)
Dairy - Lactating Cow	40	40	900	0	No	Continuous	4
Dairy - Dry Cow	15	15	900	0	No	Continuous	4
Dairy - Bred Heifer	4	4	650	0	No	Continuous	4
Dairy - Calves (<6 months)	15	15	125	0	Yes		
Dairy - Heifer (1 - 12 months)	15	15	500	0	No	Continuous	4
Beef - Calf	8	8	225	0	No	Continuous	4
Beef - Cow	1	1	700	0	No	Continuous	4

Fill in the year for the next growing

Talk about any anticipated major changes such as changes to herd size, structures being built or additional acreage being bought. If you anticipate that things will stay the same, then say so.

Each watershed has a name and a code assigned to it. Look on your watershed map for the code for your watershed.

Develop groups of animals to accurately describe your operation.

"Continuously stocked" = animals on same paddock. Select "number of paddocks" if you rotationally graze.

## LESSON I-3

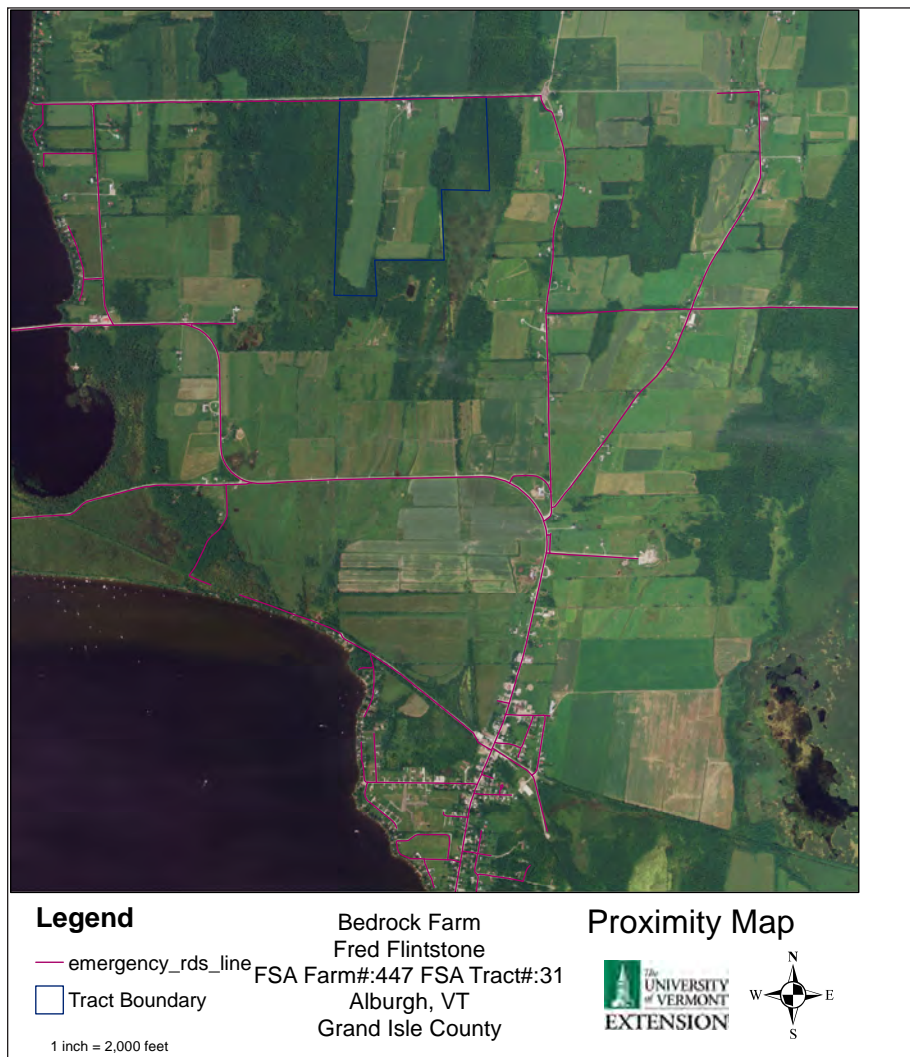
### Maps and Soil Fact Sheets

**H**ere are some examples of the several types of maps that are required for your NMP. You should have each of these types of maps for all land that is rented or owned. Your maps may have been made by a LTP, NRCS, UVM Extension, or a private consultant. Keep in mind that your maps may look different than

these examples, as each map maker has an individual style. The information on them, however, should be the same. Be sure to refer to the legends on your own maps to make sure you understand them.

#### Proximity Map

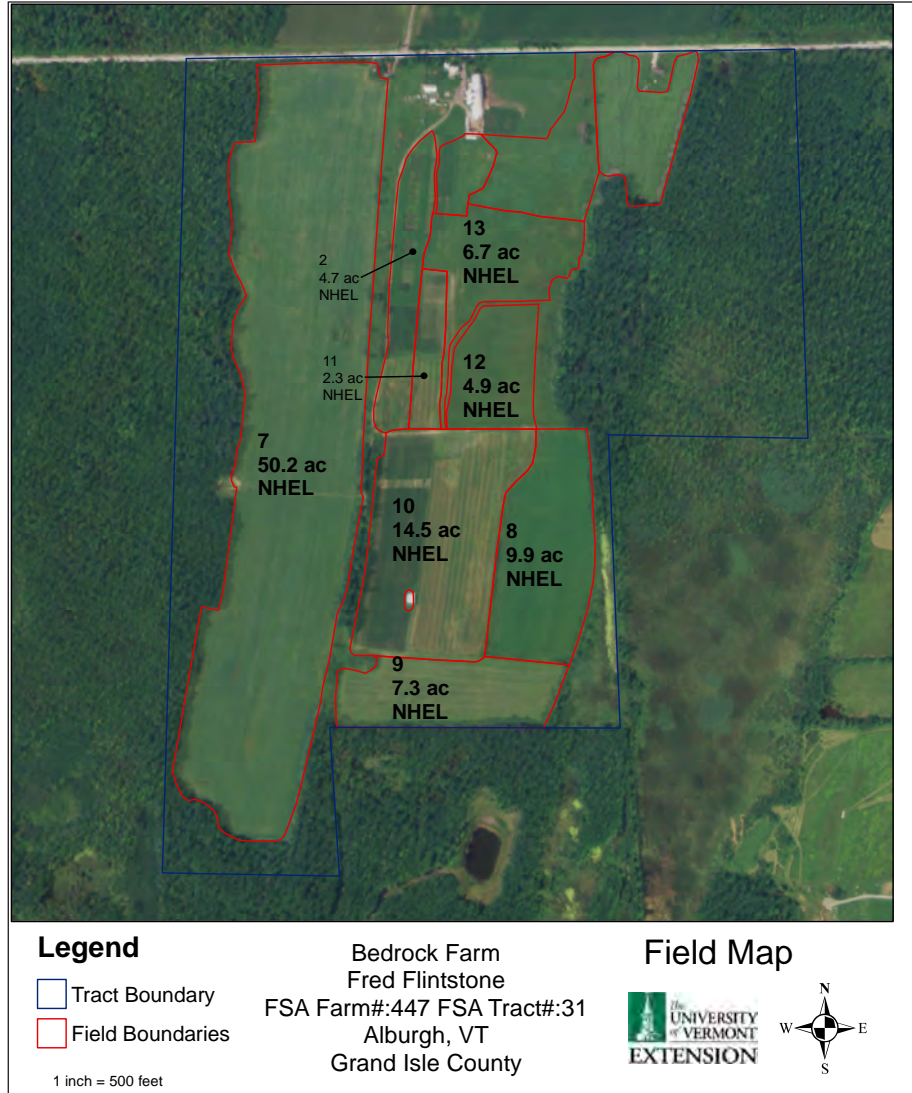
This map shows the location of all tracts of land included in the farm in relation to the town and road system. The farmstead and headquarters are pinpointed on the map.





## Plan Map

All farms that are involved in federal programs have been provided Farm Service Agency (FSA) land tract and field numbers. The designations must be used throughout the plan. If erodibility or wetland determinations have been made on your farm, the fields will be marked with those designations.



### HOW TO READ A PLAN MAP

If a community crop has been grown recently on a field it will be designated as either highly erodible land (HEL), non-highly erodible land (NHEL), or not determined (UHEL or blank).

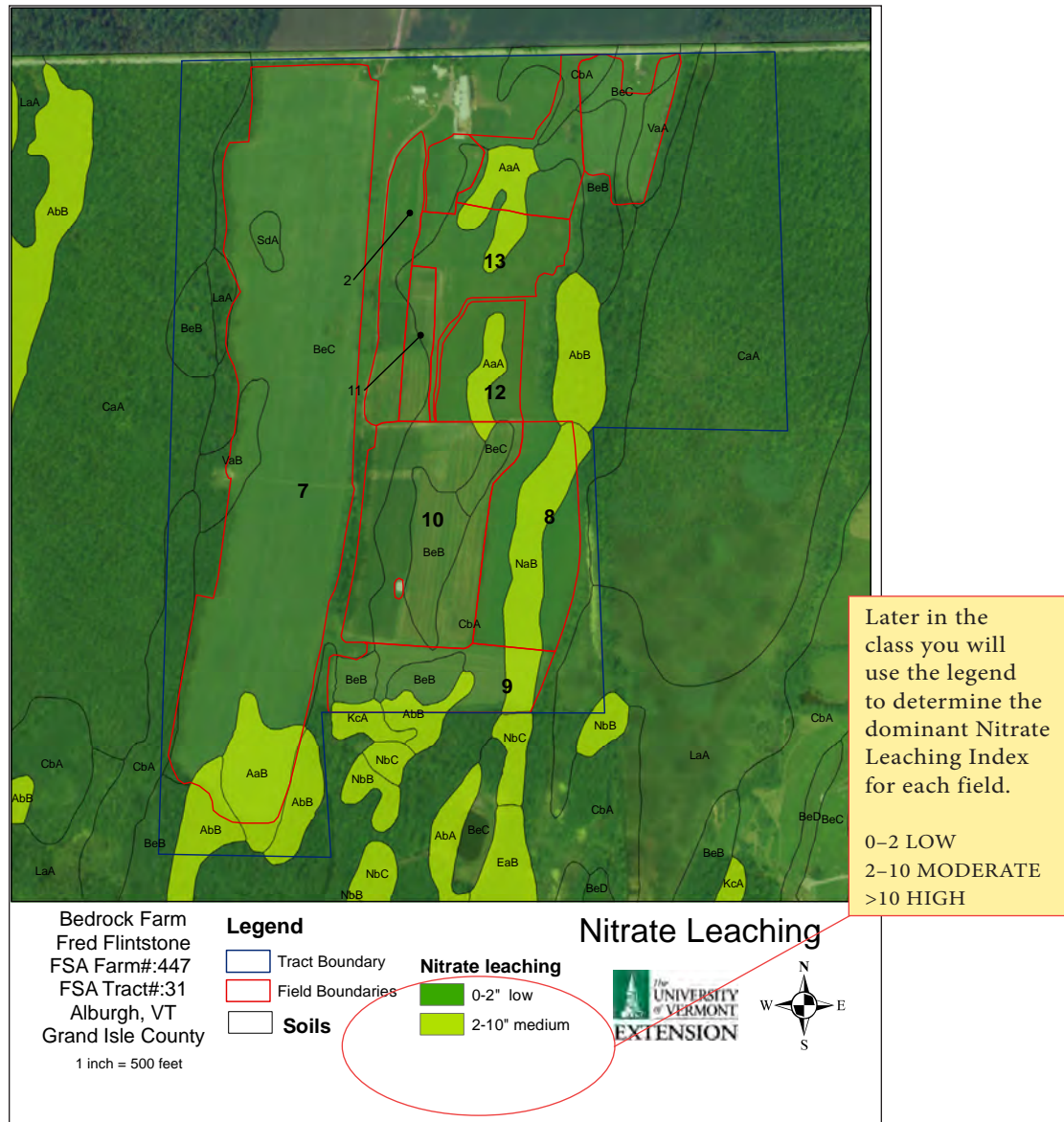
5  
30 ac  
NHEL

FSA field  
number

FSA  
acreage

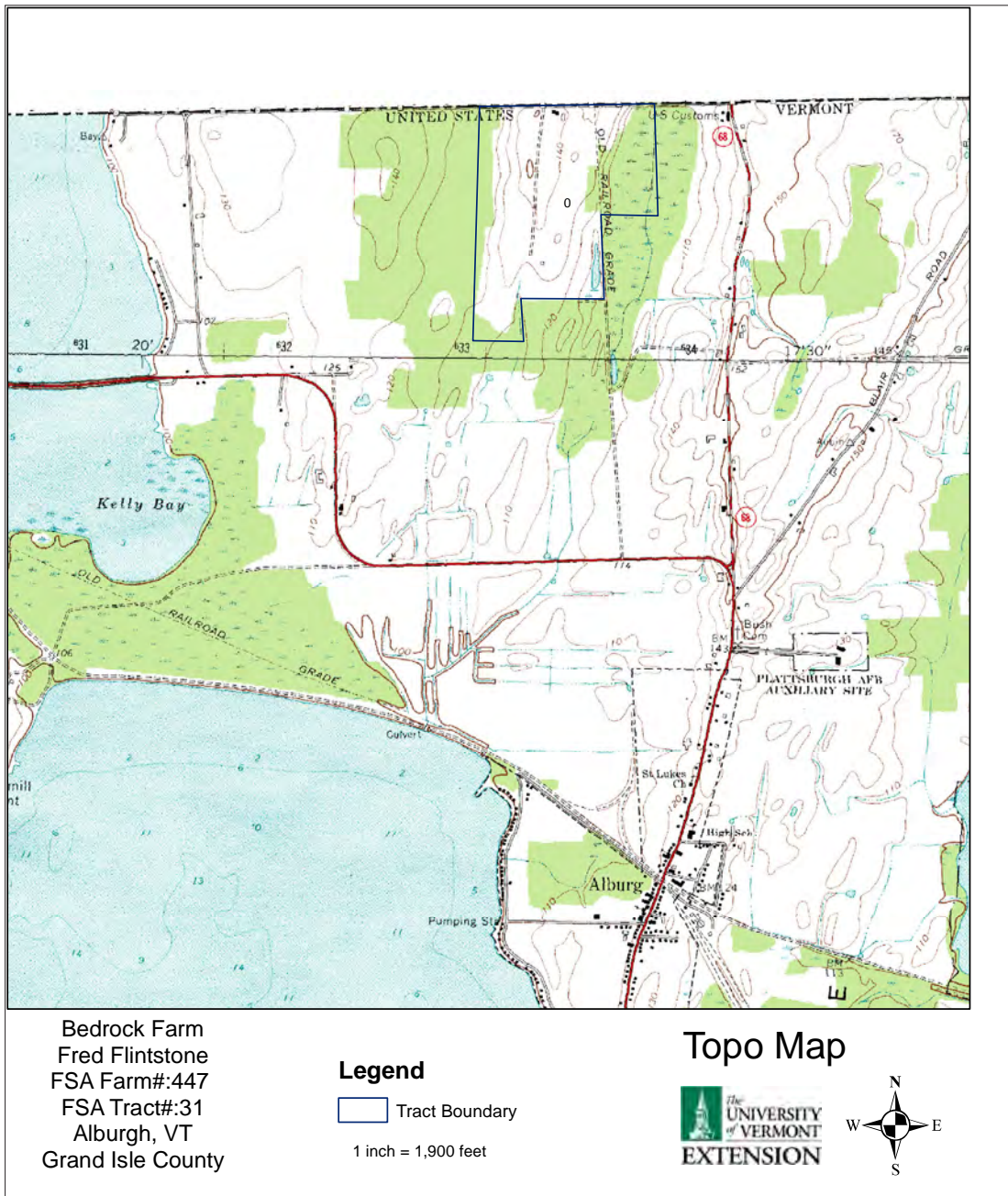
## Nitrate Leaching Map

Some soils are very prone to losing N (in the form of nitrate) into groundwater. This is usually a problem in sandier soils. Each type of soil has been rated low, moderate, or high on the Nitrate Leaching Index. The higher the index, the more likely it is that nitrates will leach through the soil into the groundwater. The level of N management on the field will be based on the leaching index. This tool will help you determine the appropriate practices to minimize N leaching. This is important from both environmental and crop nutrient perspectives. You want N to be taken up by your crops — not moving into groundwater.



## Topographic Map

This type of map is familiar to many people. It contains contour lines that show the elevation of the area (in feet above sea level). The closer the contour lines are together, the steeper the slope.



Bedrock Farm  
Fred Flintstone  
FSA Farm#:447  
FSA Tract#:31  
Alburgh, VT  
Grand Isle County



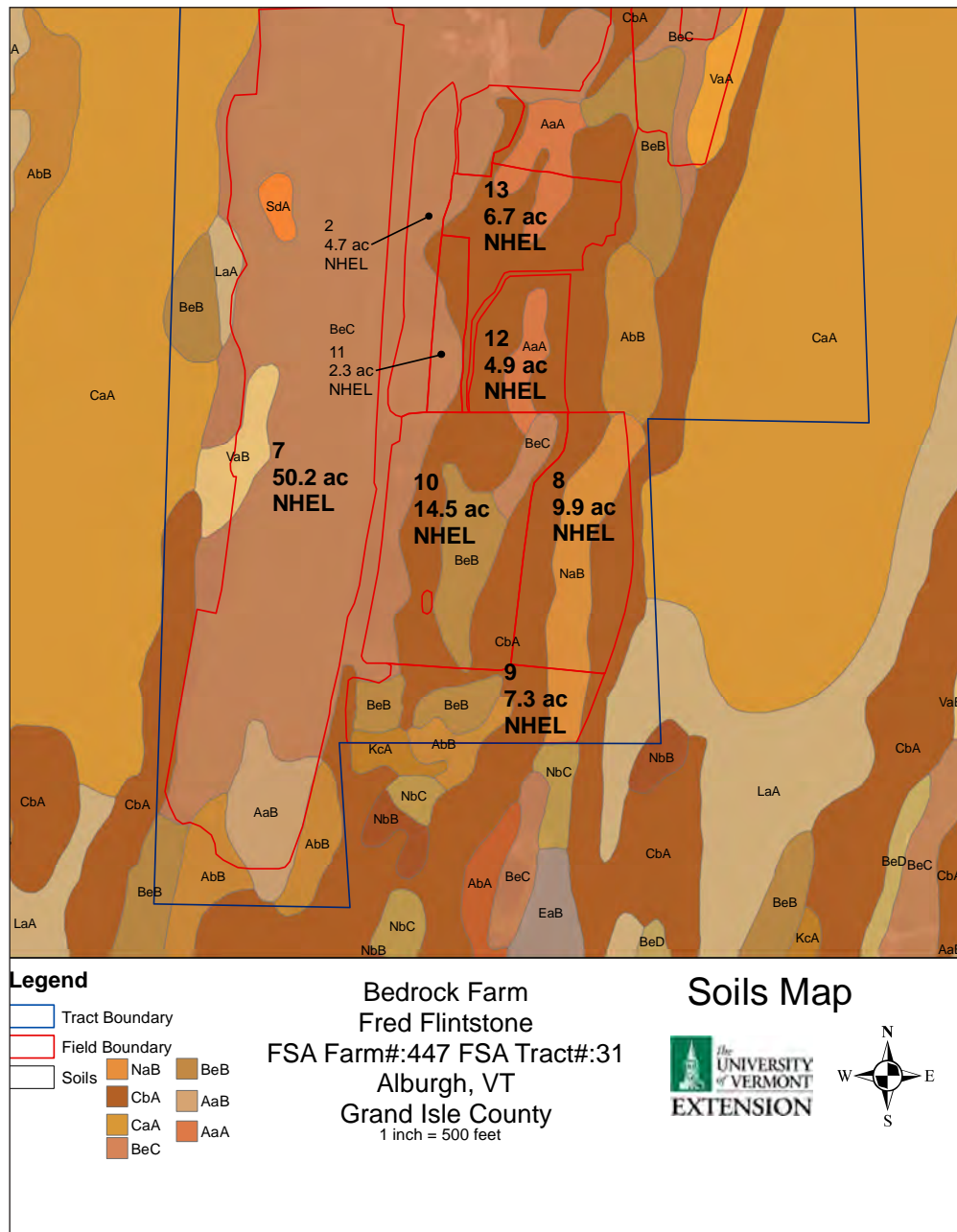
## Environmental Concerns Map

Environmentally sensitive areas are shown on this map. The map is used to highlight areas that could be threatened by pollution. This map shows the location of designated sensitive areas or resources and the associated nutrient management restrictions such as buffers or setbacks. In the example below, surface waters are shown with a blue line and the required 25-foot buffers are shown with green hash marks. Other sensitive areas such as wetlands, important wildlife habitat, wells, and buffers required around wells will be shown on this map.



## Soils Map

There are more than 180 types of soil in the state of Vermont. Each soil type has its own characteristics, which we'll be talking about next. Each soil type is identified by a code, either letters, numbers or a combination of both. Sometimes there is a third letter that indicates the slope. For example, for the soil marked "EnA" below, "En" stands for Enosburg soil and "A" means that there is a 0 to 3% slope. Note that the boundaries between soil types usually don't follow field boundaries, so it is common to have more than one type of soil in a field.



## Soil Fact Sheets

There is a soil fact sheet that describes each of the 180 distinct soil types found in Vermont. The fact sheet describes the formation of the soil, depth to water table, and how susceptible the soil is to erosion. We will only be using part of the information on the soil fact sheet, which is highlighted in the example below. You should have a soil fact sheet for each soil type on your farm.

**USDA** Natural Resources  
Conservation Service

**Vermont Soil Fact Sheet**

Franklin County, Vermont

Soil series

Soil drainage class

**MuB: Munson silt loam, 3 to 8 percent slopes**

MUNSON SOILS formed in loamy over clayey glaciolacustrine deposits on lake plains. They are very deep to bedrock and somewhat poorly drained. These soils have a perched water table at depths of 0.5 to 2.0 feet below the surface from late Fall through early Summer. Permeability is moderate in the surface layer, moderately slow to moderate in the subsoil and slow in the substratum.

This map unit is suited to cultivated crops. It is well suited to hay and pasture. Erosion is a hazard. A seasonal high water table may inhibit the establishment of some crops.

Important farmland classification: Statewide

Land capability: 3 w

Vermont Agricultural Value Group: 4d

Vermont Residential Wastewater Disposal - Group and Subgroup:

IIlc.- This unit is marginally suited as a site for soil-based residential wastewater disposal systems, based on a review by the Natural Resources Conservation Service of criteria set forth in the Vermont 2007 Environmental Protection Rules. The depth to the seasonal high water table in association with the minimal slope is the major limitation. A detailed, site-specific analysis is generally required. On-site groundwater level monitoring and determination of induced groundwater mounding is often necessary to establish the suitability of this unit. Curtain drains may help lower the water table to an acceptable level, however, the minimal slope may prevent their use in many areas.

PHYSICAL and CHEMICAL PROPERTIES							EROSION FACTORS		
Soil name	Depth (In)	Typical texture	Clay (Pct)	Soil reaction (pH)	Permeability (In/Hr)	Organic matter (Pct)			
							Kw	Kf	T
Munson	0-8	SIL	3-10	5.6 - 6.5	0.6-2	3.0-10	.49	.49	2
	8-14	SIL	3-16	5.6 - 6.5	0.2-2	0.5-3.0	.49	.49	
	14-40	SICL	35-60	5.6 - 7.3	0-0.2	0.0-1.0	.49	.49	

WATER FEATURES					SOIL FEATURES			
Soil name	Hydrologic group	Depth to seasonal high water table (Feet)	Flooding		Ponding		Hydric soil?	Depth to bedrock (range in inches)
			Frequency	Duration	Frequency	Duration		
Munson	D	0.5-2.0	None		None		No	---

LAND USE LIMITATIONS				AGRICULTURAL YIELD DATA	
Soil name	Land use	Rating	Reason **	Crop name	Yield / acre
Munson	Dwellings with basements:	Very limited	Depth to saturated zone	Corn silage	22 Tons
Munson	Pond/reservoir areas:	Somewhat limited	Slope	Grass hay	4 Tons
				Grass-clover	5.6 AUM
				Grass-legume hay	3.5 Tons

WOODLAND MANAGEMENT				
Soil name	Management concern	Rating	Reason	Vermont natural communities
Munson	Harvest equip operability:	Poorly suited	Wetness	Valley Clayplain Forest
Munson	Road suitability:	Poorly suited	Wetness	
Munson	Erosion hazard (off-road):	Slight		

Hydrologic group

Depth to water table

Frequency of flooding

Depth to bedrock

## EXERCISE I-2

### Map and Soil Fact Sheets Checklist

**B**efore you go any further, it is important to make sure that you have all of the maps and soil fact sheets that you will need for the class. Arrange them in your binder in an order that makes sense to you (maps: by tract number; soil fact sheets: alphabetically) so that you will be able to easily locate them. Put checkmarks in the table below to verify that you have all of your maps.

Now look at the soil map for each of your fields and make sure that you have a soil fact sheet for each type of soil that is on your farm. You can use the table below to keep track.

If you are missing any fact sheets, please contact your course instructor, NRCS, a LTP or UVM Extension.

#### MAP CHECKLIST

Map Type	Tract(s)	Tract(s)	Tract(s)	Tract(s)	Tract(s)	Tract(s)	Tract(s)	Tract(s)
Proximity								
Conservation Plan								
Nitrate								
Topographic								
Environmental Concerns								

#### SOIL FACT CHECKLIST

Soil Abbreviation	Fact Sheet?	Soil Abbreviation	Fact Sheet?	Soil Abbreviation	Fact Sheet?
MuB	3				



## LESSON I-4

### Soil Sampling

#### How to Take a Soil Sample

A soil test is the only practical way of telling how much fertilizer is needed in a given field. However, the reliability of a soil test is only as good as the sample you submit. The small amount of soil in the sample bag you send to the laboratory must represent the entire area to be fertilized. Avoid unusual areas, such as those where fertilizer or lime has spilled. Take samples before lime, fertilizer, or manure are applied. Use only clean equipment for collecting soil samples.

1. In order to receive your recommendations early



Using a soil probe is the easiest way to get a good soil sample.

enough to use them for planning the next crop season, it is best to take samples in the fall.

2. A soil sampling probe or auger, available from mail order catalogs and garden or farm supply outlets, is the best tool for sampling and is a necessity if sampling large numbers of fields. You may be able to borrow a probe from a UVM Extension or a local NRCS office.

3. The area to be sampled should be as uniform as possible in terms of soil type and cropping and fertilizing history. For practical purposes it should be an area you expect to fertilize as a unit. Take at least 15 soil cores or borings for each composite sample on a field of a maximum of 20 acres. If a field is more than 20 acres, take two complete samples.
4. Insert the probe or auger into the soil to plow depth for annual crops or at least 6 inches for hay and other perennial crops. In general, do not sample any area of a field that varies widely from the rest of the field in color, fertility, slope, texture, drainage, or productivity.
5. Discard any plant material and mix soil cores in a clean plastic bucket. Be sure to mix samples well.
6. Take about 1 cup of the mixed soil cores and place it in a plastic bag.
7. Identify the bag with your name, field name, and sample number.
8. Record the field, sample location, and date in your records.
9. Fill out the soil test questionnaire and place it in an envelope with the plastic bag along with a check. If submitting multiple samples, include one check for total being tested. The sample can be taken directly to the UVM lab or sent to the address below. If you need a copy of the soil test form, it can be found at the following website: [http://pss.uvm.edu/ag\\_testing](http://pss.uvm.edu/ag_testing)

The University of Vermont  
Agricultural & Environmental Testing Lab  
Jeffords Hall, Room 262, 63 Carrigan Drive  
Burlington, VT 05405-1737

Results are normally returned in two weeks.



### EXERCISE I-3

#### Soil Test Schedule

**A**n important part of developing and maintaining a NMP is to regularly monitor your soil nutrient content through soil testing. Soil testing is required for each field a minimum of once every three years. Fall is usually the best time for testing, especially if you are rotating to a different crop the next year. Soil testing in the fall will ensure that you have all the necessary parts to complete your NMP during the winter. Remember that when a field is larger than 20 acres, you should be taking two separate tests (for example, a field called “Oak Tree” could be split into “Oak Tree North” and “Oak Tree South” for the purposes of soil testing). If the results are substantially different, the sections should be treated as separate fields in the NMP.

A soil test schedule will be generated in goCrop™ once you enter your soil test information. Some people prefer to soil sample all fields at once and others like to be on a rotation so they only sample some of their fields each year. Choose the option that works best for you, given your management style.

### EXERCISE I-4

#### Organizing Your Soil Test Results

**W**riting a NMP involves a lot of paper shuffling and good organization is necessary. In order to minimize confusion, you should first write the FSA land tract and field number on each soil test. Do this even if you usually use familiar names (such as “Back Field”) rather than Farm Service Agency (FSA) tract and field numbers (such as “356-14”). For your NMP, you will get used to using tract and field numbers in conjunction to your regular field names. Next, organize all of your soil sample results in a manner that makes sense for the farm. For example, some farms put all corn fields first, followed by hay fields. Other farms put owned fields first, followed by rented fields.

As you are organizing your soil tests you should start to identify trends on your farm. For example, do you have many fields that are excessive in phosphorus? Do you have fields that are low in potassium? Getting a feel for your soil test analysis will help you determine appropriate manure and fertilizer rates later in the class. Find the worksheet in your binder called Soil Test Interpretation and Planning Strategy and fill it out based on your results. Filling out this worksheet will help you figure out how to approach the rest of the NMP based on soil test trends.

## LESSON I-5

### Soil Erosion, RUSLE2, and Choosing a Rotation

**A**fter studying the soils map it becomes clear that soil is variable from farm to farm, field to field, and even within a field. Climate, soil type, and topography can result in a soil that is more or less susceptible to erosion compared to other soil types. Erosion happens when soil has lost its structure and travels from one place to another. It can be carried away by wind or rain and its effects can be devastating to the farm and the environment.

The dustbowl is an extraordinary example of erosion. In this example of very poor farming practices, the land was farmed without providing perennial soil cover. The prairie grasses that held the soil in place were replaced with year upon year of annual crops. The soil was over-utilized and developed poor structure to the point where the winds and rain of the prairies were able to carry the soil particles, in some cases, all the way to Vermont.

#### Three Basic Types of Erosion

**Sheet Erosion.** The removal of soil in a uniform sheet-like fashion, which occurs on bare soil and may not be visible.

**Rill Erosion.** This is a concentrated flow of water down small channels. These channels are too large to be smoothed over with normal tillage.

**Gully Erosion.** This occurs when large channels form over time, usually beginning as rill erosion. These channels are too large to be smoothed over with normal tillage.

Some soils are naturally more erodible than other soils. Steep and long slopes produce more erosion than do short and flat slopes. Land use has a major effect on erosion. Exposing the soil to raindrops and surface runoff dramatically increases erosion. According to the NRCS 590 Standard, the goal is to minimize erosion to a tolerable level in all fields.



Sheet erosion.

Ben Gabos



Rill erosion.



Gully erosion.

## DEFINITION OF SOIL EROSION

Soil erosion is a two-phase process:

1. Detachment of individual particles from soil aggregates.
2. Transport of particles by erosive agents — wind or water.

Particles are eventually deposited to form new soils or to fill lakes, reservoirs, or stream channels.

can be lost without impacting crop yields or production. In the example below, Munson silt loam with a 3 to 8 percent slope, has a T value of 2. This means you can lose up to two tons of soil per acre per year and this type of soil will be formed fast enough to replenish the soil lost to erosion. This is acceptable and considered “farming to T.” To comply with the NRCS 590 Standard, all fields on a farm must be managed to meet T. The potential soil loss value for each individual field on your farm has been calculated based on your management and the soil characteristics. This information can be found on the RUSLE2 worksheet provided to you in your LTP.

## What is T?

Every soil type has a corresponding fact sheet that explains the specific characteristics of that soil. One characteristic is the soil's T value. T stands for tolerable soil loss. This is the amount of soil per acre per year that

## What is RUSLE2?

RUSLE2 stands for Revised Universal Soil Loss Equation—Version 2. RUSLE2 is a computer model that estimates potential soil loss from rill and interrill erosion caused by rainfall and overland flow. It is a

USDA Natural Resources Conservation Service		Vermont Soil Fact Sheet					Franklin County, Vermont		
<b>MuB: Munson silt loam, 3 to 8 percent slopes</b>									
MUNSON SOILS formed in loamy over clayey glaciolacustrine deposits on lake plains. They are very deep to bedrock and somewhat poorly drained. These soils have a perched water table at depths of 0.5 to 2.0 feet below the surface from late Fall through early Summer. Permeability is moderate in the surface layer, moderately slow to moderate in the subsoil and slow in the substratum.									
This map unit is suited to cultivated crops. It is well suited to hay and pasture. Erosion is a hazard. A seasonal high water table may inhibit the establishment of some crops.									
<u>Important farmland classification:</u> Statewide			<u>Land capability:</u> 3 w			<u>Vermont Agricultural Value Group:</u> 4d			
<u>Vermont Residential Wastewater Disposal - Group and Subgroup:</u>									
IIc.- This unit is marginally suited as a site for soil-based residential wastewater disposal systems, based on a review by the Natural Resources Conservation Service of criteria set forth in the Vermont 2007 Environmental Protection Rules. The depth to the seasonal high water table in association with the minimal slope is the major limitation. A detailed, site-specific analysis is generally required. On-site groundwater level monitoring and determination of induced groundwater mounding is often necessary to establish the suitability of this unit. Curtain drains may help lower the water table to an acceptable level, however, the minimal slope may prevent their use in many areas.									
PHYSICAL and CHEMICAL PROPERTIES							EROSION FACTORS		
Soil name	Depth (In)	Typical texture	Clay (Pct)	Soil reaction (pH)	Permeability (In/Hr)	Organic matter (Pct)	Kw	Kf	T
Munson	0-8	SIL	3-10	5.6 - 6.5	0.6-2	3.0-10	.49	.49	2
	8-14	SIL	3-16	5.6 - 6.5	0.2-2	0.5-3.0	.49	.49	
	14-40	SICL	35-60	5.6 - 7.3	0-0.2	0.0-1.0	.49	.49	
WATER FEATURES							SOIL FEATURES		
Soil name	Hydrologic group	Depth to seasonal high water table (Feet)	Flooding		Ponding		Hydric soil?	Depth to bedrock (range in inches)	
			Frequency	Duration	Frequency	Duration			
Munson	D	0.5-2.0	None		None		No	---	
LAND USE LIMITATIONS					AGRICULTURAL YIELD DATA				
Soil name	Land use	Rating	Reason **		Crop name	Yield / acre			

complex calculation that takes into account soil type, crops grown, tillage, slope, and manure application over the course of the cropping cycle. RUSLE2 is a powerful tool for conservation planning, inventories, and estimating sediment production.

Let's look at a sample RUSLE2 report. You should have something that looks like the example below for each of your fields. Notice that the soil type and T value are listed, as well as erosion by year. There are two different management possibilities listed and the soil loss that would occur with each strategy. A rotation is acceptable if the soil loss is less than T.

Do you have a problem with erosion on parts of your farm? Check in with your local NRCS representative to find out ways to address various types of erosion issues.



Rusle Program Version:  
Rusle Science Version:  
Data Base:

University of Vermont Extension  
278 South Main St. Suite 2  
St. Albans, VT 05478  
802-524-6501

### RUSLE2 Erosion Calculation Record

Inputs:

Owner name	Location
Fred Flintstone	Vermont\Franklin County

Field name	Soil	Slope T Value	Slope length, ft	Slope %	Description	Cons. plan. soil loss, t/ac/yr	Erosion by year
T49-1	Franklin, VT\MnA Massena extremely stony loam, 0 to 6 percent slopes\Mas sena loam 75%	3.0	120	3.0	7 yrs Corn Silage,FP - 3 yrs legume-grass Hay; 3 cuts, manure, Z60	1.95	1.9 2.3 2.5 2.5 2.5 2.5 2.4 0.22 0.37
					7 yrs Corn Silage,FP,winter cover - 3 yrs legume-grass Hay; 3 cuts, manure, Z60	1.38	1.4 1.6 1.7 1.6 1.7 1.6 1.7 2.0 0.22

### EXERCISE I-5

...

### Choosing Rotations that Meet T

**Y**ou should have received RUSLE2 reports (calculating the potential soil erosion for different rotations) for each of your fields. For each field, select a rotation that meets T by placing an X next to it on your RUSLE2 report. The rotation should have a planned soil loss of equal to or less than the T value for the soil. Remember, this should be a rotation that will actually work for your farm. If you would like to use rotations other than the ones listed on your report, work with the LTP to generate soil loss values for additional rotations.

## EXERCISE I-6

### Creating a Field Inventory

**N**ext you will create an inventory of every field you own or rent. You will record the field name (the name you call it), the FSA tract and field number, acres, and soil type (you can find this on your soil map). The order in which you add the fields will remain the same throughout the web application. Use the same order that you used for your soil tests and maps so that it is easy to find information when you need it later on. Other field characteristics such as location, soils, VT NMP field details and conservation practices will be captured. These sections can be filled out now or later. These characteristics include distance to stream, vegetated buffer width, manure spreading setback, whether it has tile drainage and other features of the predominant soil type. These features can be found on the soil fact sheets.

### New Field

#### Details

**Field Name\***

**Size\***

**Included Since\***

**Ownership Type\***  
☐ Owned  
☐ Leased

**County\***  

Grand Isle County

County in which the field primarily lies

**Notes**

Cancel

Save Field

You can fill out each of the following sections now or later.

#### Map

Map Satellite

Borderview Farm

US Customs and Border Protection

229

(Exercise I-6 is continued on the next page)



When adding Crops it is important to set a realistic crop yield for that field. Your yield goal is reported as tons per acre, and should be based on what your soils are capable of producing in a good year. Corn silage yields are reported at the harvested moisture. Hay and haylage should be reported as tons of dry matter per acre.

Field Inventory Sheet														
Farm Name	Sample Farm				Plan Date	2012-03-22		Crop Year		2012				
Producer/Farm Manager	Joe Farmer				Planner	Joe Farmer								
Example Abbreviations: CS: Corn Silage CG: Corn Grain S: Soybean W: Wheat B: Barley WR: Winter Rye T: Triticale O: Oats FSS: Forage Sorghum/Sudangrass fM: forage Millet C: Canola Su: Sunflower GHN: Grass, Hay, New GHE: Grass, Hay, Estbl. GP: Grass, Pasture GIHN: Grass/legume, Hay, New GIHE: Grass/legume, Hay, Estbl. GIP: Grass/legume, Pasture LH: Legume, Hay CSwCC: Corn Silage w/ Cover Crop CC: Cover Crop Sn: Snaplage HMC: High Moisture Corn E: Earlage WC: White Clover RC: Red Clover A: Alfalfa Tr: Trefoil Br: Brassica														
Field Name	Tract & Field #	Acres Owned	Acres Rented	Soil Type	Crop Information for Year 2013						Soil Test Levels			Yield Goal (T/A/Crop)
					Rotation	Year in Rotation	Current	Last Year	2 Yrs Ago	Next Year's	P	K	pH	
Field#1	9999-1	30.0		GeA	4CS/3GI HE/GHE	3CS	CG; W	CS	CS	CS	5.8	104.0	6.6	180 Bushels; 2 Tons
Small Pieces	60-7	11.0		Ly	5CS/GI HN/4GI HE	1CS	GHE	GIHE	GIHE	CS	4.3	94.0	6.3	4 Tons
Across Brook	60-8,9,c1	33.0		KbA	4CS/GI HN/5GI HE	6GIHE	GIHE	GIHN	CS	GIHE	2.3	78.0	6.6	6 Tons
Behind Jacks	60-10	18.0		MeA	5CS/GI HN/4GI HE	6GIHN	GIHN	CS	CS	GIHE	4.4	98.0	6.6	6 Tons
Behind Pond	60-6,11	48.0		MeA	5CS/GI HN/4GI HE	4CS	CS; S; CS	CS	CS	CS	9.5	128.0	7.1	25 Tons; 4 Tons; 0
Rileys Knoll	65-1	38.0		KbA	4CS/GI HN/5GI HE	3CS	CS; B; W; W	CS	CS	CS	5.3	122.0	7.1	25 Tons; 4 Tons; 3 Tons; 3 Tons
Back of House	65-2	13.5		KbA	4CS/GI HN/3GI HE	8GIHE	GIHE	GIHE	GIHE	CS	5.5	138.0	6.4	6 Tons
Back of Davids	65-4	35.0		MeA	4CS/GI HN/3GI HE	1CS	CS	GIHE	GIHE	CS	2.6	78.0	6.7	25 Tons
Gerards Below Hill	67-2		13.0	KbA	5CS/GI HN/4GI HE	9GIHE	GIHE	GIHE	GIHE	GIHE	9.7	120.0	7.3	6 Tons
Pieces up back Corn	67-4 Corn		38.0	KbA	5CS/GI HN/4GI HE	3CS	CS	CS	CS	CS	14.9	147.0	7.5	

## EXERCISE I-7

### Manure Application Schedule

**T**he Manure Application Schedule worksheet summarizes the time of year that you apply manure to various crops on the farm. Your answers in this section should reflect what you normally do on your farm. Remember, there is a winter spreading ban in Vermont from December 15th to April 1st, so no manure is allowed to be spread between those dates.

Producer Name: Joe Farmer  
Farm Name: Green Valley Farm

Date: January 1, 2009

#### MANURE APPLICATION SCHEDULE

CROP GROUP	Total ACRES	Land Application Of Manure Is Planned To Occur During Highlighted Months											
		JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
CORN	75					X					X		
HAY / LEGUME	126						X	X	X	X			
PASTURE	5					X	X	X	X	X	X		

#### MANURE SPREADING RESTRICTIONS

Manure may not be spread:

- Within intermittent ditches, buffers, diversions, grassed waterways, drainage ditches, or other areas of concentrated flow
- Over bedrock outcrops
- On frozen or snow-covered ground
- Between December 15th and April 1st
- On frequently flooded fields between Oct 16-April 14

## EXERCISE I-8

### Checklist

**H**ere is a list of items that you should have completed before you go on to the next session. The items that have been completed in the goCrop™ application are listed in blue.

#### SESSION I

- ☐ [Farm description](#)
- ☐ Maps (proximity, conservation plan, nitrate leaching, topographic, environmental concerns, soils)
- ☐ Soil fact sheets
- ☐ Soil test results organized
- ☐ Soil test interpretation and planning strategy
- ☐ [Soil test schedule](#)
- ☐ RUSLE2 (with your crop rotation indicated)
- ☐ [Field inventory](#)
- ☐ Manure application schedule



## SESSION II

...

# Understanding Soil Nutrients

*What will be covered in Session II:*

## A Closer Look at Soil Nutrients

LESSON 1: The Dirt on Soil

LESSON 2: The Nitrogen Cycle

LESSON 3: The Phosphorus Cycle

LESSON 4: The P-Index

## Terms to Learn

- cation exchange capacity (CEC)
- nitrate-N
- ammonium-N
- phosphorus index (P-index)

## Exercises

1. Calculating Nutrient Availability in Manure
2. P-Index Worksheet
3. Checklist

## LESSON II-1

### The Dirt on Soil

**A** NMP starts with understanding what's in your soil. Do you know what's in yours? This is the essence of nutrient management. Soil is a complex and intricate system.

Cornell Soil Health Program



Soil varies in its appearance and ability to grow crops. We can tell by looking at these two soils which would be the better one for crops, but what is the real difference?

Soil is characterized by its physical, chemical, and biological properties

### Physical

Some physical properties of soil can be seen with the eye or felt between thumb and finger. With the exception of texture, they are all subject to change caused by weather and management.

**Color.** Color can indicate soil conditions such as organic matter content, drainage conditions, degree of oxidation, and extent of weathering. Darker soils generally contain more organic matter than lighter colored soils.

**Texture.** Texture depends upon the amount of sand silt and clay particles present. A Covington soil is characterized as a clay and may contain around 65% clay, 30% silt, and 5% sand.

Cornell Soil Health Program

### SOIL-STRUCTURE EVALUATION

Good Condition vs – 2



Good distribution of friable finer aggregates with no significant clodding.

Moderate Condition vs – 1



Soil contains significant proportions of both coarse, firm clods and friable, fine aggregates.

Poor Condition vs – 0



Soil dominated by extremely coarse, very firm clods with very few finer aggregates.

**Structure.** The size and arrangement of structural pieces called soil aggregates (the crumbs or chunks of soil) affect the amount and types of pores the soil has, and therefore strongly influence water and oxygen storage and movement through the soil.

**Internal Drainage.** Water drains below the root zone following saturating rains.

**Depth.** This is the distance from the surface to the layer that stops downward growth of plant roots (bed-rock or extremely compact layer). Depth affects the capacity for water storage in a soil.

**Susceptibility to Erosion.** Susceptible soils generally have a low amount of stable surface aggregates and/or are poorly drained and/or have high slopes. Soils that have lost part or all of their top-soil layer to erosion are harder to till and not as productive.

## Chemical

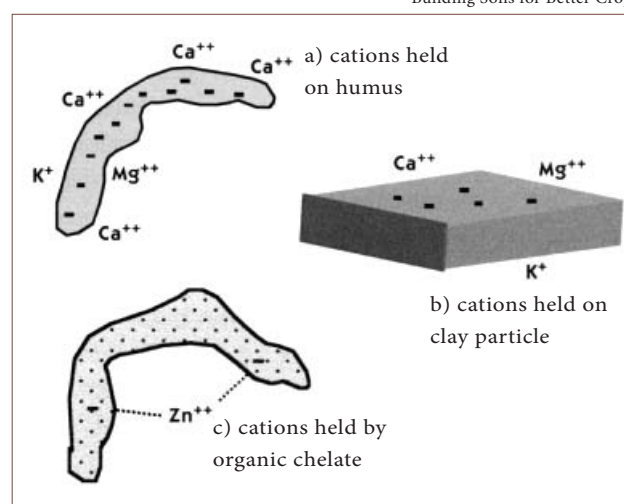
Chemical properties of soil involve the management of soil nutrients at the most basic level.

**pH.** pH measures the relative acidity or alkalinity of a soil solution. This measurement is done on a scale from one to fourteen. At a pH of 7.0, the solution is neutral. Less than 7.0 is acidic and greater than 7.0 is basic. The pH condition of the soil ranks among a number of environmental conditions that affect the quality of plant growth. Most agricultural soils in Vermont are in the range of pH 5 to pH 7. The major impact of extremes

in pH on plant growth is related to availability of plant nutrients. Most agronomic crops prefer soil pH between 6 and 7. However, some crops such as blueberries and cranberries prefer pH below 5. Because pH is expressed on a logarithmic scale, a difference of one pH unit is a tenfold difference in acidity.

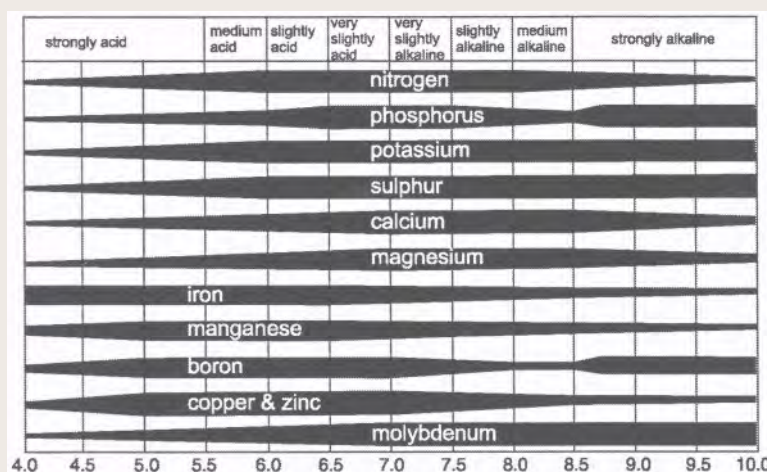
**Cation Exchange Capacity.** Mineral nutrients within the soil have either a positive or negative charge. The nutrients with a positive charge (including calcium, magnesium, potassium, ammonium, and sodium) are held by negatively charged clay particles and organic matter. Cation exchange capacity (CEC) refers to a soil's

Building Soils for Better Crops



Negatively charged organic matter (humus) and clay particles play an important role in retaining positively charged plant nutrients, or cations, in soils.

## SOIL PH AND NUTRIENT AVAILABILITY



ability to retain these nutrients (because organic matter and clays have negative charges), rather than having them leached away. The more clay and organic matter in a soil, at near neutral pH, the higher its CEC.

**Nutrients.** The soil supplies the following essential nutrients for proper plant growth and production. These nutrients can originate from weathered minerals or from decomposing organic matter.

### Nutrients and their plant-available forms:

#### Primary Nutrients

Nitrate-N ( $\text{NO}_3^-$ )  
 Ammonium-N ( $\text{NH}_4^+$ )  
 Phosphorus ( $\text{H}_2\text{PO}_4^-$  and  $\text{HPO}_4^{2-}$ )  
 Potassium ( $\text{K}^+$ )

#### Secondary Nutrients

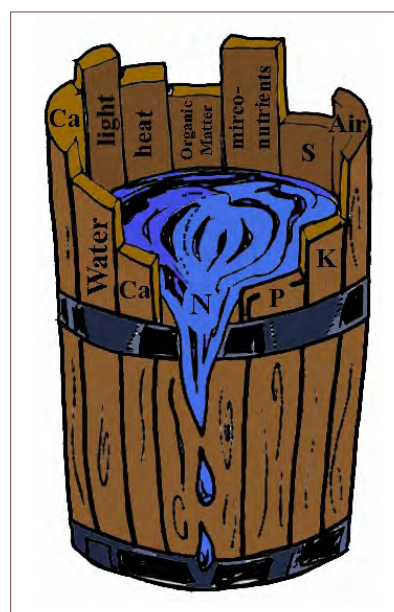
Calcium ( $\text{Ca}^{2+}$ )  
 Magnesium ( $\text{Mg}^{2+}$ )  
 Sulfur ( $\text{SO}_4^{2-}$ )

#### Micronutrients

Iron ( $\text{Fe}^{3+}$ )  
 Manganese ( $\text{Mn}^{2+}$ )  
 Boron ( $\text{Bo}_3^{2-}$ )  
 Molybdenum ( $\text{MoO}_4^{2-}$ )  
 Copper ( $\text{Cu}^{2+}$ )  
 Zinc ( $\text{Zn}^{2+}$ )  
 Chlorine ( $\text{Cl}^-$ )  
 Nickel ( $\text{Ni}^{2+}$ )  
 Cobalt ( $\text{Co}^{2+}$ )

The primary nutrients are used in the greatest amount by the plant, and are the ones you are most concerned about when creating the NMP.

- **Nitrogen** is part of the chlorophyll molecule. Plants also require N in order to produce amino acids for building proteins. When deficient in N, plants become stunted and yellow coloring appears in older leaves.
- **Phosphorus** is important in developing healthy root systems, normal seed development, uniform crop maturation, photosynthesis, respiration, cell division, and many other processes. P deficiency results in stunted plant growth and purple or reddish pigmentation in the older leaves.



Soil nutrients are much like the staves holding a barrel together. If one stave is too short, or a nutrient is in short supply, then plants cannot grow to their maximum potential.

- **Potassium** is responsible for the regulation of water usage in plants, disease resistance, stem strength, photosynthesis, and protein synthesis. Deficiency in K results in scorching or necrosis of older leaf margins and poor root systems. K deficient plants also develop slowly.

## Biological

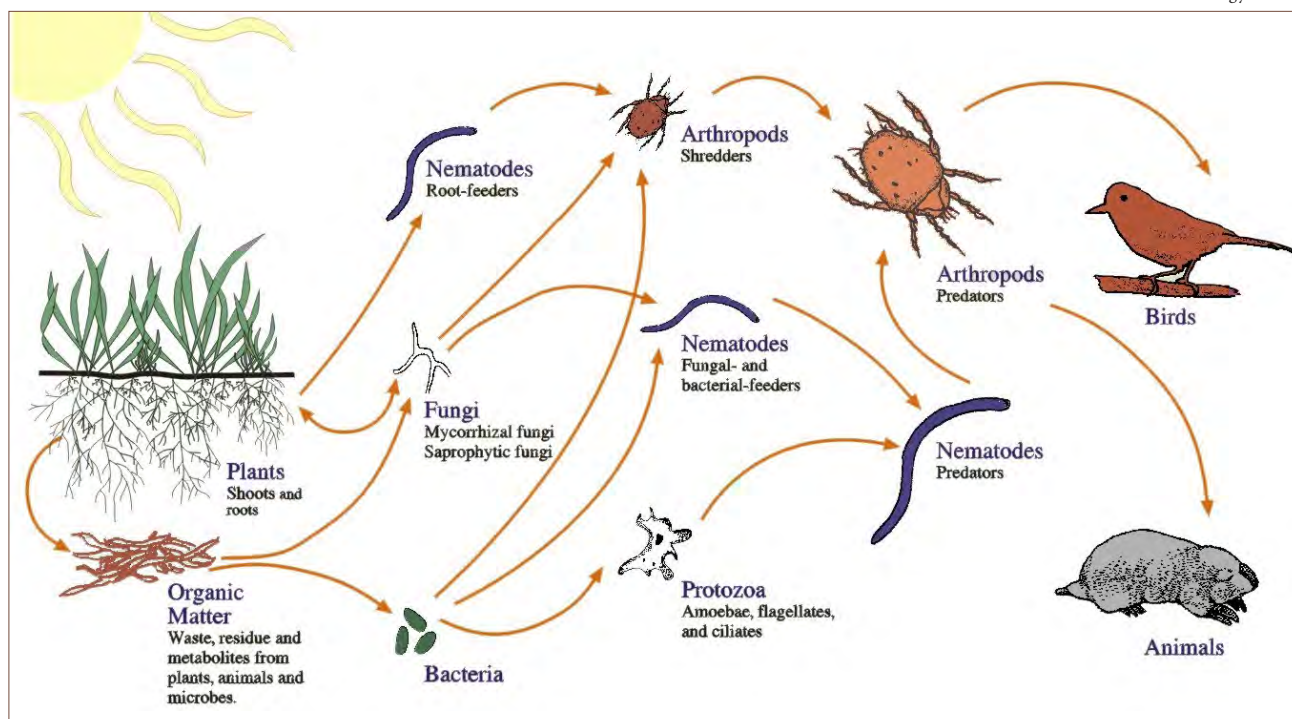
Biological properties of soil relate to the living components. Soil is much more than just lifeless dust; it is composed of living organisms such as earthworms, plant roots, insects, and microorganisms. Microorganisms, in particular, break down the remains of plants and other organisms. This process releases nutrients that support plant and soil life.

Soil has a very diverse biology and forms a delicate relationship with the plants it sustains. Do not treat your soil like dirt! Soil needs food and care, just as cows need grain and comfortable shelter.

## The Plant and Soil Ecosystem

Plants depend on soil for air, water, nutrients, and mechanical support. In order to accomplish this, a soil should be maintained in as healthy a condition as pos-





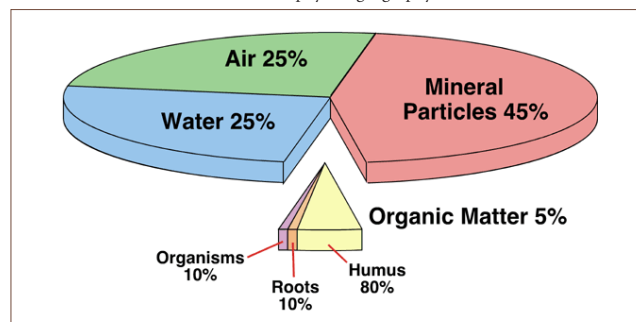
Even though it may not be obvious at first, soil is full of life. Complex food webs exist in the soil ecosystem that help to cycle nutrients.

sible.

Keep in mind that soil fertility is a delicate balance of the physical, biological, and chemical properties. To maintain a healthy balance of these properties you should try to create a soil that has the following characteristics:

- Good water infiltration and storage
- Good soil tilth
- Low rates of erosion
- Good levels of organic matter
- Contains a high level of biological diversity
- The proper pH for the crops you're growing
- All the essential nutrients in reasonable proportion to crop needs

[www.physicalgeography.net/fundamentals/10t.html](http://www.physicalgeography.net/fundamentals/10t.html)



Soil is composed of mineral particles, air, water, and organic matter. Proportions of each vary in different soils, but these are proportions for a typical soil.

We will be looking more closely at farming practices that help you maintain a balance of nutrients. The first step in maintaining healthy soil is knowing how much of each nutrient it contains, and how those nutrients behave in the soil.

## LESSON II-2

### The Nitrogen Cycle

Amanda Gervais

**A** good balance of nutrients begins with the big three: nitrogen (N), phosphorus (P), and potassium (K). Let's get started with nitrogen.

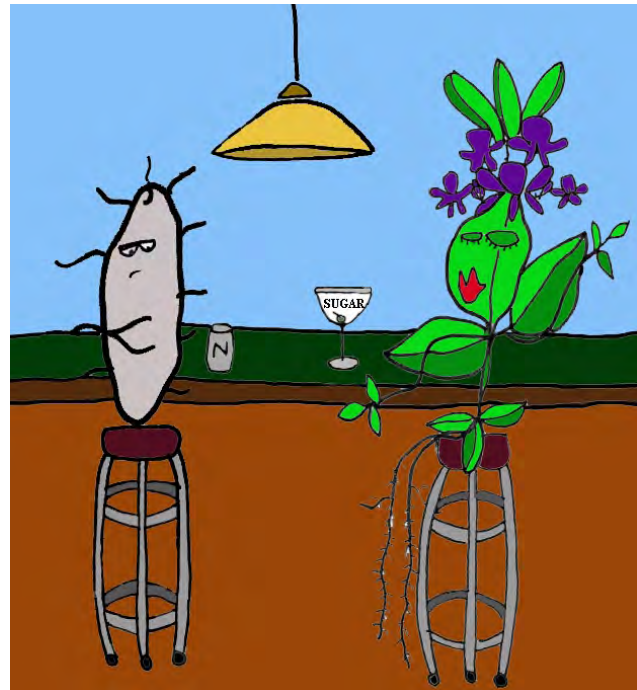
#### Forms of Nitrogen in the Soil

There are several types of N in the soil:

**Organic Nitrogen.** Organic matter contains carbon. Aside from mineral forms such as calcium carbonate (lime), anything with carbon is either living or was once living. For instance, a field of grass plowed into the soil is considered organic fertilizer because it was once a living organism. Any N bound to the carbon in the dead grass would be considered, by association, organic N. This kind of N is not readily available to the plants. It takes microbes to break down the organic matter into inorganic-N forms that plants can use.

**Inorganic Nitrogen.** Inorganic or mineral N is present in the soil in many forms:

- **Nitrate-N ( $\text{NO}_3^-$ ).** Plants prefer this type of N, and almost all N taken up by plants is in this form.
- **Ammonium-N ( $\text{NH}_4^+$ ).** This is the first form of N produced when soil microorganisms convert organic N into mineral N. Usually it is rapidly changed into nitrate.
- **Nitrogen Gas ( $\text{N}_2$ ).** This is the type of N in the air and is the most abundant form in the world (the air you breathe is 78%  $\text{N}_2$ ). The only plants that can extract N from the air are legumes (such as clover, alfalfa, and birdsfoot trefoil). If you plant legumes, you can make your own N!
- **Nitric and Nitrous Oxides (NO and  $\text{N}_2\text{O}$ ).** These are forms of N that are not utilized by plants but can be utilized by some microbes.

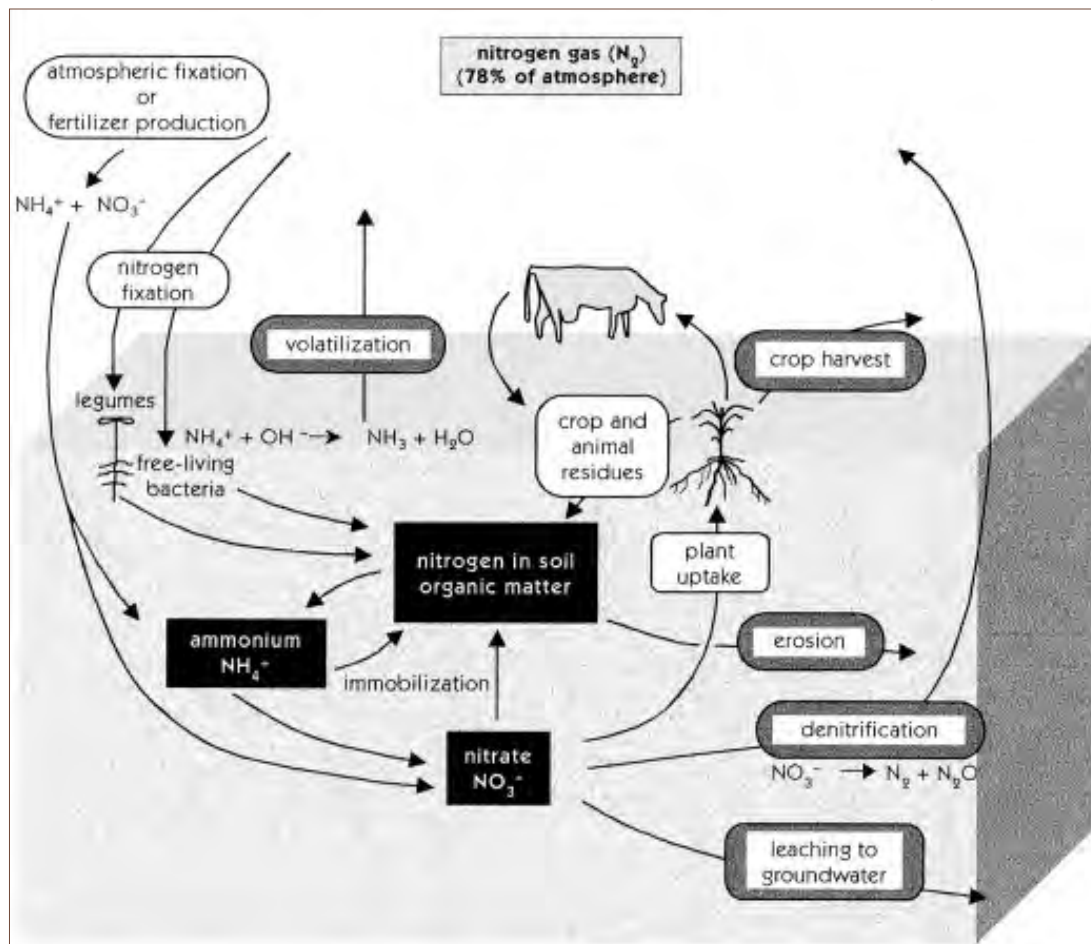


Legumes have a special relationship with nitrogen fixing bacteria called rhizobia. Like the alfalfa plant in this picture, legumes offer rhizobia sugar in exchange for the nitrogen the bacteria provide to the plant.

#### Nitrogen Cycle

**1. Nitrogen Fixation.** N gas from the atmosphere is converted to ammonium-N. This is done by the bacteria living in the nodules on legume roots. Remember the rhizobium? If you inoculate your legume seed with the rhizobium bacteria it will help ensure that atmospheric N gas is converted into a form that the plant can use. In turn, the plant will pass on some sugar to the bacteria and give the bacteria a place to live. This is how N is “fixed.” It becomes available in the soil for other crops after these legumes or their roots die.

If you give a legume too much nitrogen it can become lazy. It will start to take N almost exclusively from the soil.



The nitrogen cycle.

**2. Nitrogen Uptake** This is the process of your plants taking up ammonium-N or, more commonly, nitrate-N. They then use these forms to make amino acids and then proteins or other essential chemicals.

**3. Nitrogen Mineralization.** Organic N is converted to ammonium-N. In most soils it is converted to nitrate almost immediately. These forms can then be used by plants or other organisms in the soil.

**4. Denitrification.** Nitrate-N is converted to gas —  $N_2$  or nitrous oxide — which then go into the atmosphere. This happens when the soil is saturated with water or really compacted. The N will volatilize into the air and your soil loses valuable N.

**5. Ammonia Volatilization.** When urea is applied to the soil surface and not quickly incorporated, a significant amount of N may be changed into the form of ammonia-N gas and is lost into the atmosphere.

nificant amount of N may be changed into the form of ammonia-N gas and is lost into the atmosphere.

## Nitrogen Deficiency Symptoms

N is considered the primary limiting nutrient in many field crops. When corn is N deficient the plants will become pale, yellowish-green in color. N is a mobile nutrient in the plant, and therefore symptoms begin on the older, lower leaves and will progress up the plant if the deficiency persists. The symptoms will appear on leaves as a v-shaped yellowing, starting at the tip and progressing down the midrib toward the leaf base. Inadequate fertilization can result in N deficiencies; however, weather also plays a major role in N availability for the growing crop. In the early season deficiencies can be seen when the weather is cold and the soils are saturated with water. During the mid-season dry soil conditions can result in N deficiencies. Heavy rainfall during the



N deficiency symptoms on corn are visible as v-shaped yellowing, beginning at the tips of older leaves. An overall pale yellowish-green color can also be symptomatic of N deficiency.

growing season can result in N leaching and hence inadequate N for the crops. Other factors such as flooding can also result in N losses.

## Don't Treat Your Soil Like Dirt

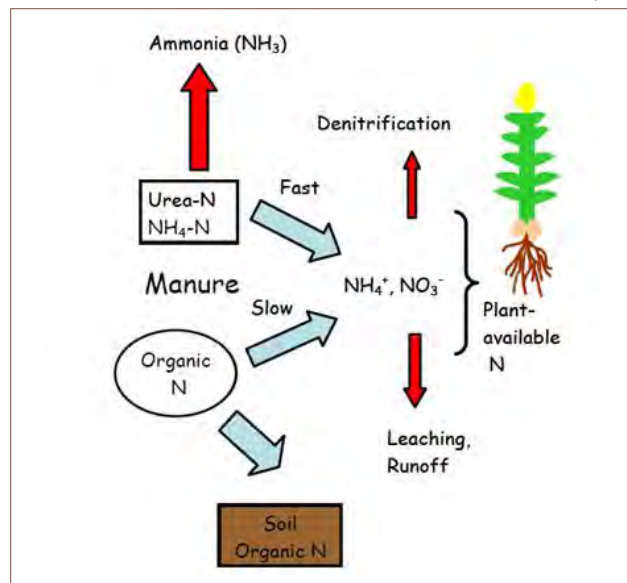
The N cycle is almost entirely biological (controlled by soil organisms), so it is important to maintain the soil biology that drives it. If there is no soil biology then there are no soil organisms, which means your soil is dead. If your soil is dead, then there will be no N cycle no matter how much fertilizer you use. You must think of your soil as “livestock” that needs to be “fed.” Producing a healthy, biologically active soil is the key to having enough N for crops.

## Nitrogen and the Environment

The excessive application or misapplication of N can have a negative impact on the environment.

N can be lost to the environment in the following ways:

**Leaching.** Nitrate-N can leach easily as excess rain-water moves through soil to groundwater. It leaches because it has a negative charge that will repel, rather than bind to, the negative charge of the soil particles. Ammonium-N, on the other hand, has a positive charge so it binds to the soil particles.



Only a fraction of the nitrogen in manure actually gets used by crops. The rest is lost into the atmosphere, leaches below the root zone, or remains in an unavailable organic form. Management practices such as incorporating manure soon after spreading can improve the fertilizer value of manure.

**Runoff and Erosion.** When the surface of the soil, fertilizer, and manure erode in a rain storm, they can carry ammonium-N and organic forms of nitrogen into the water.

**Volatilization.** Ammonium-N can volatilize through the air if it is on the surface of the soil, especially in warm weather. If possible, incorporate fertilizer and manure to avoid these types of losses.

## Maximizing the Fertilizer Value of Manure Nitrogen

N is easily lost to the air (volatilized) when ammonium-N in manure is converted into ammonia gas. The amount of ammonia volatilization will vary greatly on both the environmental conditions and management strategies. Losses can range from close to 100% for surface application to only a few percent when manure is incorporated immediately into the soil. While we can't control the weather, we can minimize N losses through various manure management strategies.

If manure is incorporated into the soil, ammonium-N is brought into direct contact with soil organic matter and clay, which attracts ammonium-N and keeps it in



the soil. Rapid incorporation of manure also reduces the chance for runoff and erosion into nearby waters. Therefore, the best practice to reduce N losses is to incorporate the manure immediately after spreading. The longer you wait to incorporate manure, the more N lost to the surrounding environment. The table on page 43 (“Ammonium-N availability from spring- or summer-applied manure,” from Table 17 Nutrient Recommendations for Field crops in Vermont) shows that immediate incorporation with standard tillage equipment or injection can increase N availability considerably.

Generally, in the spring most farmers are rapidly incorporating the manure as soon as it is applied to corn fields. However, even a brief lag between manure application and incorporation can result in a 30% loss in ammonium-N. There are situations, such as on grass fields, where manure incorporation is not possible. In these situations, where manure is primarily surface applied, ammonium-N losses can approach 100% if conditions are prime. Recently, there has been interest in alternative manure incorporation systems such as aerators and various injection systems that could be used on both corn and hay ground. These systems can provide rapid incorporation of manure with reduced or no soil tillage, thus keeping more N in the soil to be made available for plant uptake. There are many types of injection systems available but all work on the same general principle, slice the soil and drop down the manure. There is evidence that deep injection can effectively reduce ammonia losses on hay fields but the

practice has also been shown to cause root damage and occasional yield reductions. Aerator systems poke holes in the soil (prior to, or at the time of, application) and most of the manure makes its way into the holes. These systems result in reduced N runoff and volatilization as compared to surface applied manure. Some studies have also documented yield increases as a result of increased N availability to the grass and alleviation of compacted layers.

These incorporation systems can also provide a host of other benefits. The advantages of using a rapid manure injection system include: fewer odors, ability to place nutrients directly into the seedbed, and the reduction in nutrient loss via surface runoff. There are some potential drawbacks to the systems such as: they tend to be more expensive and may not be suitable for all soil types found in Vermont including steeply sloping ground or stony soils. Of course, like any new practice you implement, you must weigh all the advantages and disadvantages before deciding whether a manure injection system makes sense for your farm.

## EXERCISE II-1

### Calculating Nutrient Availability in Manure

**W**hat's in your manure? Before starting this class, you should have submitted a manure sample for nutrient analysis at a testing lab. For information on how to take a manure sample see the instructions at the end of this exercise.

Next we will calculate on-farm nutrients available from manure. In goCrop™ click on the nutrient sources section under the farm tab, and then add a source... and click on manure. You will need your manure analysis results. If you did not get a manure sample tested use the “book values,” which are average values found in the table below.

Each manure storage should have a separate analysis, and should be listed separately using a descriptor under storage name.

Next, for each storage area you use, fill in the amount of waste produced and stored each year. You can get this number from your NRCS representative. It is calculated using a formula that takes into account many factors on your farm including animal numbers, bedding, water use, and rainfall.

#### Typical values for total nutrient content of dairy manure.

(Table 15 from Nutrient Recommendations for Field Crops in Vermont)

Species/type	Dry matter	Total N	NH <sub>4</sub> -N	Organic N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	Mg	Ca
	%	pounds/1,000 gallons						
Dairy, liquid (<5% DM)	3.0	12.2	4.9	7.3	4.8	15.1	2.8	6.1
Dairy, slurry (5-10% DM)	7.0	22.3	7.6	14.7	8.9	22.0	5.0	14.3
	%	pounds/ton						
Dairy, semi-solid (10-20% DM)	14.7	8.5	1.8	6.7	4.1	6.1	2.1	5.6
Dairy, solid (>20% DM)	30.8	12.3	1.4	10.9	8.1	10.0	4.3	19.5

# New Manure Test

## Details

Manure Source: Pit

Test Date\*

Lab

Notes

## Manure Analysis Report

Name*	Result*	Unit	X
dry matter		percent	

+ Add another row

Check the box on the right to mark a row for deletion.

## Nutrients

If your results include (for a single nutrient) both a total and a breakdown of different forms, such as Total N as well as Organic N and Inorganic N, include only the breakdown. goCrop will calculate the total. Including both total and breakdown may result in double-counting the nutrient.

Nutrient*	Amount*	Unit*	X
NH4N (Inorganic Nitrogen)		lbs / 1000 gallons	
orgN (Organic Nitrogen)		lbs / 1000 gallons	
P2O5 (Available Phosphorus)		lbs / 1000 gallons	
K2O (Soluble Potash)		lbs / 1000 gallons	

Next you will move to the “Manure” tab in your binder. Here you will calculate manure N available to crops based on the type of manure, timing of application, and timing of incorporation. You need to fill out one of these for each manure storage facility that you have. This will allow you to determine the percentage N available from manure.

### Manure-N credits for Hay Fields

#### Spring/Summer Applied Manure

$$\text{NH}_4\text{-N (lbs/1,000 gal)} \times \% \text{NH}_4\text{-N Available} = \text{lbs of available NH}_4\text{-N per 1000 gal}$$
(manure test) (Table 15)

X  =

$$\text{Organic N (lbs/1,000 gal)} \times \% \text{Organic-N Available} = \text{lbs of available Organic-N per 1000 gal}$$
(manure test) (Table 17)

X  =

$$\text{lbs of available NH}_4\text{-N per 1000 gal} + \text{lbs of available Organic-N per 1000 gal} = \text{Total Manure-N Credits}$$

+  =

1

Calculations for hay fields

#### Fall Applied Manure

$$\text{NH}_4\text{-N (lbs/1,000 gal)} \times \% \text{NH}_4\text{-N Available} = \text{lbs of available NH}_4\text{-N per 1000 gal}$$
(manure test) (Table 16)

X  =

$$\text{Organic N (lbs/1,000 gal)} \times \% \text{Organic-N Available} = \text{lbs of available Organic-N per 1000 gal}$$
(manure test) (Table 17)

X  =

$$\text{lbs of available NH}_4\text{-N per 1000 gal} + \text{lbs of available Organic-N per 1000 gal} = \text{Total Manure-N Credit}$$

+  =

### Manure-N credits for Annual Cropped Fields

#### Spring/Summer Applied Manure

$$\text{NH}_4\text{-N (lbs/1,000 gal)} \times \% \text{NH}_4\text{-N Available} = \text{lbs of available NH}_4\text{-N per 1000 gal}$$
(manure test) (Table 15)

X  =

$$\text{Organic N (lbs/1,000 gal)} \times \% \text{Organic-N Available} = \text{lbs of available Organic-N per 1000 gal}$$
(manure test) (Table 17)

X  =

$$\text{lbs of available NH}_4\text{-N per 1000 gal} + \text{lbs of available Organic-N per 1000 gal} = \text{Total Manure-N Credits}$$

+  =

2

Calculations for corn and other annual crops

#### Fall Applied Manure

$$\text{NH}_4\text{-N (lbs/1,000 gal)} \times \% \text{NH}_4\text{-N Available} = \text{lbs of available NH}_4\text{-N per 1000 gal}$$
(manure test) (Table 16)

X  =

$$\text{Organic N (lbs/1,000 gal)} \times \% \text{Organic-N Available} = \text{lbs of available Organic-N per 1000 gal}$$
(manure test) (Table 17)

X  =

$$\text{lbs of available NH}_4\text{-N per 1000 gal} + \text{lbs of available Organic-N per 1000 gal} = \text{Total Manure-N Credits}$$

+  =

Organic N acts differently in well drained and poorly drained soil, so we calculate the credits separately.

Availability of ammonium nitrogen from spring- or summer-applied manure (% fertilizer N equivalent).  
(Table 17 from Nutrient Recommendations for Field Crops in Vermont)

Time to incorporation by tillage or rain	Dairy cattle or other livestock				Poultry
	Liquid or slurry			Solid	
	Thin ( < 5% DM)	Medium (5–10% DM)	Thick or semi-solid ( > 10% DM)	( > 20% DM)	
	% available				
Immediate/1 hour	95	95	90	95	95
< 8 hours	80	70	60	80	90
1 day	70	55	40	60	85
2 days	65	50	30	45	80
3–4 days	65	45	25	35	70
5–7 days	60	40	25	25	60
> 7 days (or non-incorporated)	60	40	20	10	50

Availability of ammonium nitrogen from fall-applied manure (% fertilizer N equivalent).  
(Table 18 from Nutrient Recommendations for Field Crops in Vermont)

Time to incorporation by tillage or rain	Dairy Cattle or other livestock				Poultry
	Liquid or slurry			Solid	
	Thin (<5% DM)	Medium (5-10% DM)	Thick or semi-solid (>10% DM)	(>20% DM)	
	% available				
Immediate/1 hr	40	35	35	40	40
<8 hr	30	25	25	30	35
1 day	30	25	15	25	35
2 days	25	20	10	20	30
3-4 days	25	20	10	15	25
5-7 days	25	15	10	10	25
>7 days (or non-incorporated)	25	15	10	0	20

# Availability (% fertilizer N equivalent) of organic N from manure applied in current and past years.

(Table 19 from Nutrient Recommendations for Field Crops in Vermont)

Dry matter	Current year			1 year ago	2 years ago
	Soil drainage	Tilled	Surface		
		% available			
20 or less	Well to moderately well drained	36	24	12	5
	Somewhat poorly to poorly drained	24	16	10	4
> 20	Well to moderately well drained	30	20	12	5
	Somewhat poorly to poorly drained	20	14	10	4



**EXAMPLE:**  
**CALCULATING SPRING/SUMMER**  
**SURFACE-APPLIED MANURE N CREDITS**

Let's start by looking at the first equation in the worksheet.

Surface Applied		
Spring/Summer		
NH <sub>4</sub> -N Equation		
12.0 <small>NH<sub>4</sub>-N (lbs/1000 gal)</small>	× <span style="border: 1px solid black; display: inline-block; width: 40px; height: 20px; vertical-align: middle;"></span> × <span style="border: 1px solid black; display: inline-block; width: 40px; height: 20px; vertical-align: middle;"></span> = <span style="border: 1px solid black; display: inline-block; width: 40px; height: 20px; vertical-align: middle;"></span>	= <span style="border: 1px solid black; display: inline-block; width: 40px; height: 20px; vertical-align: middle;"></span> <small>avail NH<sub>4</sub>-N (lbs/1000 gal)</small>
<small>(lbs/1000 gal)</small>	<small>% NH<sub>4</sub>-N Avail (Table 15)</small>	<small>avail NH<sub>4</sub>-N (lbs/1000 gal)</small>

The worksheet tells us that we will be using Table 15 for this equation:

Time to incorporation by tillage or rain	Dairy cattle or other livestock				Poultry
	Liquid or slurry			Solid	
	Thin ( < 5% DM)	Medium (5–10% DM)	Thick or semi-solid ( > 10% DM)	( > 20% DM)	
	% available				
Immediate/1 hour	95	95	90	95	95
< 8 hours	80	70	60	80	90
1 day	70	55	40	60	85
2 days	65	50	30	45	80
3–4 days	65	45	25	35	70
5–7 days	60	40	25	25	60
> 7 days (or non-incorporated)	60	40	20	10	50

Let's say that the manure on your farm is liquid dairy with less than 5% dry matter. You will use values in the column for thin liquid manure. Next, we need to decide which row to use based on the time to incorporation of the manure. Since we are doing calculations for surface-applied manure (on hay fields), which is non-incorporat-

ed, we use the last row of numbers. Our number is 60. What does this mean? It means that for manure spread in the spring or summer on hay fields, 60% of the ammonium nitrogen will be available for crop use.

Remember to convert percentages to decimals:

$$60\% = 0.60$$

So for each 1000 gallons of manure spread on a hay field, there are 7.2 lbs. of ammonium

Surface Applied		
Spring/Summer		
NH <sub>4</sub> -N Equation		
12.0 <small>NH<sub>4</sub>-N (lbs/1000 gal)</small>	×    0.60    × <span style="border: 1px solid black; display: inline-block; width: 40px; height: 20px; vertical-align: middle;"></span> = <span style="border: 1px solid black; display: inline-block; width: 40px; height: 20px; vertical-align: middle;"></span>	=    7.2 <small>avail NH<sub>4</sub>-N (lbs/1000 gal)</small>
<small>(lbs/1000 gal)</small>	<small>% NH<sub>4</sub>-N Avail (Table 15)</small>	<small>avail NH<sub>4</sub>-N (lbs/1000 gal)</small>

nitrogen available for the next crop. Do the same thing for each of the other fields, being sure that you use the table indicated. The worksheet will automatically do the calcu-

lations for you.

## Manure Nutrients Available for Crop Production

The worksheet called “Manure Nutrient Values” will be calculated automatically. Here we calculate the total manure nutrients on your farm that are available for crop use based on your manure nutrient analysis and the amount of manure produced. Notice that phosphorus and potassium are 100% available. Nitrogen availability is not 100% and that is why we calculated it separately. These are the total nutrients that you will be allocating to your fields as you create your nutrient management plan.

Manure Nutrient Values			
Producer: Joe Farmer	Farm Name: Green Valley Farm	Crop Year: 2009	
<b>Manure Storage 1</b>			
<b>Phosphorous Availability - 100%</b>			
<div style="border: 1px solid black; width: 150px; height: 25px; margin: 0 auto; text-align: center; background-color: #f0f0f0;">8.0</div> <div style="text-align: center; font-size: small;">P2O5 (lbs/1,000 gal)</div>	×	<div style="border: 1px solid black; width: 150px; height: 25px; margin: 0 auto; text-align: center; background-color: #f0f0f0;">1,357,007</div> <div style="text-align: center; font-size: small;">Total gal Produced</div>	<div style="display: flex; align-items: center; justify-content: center;"> <div style="margin: 0 10px;">÷ 1000 =</div> <div style="border: 1px solid black; width: 150px; height: 25px; margin: 0 auto; text-align: center; background-color: #ffccff;">10,856</div> </div> <div style="text-align: center; font-size: small;">Total lbs P<sub>2</sub>O<sub>5</sub> Available For Crops</div>
<b>Potassium Availability - 100%</b>			
<div style="border: 1px solid black; width: 150px; height: 25px; margin: 0 auto; text-align: center; background-color: #f0f0f0;">20.0</div> <div style="text-align: center; font-size: small;">K2O (lbs/1,000 gal)</div>	×	<div style="border: 1px solid black; width: 150px; height: 25px; margin: 0 auto; text-align: center; background-color: #f0f0f0;">1,357,007</div> <div style="text-align: center; font-size: small;">Total gal Produced</div>	<div style="display: flex; align-items: center; justify-content: center;"> <div style="margin: 0 10px;">÷ 1000 =</div> <div style="border: 1px solid black; width: 150px; height: 25px; margin: 0 auto; text-align: center; background-color: #ccffcc;">27,140</div> </div> <div style="text-align: center; font-size: small;">Total lbs K<sub>2</sub>O Available For Crops</div>
<b>Nitrogen Availability</b>			
<div style="border: 1px solid black; width: 150px; height: 25px; margin: 0 auto; text-align: center; background-color: #f0f0f0;">7.9</div> <div style="text-align: center; font-size: small;">Total N (lbs/1,000 gal)</div>	×	<div style="border: 1px solid black; width: 150px; height: 25px; margin: 0 auto; text-align: center; background-color: #f0f0f0;">1,357,007</div> <div style="text-align: center; font-size: small;">Total gal Produced</div>	<div style="display: flex; align-items: center; justify-content: center;"> <div style="margin: 0 10px;">÷ 1000 =</div> <div style="border: 1px solid black; width: 150px; height: 25px; margin: 0 auto; text-align: center; background-color: #ccffcc;">10,775</div> </div> <div style="text-align: center; font-size: small;">Total N lbs Available For Crops</div>

## HOW TO SAMPLE MANURE FOR NUTRIENT ANALYSIS

A field-by-field nutrient management program requires multiple components to maintain adequate fertility for crop growth and development. Animal manure has long been used as a source of nutrients for crop growth. Standard nutrient values from manure like those obtained from the Nutrient Recommendations for Field Crops in Vermont booklet are reasonable average values, but an individual farm's manure analyses can vary from those averages by 50 percent or more. Species, age of animal, feed rations, water use, bedding type, management, and other factors make every farm's manure different. Because every livestock production and manure management system is unique, the best way to assess manure nutrients is by sampling and analyzing the manure at a laboratory. Accurate manure analyses are essential for proper nutrient management planning, but manure analyses are only as good as the sample taken. The 590 Standard requires that a manure analysis be conducted for each storage facility every year.

### How to Sample Liquid Storage

Agitate and thoroughly mix the manure before sampling. Make a dipper by fastening a cup to a broomstick or pole and take a sample or two from the tank spreader and place them in a pail. Do this for multiple loads as the storage is being emptied.

### How to Sample Non-Liquid Storage

Use a garden trowel and pail to collect a sample of manure from various spots on a load. Do this for representative loads as the storage is emptied.

### How to Sample from Daily Spreading

Use a garden trowel and pail to collect a sample of manure from various spots on the spreader. Sample the loads for two to three consecutive days. It is recommended to avoid large chunks or pieces of bedding and to select five to ten sub-samples from different places in the spreader.

### Handling the Sample

Immediately after sampling the load, thoroughly mix the contents of the sampling pail, remove a small amount with a ladle and place it in a plastic jar, then cap it tightly and freeze immediately. Collect several sub-samples from different loads on different days and add each new sub-sample to the jar of frozen material and refreeze immediately. Repeat until you feel that you have a representative bulk sample. Be sure that the plastic jar is three-quarters full to allow room for expansion. Properly preparing the sample is very important to prevent ammonia loss.

Wipe the container to remove any manure that may have spilled down the sides. The outside of the container should be clean prior to shipping. Secure the lid firmly and label with its name and date.

Joanne Yousten



This method of sampling a manure pit is not recommended.

## LESSON II-3

### The Phosphorus Cycle

**P**hosphorus (P) is an essential nutrient for plants and animals. In plants it plays a role in energy transformation, photosynthesis, respiration, and cell growth. Adequate P is needed for early root formation and growth as well as for seed formation. Livestock also require P for proper growth. It is an essential component of bones and teeth. Most of the world's soils are deficient in P, but excesses are seen in states like Vermont that have areas with a lot of animals, feed imported from other parts of the country, and manure. In general, the total amount of available phosphorus in most Vermont soils was once quite low, therefore it is ingrained in some farmers to add phosphorus to fields every year. Would anyone think of putting on a starter fertilizer that doesn't contain P?

#### Forms of Phosphorus in the Soil

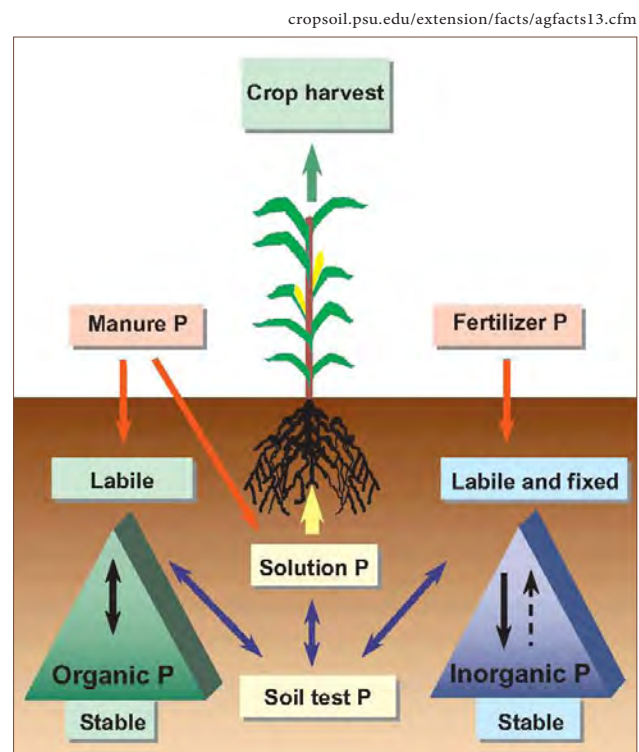
Phosphorus exists in many different forms in soil, including organic, soil solution, “bound,” and primary mineral forms. Organic P is bound to carbon compounds in the soil. It was produced from a once living organism. Most of the organic-P in agricultural soils comes from livestock manure applications or crop residues. In order for the organic-P to become plant available it must be released from the carbon bond by microorganisms. Soil solution P is the soluble inorganic form of P, also known as orthophosphates ( $\text{H}_2\text{PO}_4^-$  or  $\text{HPO}_4^{2-}$ ). This is the form taken up by plants, but it is also the form that accounts for the smallest proportion of the total P in most soils. Bound P makes up a large proportion of the soil P and is unavailable to plants because it is chemically bound to soil particles. P forms insoluble compounds with different minerals in the soil such as iron (Fe), aluminum (Al), or manganese (Mn) in acidic soils, or calcium (Ca) in basic soils. Primary mineral P is unavailable in the form of rocks and minerals.

#### Phosphorus Cycle

Most P in the soil originates from the weathering of

rocks, and from additions in the form of fertilizer or manure. Plants can only absorb P that has become dissolved in the soil solution. The release of P to plant roots is controlled by three chemical and biological processes: 1) when phosphorus-bearing minerals slowly dissolve over long periods of time, 2) when P bound to the surface of soil minerals is uncoupled, and 3) when soil organic matter decomposes. Organic P can be mineralized by microbes into plant available forms. Soil temperatures between 65 and 105°F favor P mineralization of organic P. Most of the P added to the soil as fertilizer and manure can become rapidly bound by the soil minerals in chemical forms that are not subject to rapid release. This can happen one of two ways:

- P reacts with Fe, Al, Mn or Ca (precipitation), or
- P can be held by soil particles.



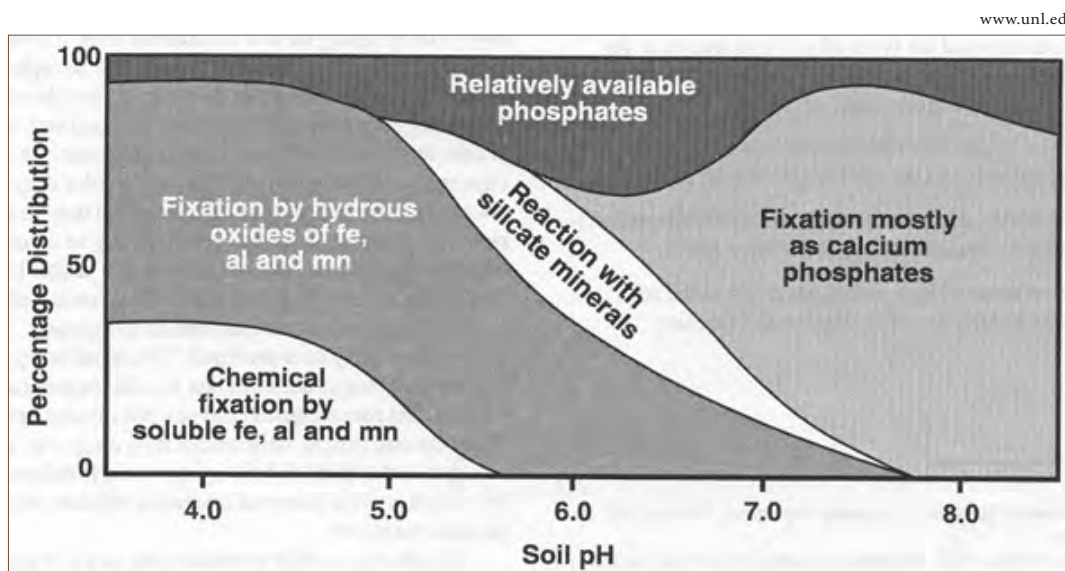
The phosphorus cycle in soil.



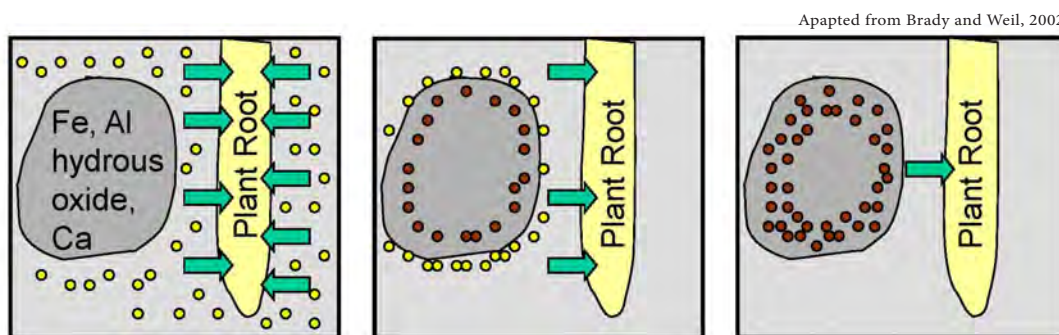
The availability of P is largely based on soil pH. At a high pH (basic soil), P can precipitate with Ca. For instance, clay soil has lots of calcium or magnesium (also positively charged) that binds quickly with the P. Once again, your P is rendered unavailable to your plants. At lower pH (acidic soil), P tends to be bound to Fe and Al compounds in the soil. Soils that have higher Fe and/or Al contents have the potential to hold more P than other soils. Phosphorus is in its most plant available form when the pH is between 6.2 and 6.5.

Because soil P is so easily bound in unavailable

forms in the soil, soil solution P is typically very low, even when plants are able to obtain sufficient quantities. However, at very high soil test levels, P can be available to plants in sufficient quantities, but can also be more prone to runoff and even leaching. In order to assure that plants have sufficient P for growth, a farmer must conduct routine soil tests. The soil tests will allow the farmer to determine if the pH must be adjusted to keep P in a plant-available state. In addition, it will also inform a farmer if additional P should be added in the form of manure or fertilizer.



Phosphorus is fixed by different soil minerals depending on soil pH. Phosphorus is most available between a pH of 6.2 and 6.5.



**Day 1**

Soluble phosphorus is added to the soil and goes into soil solution, where it is highly available to the plant. Available and unavailable P are shown as light circles and dark circles, respectively.

**Day 5**

Much of the phosphorus is quickly bound to soil particles and only some of the P is readily available to plant roots.

**Day 10**

Nearly all of the phosphorus has been tightly bound to soil particles and is no longer readily available to the plant.

## Phosphorus Deficiency Symptoms

Phosphorus deficiency is usually visible on young corn plants. Plants deficient in P will be dark green with reddish-purplish leaf tips and margins on older leaves. The newly emerging leaves will not show the purple coloration. P deficient plants will be smaller and grow more slowly than plants with adequate P levels. Deficiency symptoms nearly always disappear when plants grow to three feet or taller. It is important to note that some corn hybrids tend to show purple colors at early stages of growth even though P nutrition is adequate. P is relatively immobile in soils therefore it is important to apply P where newly emerging plant roots can easily absorb it. P deficiency is not always caused by low soil P levels. P deficiency can be induced when soils are cold, too wet or too dry. Other factors that can impact P uptake include restricted root growth in compacted soils; and roots injured by insects, herbicides, fertilizers, or cultivation.

## Phosphorus and the Environment

Most P loss to the environment occurs during field runoff events. P in runoff is either sediment-bound (attached to soil particles) or dissolved in water. Sediment-bound P makes up the major proportion of P transported from tilled soils. Runoff from grass fields carries little sediment, and is generally dominated by the dissolved form. Leaching of P is very rare but is possible under some conditions, especially in fields that have been recently tilled,



P deficiency symptoms on corn usually appear as red or purple coloring on the leaf tips and margins of older leaves.

or on well structured soil with many large pores.

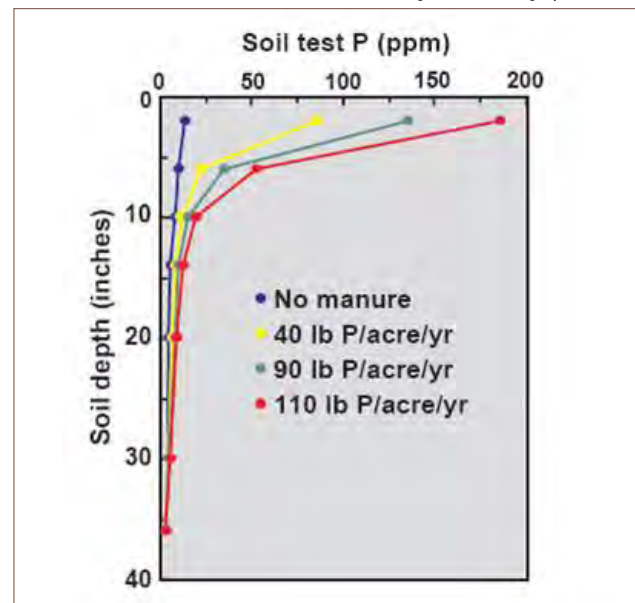
As soil test P increases, the potential for sediment and dissolved P transport in runoff also increases.

The soil is not an infinite sink for P. We can reach a saturation point at which the risk of P loss is high. Once saturated, the soluble P is free to flow and can run into the surrounding water. P can even leach into the groundwater — something we didn't used to think could even happen. The soil only needs 0.2 to 0.3 milligrams/liter of P. Algae in the lake only needs one tenth of that amount. It doesn't take much high-P runoff to start causing problems.

You have to be careful about the way you manage P. This is especially true with manure application. If you are applying manure to increase your N content, keep in mind that the manure is rich in P content as well. So as you apply it to increase your N, you also increase your soil's P. You could end up doubling your amount of P to reach the required amount of N. The problem with excess P is that it is much easier to build up than to use up after high levels are reached.

One of the goals of our NMP is to reduce P losses from agriculture to surface waters. This goal can be reached by minimizing inputs of P in feed and fertilizer, consistent with modern dairy cow and crop management, and by balancing inputs with outputs in crop and animal products. The buildup of P to excessive levels in soils can occur when any P source, including com-

Adapted from Sharpley et al. 1984



Soil test P accumulates at the surface with repeated application of P for ten years.



mercial fertilizer and manure, is over-applied for a long period of time. The greatest concern is the addition of P to land from manure applications.

In the Northeast, most animal operations are located in grain-deficient areas and require that grain for animal feed be imported. This type of production system represents a net import of nutrients into Vermont due to the combined inputs of P-enriched feed, dietary feed supplements, and fertilizer. Manure is then applied near the point of generation and most commonly within the boundaries of the “home farm.” Primary outputs of P from these farms include crop and animal products that are removed and utilized off-farm. The flow of nutrients onto the farm is generally out of balance with the flow of nutrients off the farm. Simply put, more P is entering the farm boundary than is exiting in the form of salable products. The greatest problems with excess P occur on farms with relatively low acreage for the number of animals. In this situation, the amount of manure generated exceeds the needs of the land.

There are two types of P that can erode or run off:

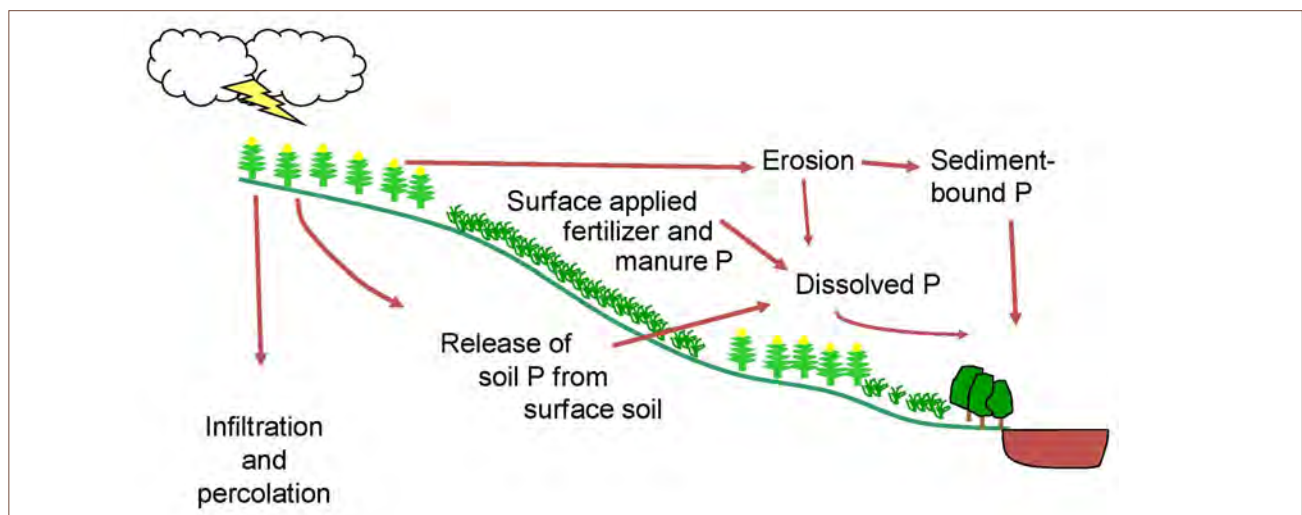
**Sediment-bound Phosphorus.** This is P bound to soil. When soil erodes, the P bound to that soil is moved into water. 80 to 90% of all P loss happens as a result of erosion. If you can greatly reduce erosion, you can significantly decrease P pollution. P is a limiting nutrient for algae just as N is the limiting nutrient for corn. (P can be a limiting nutrient for crops — although it is not as common as N limitation.) Algae cannot grow without P.

**Dissolved phosphorus.** This type of P moves freely in solutions such as water and is readily available. It is difficult to control runoff of dissolved P. The best management strategy is to make sure that it infiltrates into the ground immediately.

## Phosphorus Movement and Pollution

Phosphorus moves in two ways:

- Runoff and erosion (the major forms of movement)
- Leaching (less common)



Sources of P for potential runoff include both the P added to the surface from manure and fertilizer as well as dissolved and sediment-bound P from the soil.

## LESSON II-4

### The P-Index

**T**he P-index is a tool developed to assess the potential for P runoff from individual fields based on soil and field characteristics and on management practices. Use of the P-index provides a way to identify fields that have a high P runoff potential and require conservation practices or limitations of manure or fertilizer P. The P index provides a way to prioritize nutrient management practices to the fields that have the highest potential P loss.

The index is based on two variables:

- Potential erosion and sediment P
- Potential for dissolved P to runoff.

This is influenced by the following factors:

**Type of soil (i.e. clay or sandy).** Some soil types are more prone to runoff or flooding than others.

**Soil P and aluminum levels.** The amount of P and Al in your soil will affect the likelihood of P loss.

**Water.** Which part of Vermont are you in? Are you at a high elevation that receives more rainfall?

**Soil erosion rate.** This uses the RUSLE2 number for the rotation you chose.

**Timing and rate of manure application.** Are you applying manure in the fall or in the spring or both?

**Method and timing of manure incorporation.** Do you minimize applied manure's exposure to rain?

**Method , timing and rate of fertilizer P application.** Is the fertilizer broadcasted or injected at planting?

**What's growing.** Are you growing a hay crop or corn? How well is the soil protected by crop residue?

**Buffer width.** What is the distance, in feet, of grass or other vegetated buffer between the field edge and a waterway or area of seasonal concentrated flow.

The P-index gives a relative rating for risk of P loss

from a field. It is better to use the P-index to determine losses than to rely on soil P levels alone because it takes into account the above factors that affect P movement.

Each of your fields will fall into one of four categories, which are described below.

**Low** potential for P movement from site. If farming practices are maintained at the current level there is a low probability of an adverse impact to surface waters from P loss.

**Medium** potential for P movement from site. A chance for adverse impacts to surface water exists.

**High** potential for P movement from the site and for an adverse impact on surface waters to occur unless remedial action is taken. Soil and water conservation as well as P management practices are necessary to reduce the risk of P movement and water quality degradation.

**Very high** potential for P movement from the site and for an adverse impact on surface waters. Remedial action is required to reduce the risk of P movement. Soil and water conservation practices, plus a P management plan must be put in place to reduce potential for water quality degradation.

During the next session, we will discuss what these categories mean for your NMP. You will be filling out a P-index for each field on your farm, so let's look more closely at the worksheet.

## EXERCISE II-2

### P-Index Worksheet

**T**he P-index will be calculated automatically in goCrop if all the field information was entered into the program.

The P-Index for this field is "Medium."

Farm Name	Sample Farm				
Producer/Farm Manager	Joe Farmer				
Field Name:	Rileys Knoll	Back of House	Back of Davids	Gerards Below Hill	Pieces up back Corn
Track & Field #:	65-1	65-2	65-4	67-2	67-4 Corn
P Index:	58	53	33	57	60
Interpretation:	Medium	Medium	Medium	Medium	Medium
Pathway I: Sediment-bound P	17	9	6	9	11
Pathway II:	40	44	28	48	49
Location (Vermont County)	NW (Addison, Chittenden, Franklin, Grand Isle)	NW (Addison, Chittenden, Franklin, Grand Isle)	NW (Addison, Chittenden, Franklin, Grand Isle)	NW (Addison, Chittenden, Franklin, Grand Isle)	NW (Addison, Chittenden, Franklin, Grand Isle)
Elevation zone, feet	< 600	< 600	< 600	< 600	< 600
Soil test P, ppm (Mod.Morgan)	5	6	3	14	15
Reactive soil aluminum, ppm	14	20	8	76	8
Fall manure, lb P2O5/ac	76	8	76	59	59
Fall application method	Chisel	Not incorporated	Chisel	Chisel	Chisel
Fall time to incorporation	< 2 days	8-21 days	< 2 days	< 2 days	< 2 days
Spring manure, lb P2O5/ac	0	0	0	0	0
Spring application method	None applied	None applied	None applied	None applied	None applied
Spring time to incorporation	None applied	None applied	None applied	None applied	None applied
Summer manure, lb P2O5/ac	0	0	0	0	0
Summer application method	None applied	None applied	None applied	None applied	None applied
Summer time to incorporation	None applied	None applied	None applied	None applied	None applied
Manure type	Dairy - Lactating Cow	Dairy - Lactating Cow	Dairy - Lactating Cow	Dairy - Lactating Cow	Dairy - Lactating Cow
Fertilizer rate, lb P2O5/ac	12	40	12	40	12
Fertilizer method/timing	Surf. appl. May-Sept. (0.70)	Surf. appl. May-Sept. (0.70)	Surf. appl. May-Sept. (0.70)	Surf. appl. May-Sept. (0.70)	Surf. appl. May-Sept. (0.70)
Erosion rate(RUSLE, tons/ac)	2.4	1.1	0.56	1.0	1.0
Soil type or series (HydrGrp)	(D)	(D)	(C)	(D)	(D)
Surface cover %	0 - 20 %	> 20 %	0 - 20 %	0 - 20 %	20 %
Crop / Vegetation type	Corn & other row crops	Alfalfa & other forages	Corn & other row crops	Alfalfa & other forages	Corn & other row crops
TOTAL distance to stream, feet	100	50	300	300	300
Vegetated buffer width, feet	100	50	300	300	300
Manure spreading setback, feet	0	0	0	0	0
Sediment trap structure or other erosion control	None	None	None	None	None

Enter from soil test results

The total lbs. of P in the manure applied will be calculated.  
Example:  
5000 gal. manure  
x 8 lbs. P/1000 gal.  
= 40 lbs. P

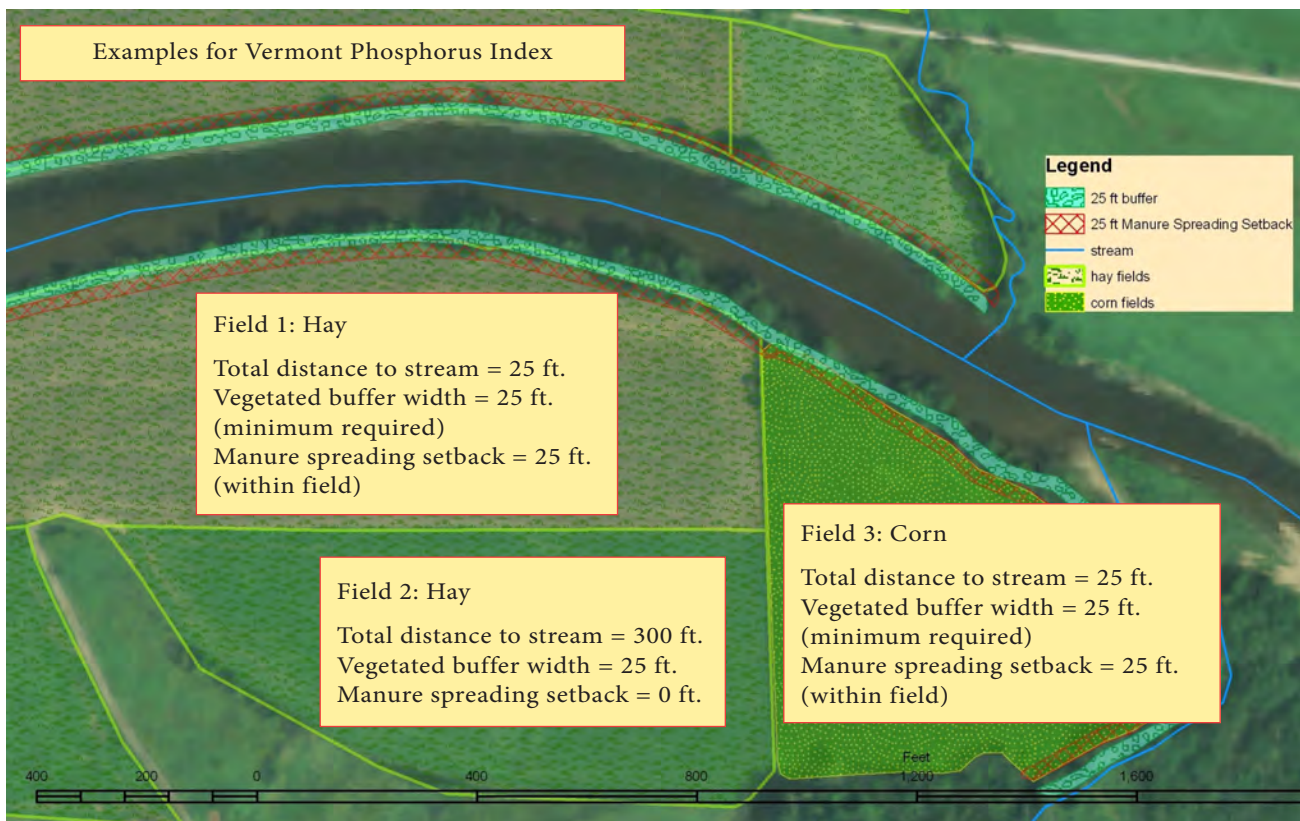
If you need help calculating fertilizer rates, see page 89

Use the RUSLE2 number from the rotation you chose.

Corn and row crops:  
0-20% cover  
Hay: >20% cover

See the illustration on page 54 explaining "Total distance to stream" and "Vegetative buffer width."

## Distance to stream, buffers and manure spreading setbacks.



Here are three different scenarios showing how the distance to stream and vegetated buffer width would be entered in the P-Index.

**Manure spreading setback:**  
Although not required under regulation, the addition of a manure spreading setback is implemented to better protect water resources.

**Total distance to stream:**  
Although the stream may be directly adjacent to a field, installation of the required buffer increases total distance to stream to 25 ft.

## EXERCISE II-3

### Checklist

**H**ere is a list of items that you should have completed before you go on to the next session. Those items found in goCrop™ are listed in [blue](#).

#### SESSION I

- ☐ [Farm information worksheet](#)
- ☐ Maps (proximity, conservation plan, nitrate leaching, topographic, environmental concerns, soils)
- ☐ Soil fact sheets
- ☐ Soil test results organized
- ☐ Soil test interpretation and planning strategy
- ☐ [Soil test schedule](#)
- ☐ RUSLE2 (with your crop rotation indicated)
- ☐ [Field inventory](#)
- ☐ Manure application schedule

#### SESSION II

- ☐ Animal waste system overview sheet
- ☐ Calculation of amount of manure produced
- ☐ Manure test for each storage
- ☐ Manure analysis documentation
- ☐ Manure storage nitrogen calculations (one for each manure storage)
- ☐ Manure nutrient values
- ☐ P-index





SESSION III  
...  
**Managing  
Soil Nutrients**

*What will be covered in Session III:*

**Minimizing Environmental Risks  
Through Nutrient Management**

LESSON 1: Managing the Plant and Soil Ecosystem

LESSON 2: Potential Environmental Risks on Your Farm

LESSON 3: N- or P-Based Management and Manure Spreading Restrictions

**Terms to Learn**

- mineralization
- tith
- compaction
- farm nutrient balance
- dominant soil
- nitrogen leaching index
- N- or P-based management
- manure spreading restriction

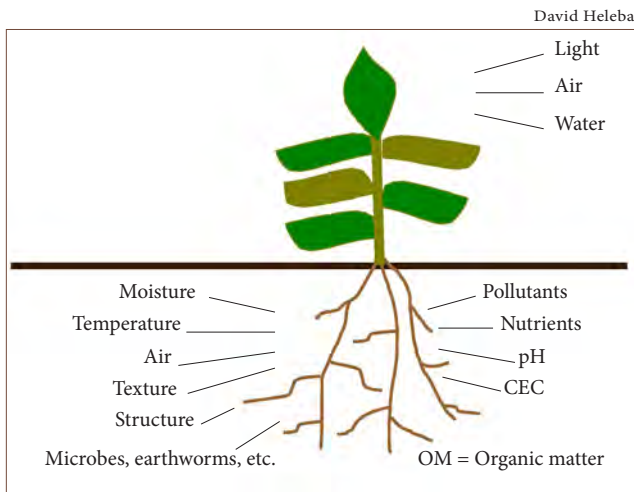
**Exercises**

1. Farm Nutrient Balance
2. Risk Assessment Worksheet
3. Checklist

## LESSON III-1

### Managing the Plant and Soil Ecosystem

**P**lants and soil form a complex ecosystem. In terms of nutrient management we have focused primarily on managing individual nutrients such as nitrogen, phosphorus, and potassium. It is important that farmers understand that soil fertility management goes beyond just managing these nutrients. This lesson will help give you a broader understanding of soil fertility as it exists within the context of the plant and soil ecosystem.



There are many variables integrally involved in sustaining a plant.

Soil fertility is defined as the ability of a soil to provide a physical, chemical, and biological environment for plants that is health-sustaining. In order for farmers to maintain soil fertility there are six basic principles to achieve:

- Soil organic matter levels
- Biological activity
- Soil tilth
- Minimal or no erosion
- Proper soil pH
- A balance of nutrients

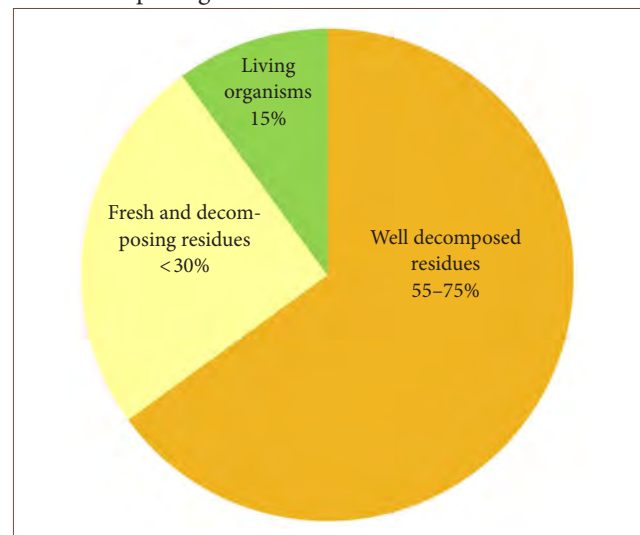
We will describe these principles of soil fertility and demonstrate how they are critical to supporting the plant and soil ecosystem.

### What's the Big Deal About Organic Matter?

Soil fertility and many of its principles are profoundly influenced by soil organic matter (SOM). Soil organic matter is the portion of soil that is derived from decomposing plants and animals. For example, when you plow down a grass field, the leaves and roots become part of the SOM. The soil organic matter is composed of several different fractions including the living organisms, the fresh residues, and the decomposed residues.

**Living Organisms.** Living organisms make up about 15% of the soil organic matter. The living portion of soil includes earthworms, insects, bacteria, fungi, plant roots, and animals such as voles and moles. These organisms help break down freshly added plant residues, manures, and other organic debris. In the process of breaking down the debris, the organisms obtain energy and nutrients and release nutrients that become available for plant uptake. This process of nutrient release is called mineralization. These organisms also play a role in soil aggregation and disease suppression. These functions will be addressed later.

**Fresh and Decomposing Residues.** The fresh and decomposing residues are another fraction of the



Composition of soil organic matter.

SOM. In most soils these residues consist of 30% or less of the organic matter. Fresh residues include partially decomposed once-living organisms. These residues are generally no more than three years old. Again, as these fresh residues are decomposed by living organisms the nutrients in the fresh residues are digested. In the process, some nutrients are released to surrounding living organisms (mineralization). The relative speed of decomposition of these materials is related to the carbon to nitrogen ratio of the fresh residues added to the soil. Residues that have a high carbon to nitrogen ratio (C:N) can be slow to decompose. This is because the microorganisms require additional nitrogen to decompose the high carbon materials. Often times these amendments will result in the microorganisms “tying-up” nitrogen that would have otherwise been available to the crop. Generally, residues with a C:N ratio of 20:1 or less have enough available nitrogen for rapid decomposition. In addition, the decomposition of fresh residues will also contribute to improving soil tilth.

**Well Decomposed Residues.** The well decomposed residues make up the majority of the soil organic matter (75 to 80%). As you might have guessed, the well



Decomposing organic residues provide food for soil organisms.

decomposed residues were at one time living organisms. These residues have been thoroughly decomposed to unrecognizable carbon compounds. Essentially, these compounds are no longer considered food for the living organisms in the soil. This fraction of organic matter carries a negative charge and is considered essential for other soil functions including the cation exchange capacity. These residues are anywhere from five to thou-

sands of years old.

## Fertility Principle 1 — Maintaining Soil Organic Matter Levels

It is critical to maintain sufficient levels of organic matter in the soil. This can be a difficult task for some farms and requires a diversified approach. Essentially, organic matter can be maintained through additions of a variety of types of organic matter while simultaneously decreasing losses of organic matter from the system. On dairy farms the primary organic matter addition is manure. Other organic matter additions can occur from cover crops and crop residues. Even farms with a readily available source of organic matter must work to reduce losses of organic matter from the cropped fields. For example, crop rotations that include perennial hay crops will reduce organic matter losses. Hay crops keep the soil from eroding and also do not require tillage. Aggressive and continuous tillage will reduce organic matter levels in soil. Lastly, it is important to remember that applying organic matter also adds nutrients to the soil. Therefore we must add organic matter in a manner as to not over-apply nutrients such as phosphorus. The SOM has a significant influence on several of the other physical and biological aspects of soil fertility.

## Fertility Principle 2 — Maintaining Soil Biological Activity

The second principle of soil fertility is to maintain biological diversity in the soil. The soil food web consists of a multitude of organisms that range in size but rely heavily on each other for survival. A biologically diverse soil can have up to 100,000 different types of living organisms.

The biology in the soil has many important functions that make it possible to have healthy plants and clean water. The primary activity of most soil organisms is to grow and reproduce. Soil organisms depend on interactions with each other to survive. The by-products that come from roots and fresh residues feed the soil organisms. In turn, the soil organisms will support plant health as they decompose organic matter, cycle nutrients, hold nutrients, degrade pollutants, improve soil structure, and control populations of crop pests. Earthworms, for example, break down large pieces of



Mycorrhizae are symbiotic associations between fungi and plant roots. The mycorrhizal fungus colonizes plant roots and allows the plant access to more nutrients.

plant residues into smaller pieces for other soil organisms. Earthworms also burrow through soil providing lots of air channels for root growth. Lastly, earthworms secrete a mucigel as they burrow through the soils. This mucigel is one of the ingredients that help the soil bind together.

### Fertility Principle 3 — Maintaining Soil Tilth

The next fertility principle is to maintain soil tilth. Soils in good physical condition are considered to have good tilth. This means the soil is porous and allows easy infiltration of water and penetration of roots. The pore space is created by aggregated soil. Soil aggregates are formed when soil particles (sand, silt, clay) become glued together with organic matter, soil organisms, and plant roots. The glue that holds all of this together come from the plants' roots and soil microorganisms. These aggregates come in all shapes, sizes, and levels of stability. The placement of aggregates in the soil ecosystem forms the soil structure. The space between the aggregates allows room for air and water. Therefore these soils have fewer issues with erosion and runoff. These porous soils also have ample air space. Roots and microbes require oxygen and open exploration of the

### CARING FOR YOUR SOIL LIVESTOCK

To increase and maintain the diversity of organisms in the soil we must take care of the soil “livestock.” Similar to feeding our cows, soil organisms require energy, protein, water, oxygen, and a proper habitat. We can provide these key diet ingredients by adding a diversity of organic residues. It is probably obvious from the previous section that adding fresh organic residues to the soil will feed the soil life. However, different soil organisms require slightly different foodstuffs. For example, fungi are common decomposers of plant residues because they generally have large amounts of hard-to-decompose carbon. Bacteria are generally more abundant on green litter of younger plants because they contain more simple carbon compounds. The bacteria and fungi are only able



Earthworms are one of the most visible soil organisms and are often used as indicators of a healthy soil. Credit: US Composting Council

to access plant residues after shredder organisms, such as earthworms, break residues into smaller chunks.

Oxygen and air space can be provided by implementing practices that foster good tilth. Soil organisms do not grow well in compacted soils that contain little air space. Growing a variety of plants species can also create diversity of soil life. The plant roots of different organisms attract different microorganisms.

The take home message is to treat your soil livestock like you would your own animals. Think about what practices will not only provide adequate food, but a healthy home for the animals that lie beneath your feet.



soil for optimum growth. The ample pore space allows plant roots to explore the soil and access nutrients freely. Stable aggregates are preferred as they can resist stress that might afflict the soil. For example, a soil that is well aggregated can resist rainfall, harsh tillage, and compaction.

The problems start when these aggregates are broken and remaining soil particles are squished together. We refer to this as compaction. Once the pore space is eliminated it is difficult for roots to grow properly and for microbes to survive. Compaction also keeps the soils water logged, resulting in anaerobic losses of nutrients. Essentially, nutrient cycling is severely limited without proper pore space.

There are three types of compaction that we observe on farms: surface, plow layer, and subsoil compaction. Surface compaction is common in annually cropped fields. Surface crusting occurs when soil is unprotected by surface residue, and raindrops disperse the aggregates by smearing them together into a thin layer of soil. Surface compaction can inhibit the germination of crops and increase the chance of erosion runoff.

Plow layer compaction is also common in our fields. The causes of plow layer compaction are erosion, reduced SOM levels, and heavy field equipment. Fields that are too wet for tillage are prone to this type of compaction.

Subsoil compaction occurs below the normally tilled surface layer. Subsoil is easily compacted because it is commonly wetter and more dense than the topsoil. This compaction occurs when a tillage implement applies pressure to the subsoil or when heavy equipment with poor weight distribution is run over the surface of the soil. Compaction is always most severe on wet soils.



Soil compaction is a common problem in Vermont fields.

Certainly the goal of a farmer should be to implement practices that maintain and improve soil tilth. Maintaining soil tilth first requires the addition of various types of organic matter to the soil. This organic matter increases the biological activity of the soil, resulting in the glues that form aggregates. These aggregates create ample pore space to allow for root, air, and water movement in the soil. Organic matter additions can help reduce the chance of surface and plow layer compaction. It is also important to maintain soil tilth through tillage. Tillage can be a detriment to soil tilth but also can be beneficial in alleviating soil compaction. Reduced tillage can increase SOM and reduce traffic on the fields. It is important to work the soil when it is at proper moisture. One rule of thumb is to roll some soil into a ball and drop it on the ground. If it breaks apart when dropped it is a signal that the soil is dry enough to be worked.

## Fertility Principle 4 — Preventing Erosion

When managing fertility it is important to reduce nutrient losses to the environment. Erosion is a principle mechanism by which valuable topsoil is lost from agricultural fields. Eroding soil generally has nutrients attached to it. As this soil is moved and deposited, valuable nutrients and organic matter are removed from crop fields. It is important to reduce or eliminate erosion to keep nutrients and organic matter on the field. Ways to reduce erosion from agricultural fields include reducing the speed of water or wind and keeping the soil in a condition that will resist the impact of rain and wind.

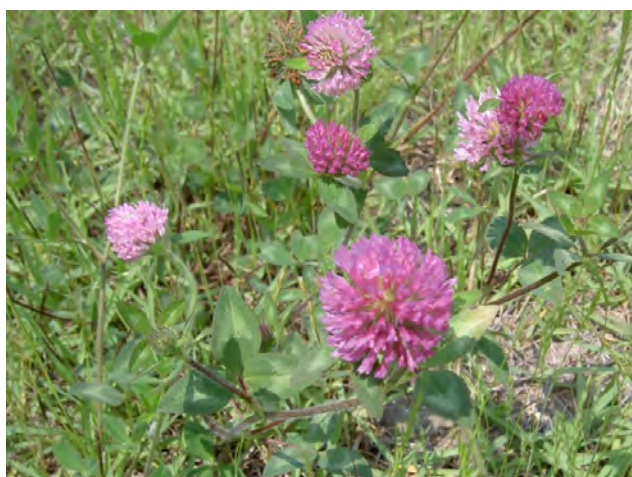
There are many practices that can be implemented to control erosion that will not hinder plant productivity. First, keep the soil covered with plant material as much as possible. For example, there is a greater chance of losing soil from a row crop than from a perennial grass crop. The grass crop holds the soil in place and the leaves can provide more coverage of the bare soil. In row crop systems, cover crops can be grown to protect the soil from erosion during the fall and winter months. Reduced tillage can also reduce erosion. When the soil is turned with a moldboard plow more bare soil is exposed, making it susceptible to erosion. Reduced or no-tillage options will leave more plant residue on the soil surface. However, in the case of corn silage, where

the whole plant is removed, there is minimal residue, even with no-tillage. Cover cropping will need to be implemented in order to have enough residue to protect against erosion. The residue can absorb the impact of rain droplets and improve soil infiltration. In general, soils with higher levels of organic matter and good structure are less prone to erosion. The organic matter helps to create good soil tilth. These soils are better able to absorb rainfall because they have more pore spaces to allow for water flow through the soil.

### Fertility Principle 5 — Maintaining a Proper Soil pH

Next we must remember to maintain the soil pH. It remains true that spending money on lime is probably the biggest bang for your fertilizer buck. A neutral soil is at a pH of 7. An acidic soil would fall below 7 and an alkaline pH would rise above 7. The pH can highly influence the nutrient availability in the soil. Most crops prefer a pH between 6.0 and 6.8. Some crops such as alfalfa prefer a pH of 6.8. This crop will perform poorly when the pH falls below 6. Some of this sensitivity is due to the fact that legumes generally form an association with a special type of bacteria. The bacteria have the ability to fix atmospheric N into plant-available N. These bacteria require a soil pH of 6.0 to survive. Molybdenum, which is necessary for nitrogen fixation in legumes, is more available at a more basic pH.

### Fertility Principle 6 — Maintaining a Balance of Nutrients



Legumes such as this red clover are an important part of a crop rotation.

### CREATING BIODIVERSITY

It is important to increase biodiversity above and below ground. Above-ground biodiversity can both enhance soil characteristics and help control pest populations. When crops are grown in monoculture there is a better chance of significant pest outbreaks. The living organisms above ground can play an important role in pest management. To encourage beneficial insects above ground we must provide them with a diversity of food and a proper home. Generally these requirements can be met by making sure that there is more than one crop growing in an area. This can be done by planting biological or ecological islands; habitat and food for beneficial organisms; biostrips, flower strips, beetle banks, strip insectary intercropping, vegetative corridors, or hedge rows. It can also be accomplished by planting a diversity of crops on the farm. Lastly, the judicious and careful use of pesticides is important to minimize harm to beneficial organisms.



Hedgerows provide habitat for many beneficial insects that help control pests.

The last principle of soil fertility is to balance the nutrients needed by plants while reducing their impact on the environment. This probably sounds familiar, as it is the primary goal of nutrient management. The goal is to provide what the crops require while being careful not to over-apply various nutrients. This is difficult to achieve, especially when manure is used as a nutrient source. We want to make sure that nutrients added to the soil do not become environmental hazards.

Hopefully from this session you have learned that there are many factors that affect soil fertility. It is not as easy as just maintaining N-P-K. Careful management of

the soil's biological, physical, and chemical properties will provide optimum crop production.

#### CHARACTERISTICS OF HEALTHY SOIL

Farmers usually know when a soil is healthy by its ability to grow healthy crops. Healthy soils have the following characteristics:

- Good soil tilth
- Sufficient depth
- Sufficient but not an excessive supply of nutrients
- Small populations of plant pathogens and insect pests
- Good soil drainage
- Large populations of beneficial organisms
- Low weed pressure
- No chemicals or toxins that may harm the crop
- Resistance to degradation
- Resilience when unfavorable conditions occur

## THE CORNELL SOIL HEALTH TEST

While traditional soil tests measure the chemical properties of soil such as pH and nutrient levels, it is well accepted that biological and physical properties also play an important role in soil's ability to grow crops. This more holistic approach to looking at soil has been called "soil health." Soil health (or soil quality) can be defined as the capacity of a soil to function within ecosystem and land use boundaries, to sustain productivity, maintain environmental quality, and promote plant and animal health (Doran and Parkin, 1994).

Since 2001, Cornell University has been developing a test to measure soil health. Twelve indicators of biological, physical, and chemical soil properties are used to make a comprehensive assessment. Some of these indicators include: available water capacity (a measure of the ability

of crops to store water between rains), aggregate stability (a measure of how well soil aggregates hold together in rain and resist surface crusting), and active carbon (a measure of the soil organic matter fraction that is available as a food source for microorganisms). The test results show how your soil compares with more than a thousand soil samples that have been submitted from the northeastern United States.

The procedure for submitting a soil sample for the Cornell soil health test is somewhat different than for traditional soil tests. First of all, the sample should be taken in the spring before the ground is tilled. If you are interested in submitting a sample from your farm, you will need to borrow a special piece of equipment called a penetrometer (or soil compaction meter) as measuring field compaction is part of the test. Biological properties

are very sensitive to changes in temperature, thus, the sample must be kept refrigerated until it is submitted. It is important to follow the sampling instructions carefully or to get help from someone with experience taking soil health samples in order to obtain meaningful results.

Because of the wide array of tests that are performed on each sample, the soil health test is more expensive than a standard chemical soil test. The current cost of a soil health test is \$45 per sample (2008 price). Because of the cost, it is most economical to target specific "problem areas" on the farm for sampling and compare them with "good areas." The test will identify constraints on plant growth that exist for a particular soil, but will require interpretation to determine the best management strategies for dealing with constraints.

For more information on the Cornell soil health test, visit the following website: [www.hort.cornell.edu/soilhealth](http://www.hort.cornell.edu/soilhealth).

CORNELL SOIL HEALTH TEST REPORT					
FARM NAME/FARMER:		SAMPLE ID: E415	DATE: 5/15/2007		
ADDRESS:		E-MAIL:	PHONE:		
FIELD/TREATMENT: RIVER FIELD		AGENT: Heather Darby - UVM Extension	SLOPE: 0.2%		
TILLAGE:		DRAINAGE: EXCELLENT	SOIL SERIES: ONDAWA FINE SANDY LOAM		
CROPS: GRT/GRT/GRT		SOIL TEXTURE: SANDY			
INDICATORS		VALUE	RATING	CONSTRAINT	PERCENTILE RATING*
PHYSICAL	Aggregate Stability (%)	45.2	1.0		
	Available Water Capacity (m/m)	0.16	7.0		
	Surface Hardness (psi)	233	1.0	rooting, water transmission	
	Subsurface Hardness (psi)	280	4.0		
BIOLOGICAL	Organic Matter (%)	1.6	1.0	energy storage, C sequestration, water retention	
	Active Carbon (ppm)	370	1.0	soil biological activity	
	Potentially Mineralizable Nitrogen (µgN/gdwsoil/week)	7.1	6.0		
	Root Health Rating (1-9)	2.5	3.0		
CHEMICAL	pH (see CNAL Report)	6.6	10.0		
	Extractable Phosphorus (see CNAL Report)	4.0	5.0		
	Extractable Potassium (see CNAL Report)	35	3.0		
	Minor Elements (see CNAL Report)		10.0		
OVERALL QUALITY SCORE (OUT OF 100)			MEDIUM		55.8
Ratings on this report are based on generalized crop production standards for New York. For crop specific nutrient interpretation and recommendation, see the attached chemical test report.					

The Cornell soil health report uses a stoplight system to show how your soil compares with other soils of similar texture. Red indicates problem areas.



## EXERCISE III-1

### Farm Nutrient Balance

**N**ext we will calculate crop nutrient removal rates in order to determine if there is enough crop need for the amount of manure nutrients produced on your farm. You will be using the Typical Crop Nutrient Removal table which can be found on page 66.

In the example below, the farm grows 150 acres of corn grain and has an average yield of 120 bushels per acre. From the table, we can find the nutrient removal rate (or nutrient need) per bushel of grain corn (nitrogen 0.75 lbs./bushel, phosphorus 0.4 lbs./bushel, potassium 0.3 lbs./bushel). Note that the units are different for different crops. The total nutrient need for each crop grown on the farm will be automatically calculated and totaled. In Session II, you calculated the nutrients that are available from manure, and those values will automatically fill in the “Manure Supplies” row.

Now we will look at the most important part of the worksheet — the balance. If the number is positive, this means that you have enough crop need to account for the nutrients in your manure. If the number is negative, it will show up in **red** and this indicates that you have too much manure for your land base. You will need to export some of your manure so that you are in compliance with state regulations. This is just an exercise. The total crop need and manure nutrients produced on your farm will be created for you in the goCrop™ program. The report titled Farm Nutrient Balance will give the information required to determine if you have the required land base for the manure produced on your farm (see page 66).

Farm Nutrient Balance (Based on Crop Removal Rates)								
Yield X Acres X lbs of nutrients removed per unit of yield = Total Nutrient Need								
Crop Removal Rates can be found on Table 19 in "Nutrient Recommendations For Field Crops in Vermont".								
(See Appendix for Table 19 data)								
Producer: Joe Farmer			Farm Name: Green Valley Farm				2009	
Crop	Yield per Acre	Acres	Nitrogen		P <sub>2</sub> O <sub>5</sub>		K <sub>2</sub> O	
			lbs/unit	Total Need	lbs/unit	Total Need	lbs/unit	Total Need
corn grain	120	150	0.75	13,500	0.4	7,200	0.3	5,400
corn silage	20	10	9.0	1,800	5.0	1,000	11.0	2,200
soybeans	40	60	3.2	7,680	1.0	2,400	1.4	3,360
alfalfa	5	40	50.0	10,000	15.0	3,000	50.0	10,000
grasses	4	140	40.0	22,400	15.0	8,400	50.0	28,000
small grains	80	40	1.1	3,520	0.9	2,880	1.5	4,800
<b>Total Crop(s) Need:</b>				58,900		24,880		53,760
<b>Manure Supplies:</b>				Use Manure NutValue Worksheet*	10,775		10,856	
<b>Balance:</b>				Estimated Nutrients Needed (Negative # indicates excess)	48,125		14,024	
*Use the figures from the sheet "Estimate of Manure Nutrients Available for Crop Production" in the Manure Production section.								
<b>Does this Balance indicate that you have the land base needed for appropriate application of the volume of waste that your farm produces?</b>								
yes								



## Typical crop nutrient removal.

(Table 19 from Nutrient Recommendations for Field Crops in Vermont)

Crop (units)	Per unit of yield			Typical yield/A	Removal for given yield		
	N	P <sub>2</sub> O	K <sub>2</sub> O		N	P <sub>2</sub> O	K <sub>2</sub> O
Corn (bu)	.75	0.4	0.3	120 (bu)	90	50	35
Corn silage (T) <sup>4</sup>	9	5	11	20 (T)	180	100	220
Grain Sorghum (bu)	0.5	0.6	0.8	120 (bu)	60	70	95
Forage Sorghum (T) <sup>4</sup>	9	3	10	15 (T)	135	45	150
Sorghum/sudangrass <sup>4</sup>	8	7	7	15 (T)	120	105	105
Alfalfa (T) <sup>2,5</sup>	50 <sup>1</sup>	15	50	5 (T)	250	75	250
Red clover (T) <sup>2,5</sup>	40 <sup>1</sup>	15	40	3.5 (T)	140	55	140
Trefoil (T) <sup>2,5</sup>	50 <sup>1</sup>	15	40	3.5 (T)	175	55	140
Cool-season grass (T) <sup>2,5</sup>	40	15	50	4 (T)	150	60	200
Bluegrass (T) <sup>2,5</sup>	30	10	30	2.5 (T)	75	25	75
Wheat/rye (bu) <sup>3</sup>	1.5	1	1.8	60 (bu)	90	60	110
Oats (bu) <sup>3</sup>	1.1	0.9	1.5	80 (bu)	90	70	120
Barley (bu) <sup>3</sup>	1.4	0.6	1.5	75 (bu)	105	45	110
Soybeans (bu)	3.2	1	1.4	40 (bu)	130	40	56
Small grain silage (T) <sup>4</sup>	17	7.0	26	40 (bu)	100	40	160

Note: Adapted from Beegle, 2003.

<sup>1</sup> Legumes fix all their required nitrogen. However, they also are able to use nitrogen as indicated.

<sup>2</sup> For legume-grass mixtures, use the predominant species in the mixture.

<sup>3</sup> Includes straw.

<sup>4</sup> 65% moisture.

<sup>5</sup> 10% moisture.

Farm Nutrient Balance report generated in goCrop.

Below Gravel Pit Piece	70-4	12.0	9.0	647	0.0	983	0.0	335
Across Brook	70-1,13,14,15,16	32.0	9.0	359	0.0	983	0.0	335
Across From A/C	10662-2	41.0	9.0	-10	0.0	983	0.0	335
By the Road	10662-1	10.44	7.0	-83	0.0	983	0.0	335
Back of Road Piece	10662-14,15,16	36.5	0.0	-83	0.0	983	9.2	-1
Maple Tree Piece	52-1,2	14.75	0.0	-83	9.0	850	0.0	-1
Behind House	52-3	28.0	0.0	-83	9.0	598	0.0	-1
Side Hill Piece	52-27	48.4	0.0	-83	9.0	163	0.0	-1
Across From Barn	52-13	6.5	7.0	-128	0.0	163	0.0	-1
South of Barn	52-19	24.8	0.0	-128	0.0	163	0.0	-1
Back of Barn	52-18	3.8	0.0	-128	5.0	144	0.0	-1
South West Corner	52-25,26	19.5	0.0	-128	2.0	105	0.0	-1
North of the Barn	52-14,15,16,17,23,24	37.7	0.0	-128	3.0	-8	0.0	-1
test	999	45.0	0.0	-128	0.0	-8	0.0	-1
test2	9998	50.0	0.0	-128	0.0	-8	0.0	-1
Balance		1,838.4		-128		-8		-1
				N		P		K
Planned Crop Needs (lb)				437,184		210,219		526,725
(Negative indicates an excess)								
Soil Test Crop Needs (lb)				199,789		28,310		106,175
Balance (lb)				-5,664		-76,532		-178,573
(Negative indicates an excess)								

## LESSON III-2

### Potential Environmental Risks on Your Farm

One of the goals of nutrient management planning is to produce high yield and quality crops while protecting the environment. In order to minimize the farm's environmental impact you must understand the factors that influence the risk of water pollution. Once these factors are identified, appropriate control and management measures can be implemented to minimize environmental pollution.

In previous lessons, we have learned how various nutrients can be lost from our farms. For example, nitrogen can be lost through volatilization, denitrification, leaching, and runoff. Phosphorus can be lost through runoff and erosion. It is important to know how the soil properties, landscape, and management practices on the farm will influence the loss of these nutrients. Some of these properties cannot be modified, such as soil type and slope. A clay soil will be denser and more poorly drained than a sandy soil, leading to an increased chance for runoff. However, there are a number of cropping practices that can be implemented or modified to lower the potential impact.

Most farmers know their soil and land better than anyone else. You know which crops grow best where, what fields require the most tillage, which fields require the most rock picking, and which fields are close to ground or surface water. The goal of analyzing risk is to combine your knowledge with scientific principles to reduce the risk of pollution. This is primarily accomplished by the use of risk models. We have already learned about several of these risk models in the other sessions. The first risk assessment model is RUSLE2. This program incorporates your management practices as well as soil types and slopes into a computer model and determines the potential amount of soil loss from your fields. The more soil loss potential, the riskier the field is in terms of water quality.

Another model is the phosphorus or P-index. This program is used to determine the potential for phosphorus erosion and runoff from your fields into surface

water. It incorporates your management, soil type, slope, and proximity to water into its calculation. A high P-index indicates a threat to water quality.

Lastly, there is the nitrogen leaching index. This model determines the potential for soil-applied nitrogen (in the form of fertilizer or manure) to be leached into the groundwater. The benefit of these models is that you can change your management practices to reduce your potential risk to water quality. For example, crop rotations with perennial crops and manure incorporation practices can greatly reduce nutrient loss.

In addition to the risk models, there are other potential environmental risks on farms that should be noted and managed. For example, determine where waterways and wells are located on the farm. A waterway might be a brook, stream, river, or sometimes a farm ditch. It is important to identify these areas and provide appropriate vegetated buffers between agricultural crops and the water. The State of Vermont requires adjacent surface waters to be buffered by 25 feet of perennially vegetated

buffers between fields and surface water banks, 10 feet between fields and ditches, and 25 feet between fields and inlets or inlets of open drains. Buffers are harvestable and they can be grazed but the buffer cannot be tilled or have compost or fertilizer applied except for establishment or maintenance. Identification of public and private wells is important so that proper manure spreading setbacks can be determined.

While identifying risks is often tedious, it is important to remember that we need to be responsible stewards of the land. These risk assessments benefit not only our farms but our local communities.



Vegetated buffer strips between fields and waterways help to minimize the risk of nutrient loss to surface water.

## EXERCISE III-2

### Risk Assessment

It's time to discuss the Environmental Concerns Risk Assessment. This information is entered when creating the field inventory and automatically populates the Risk Assessment Report.

Edit Farm

### Risk Factors

**Distance To Stream (ft):**

**Vegetated Buffer Width (ft):**

**Manure Spread Set Back (ft):**

**Sediment Trap Structure:**

**N Leaching Index:**

**Water Qual. Site Considerations:**

**Soil Type:**

**Limiting Soil Type:**

**Hydrologic Group:**

**Drainage Class:**

**Water Table Depth (ft):**

**Flood Potential:**

[Delete This Field](#)
[Cancel](#)
[Update](#)

Note any water quality site considerations for this field (springs, wells, etc.).

"Limiting soil" is found on the soil map. You've chosen the dominant soil already, but the limiting soil is the one that will limit your yield (it can be the same as the dominant soil in some cases).

For "N Leaching Index" you will need to use your nitrate leaching maps and select the dominant category (low, medium, or high) for each field.

Nitrogen leaching index categories:

0-2	Low
2-10	Moderate
10-20	High

All information for these columns can be found on the soil fact sheets. Fill these out according to the soil fact sheet for the dominant soil (the most prevalent soil type in the field). For a review of how to read soil fact sheets, go to page 20.

Risk assessment report generated in goCrop™.

Environmental Concerns Risk Assessment																
Farm Name	Sample Farm			Plan Date							2012-03-22	Crop Year		2012		
Producer/Farm Manager	Joe Farmer			Planner							Joe Farmer					
The Environmental Concerns Risk Assessment provides a field by field assessment to identify environmentally sensitive features. This assessment also provides information on the potential for phosphorus and nitrogen transport from the field to sensitive areas.																
Field Name	Tract & Field #	Acres	Crop	Dominant Soil	Limiting Soil	Hydro-logic Group	Dom. Drainage Class	Water Table Depth	Flood Potential	Depth to Bedrock	RUSLE2 Soil Loss (as planned)	Water Qual. Site Considerations	Soil Test P Range	P-Index as Planned	Nitrate Leaching Potential	Mgmt Based
Field#1	9999-1	30.0	Corn Grain	GeA	MeA	C	Moderately Well	1-1.5	None	> 60	1.7	Private Well	Optimum	Not known	Medium	
Field#1	9999-1	30.0	Wheat	GeA	MeA	C	Moderately Well	1-1.5	None	> 60	1.7	Private Well	Optimum	Not known	Medium	
Small Pieces	60-7	11.0	Grass, Hay, Estbl.	Ly	Ly	D	Very Poorly	0.5	None	> 60	1.5	Stream	Optimum	Not known	Medium	
Across Brook	60-8,9,c1	33.0	Grass/le gume, Hay, Estbl.	KbA	MeA	D	Somewhat Poorly	0 1.5	None	> 60	2.2	Stream	Medium	Medium	Medium	N-based
Behind Jacks	60-10	18.0	Grass/le gume, Hay, New	MeA	MeA	C	Very Poorly	0 1.5	None	> 60	1.2	Neighbors	Optimum	Medium	Medium	N-based
Behind Pond	60-6,11	48.0	Corn Silage	MeA	MeA	C	Somewhat Poorly	1 1.5	None	> 60	1.2	Private Well	High	Low	Medium	N-based
Behind Pond	60-6,11	48.0	Soybean	MeA	MeA	C	Somewhat Poorly	1 1.5	None	> 60	1.2	Private Well	High	Low	Medium	N-based
Behind Pond	60-6,11	48.0	Corn Silage	MeA	MeA	C	Somewhat Poorly	1 1.5	None	> 60	1.2	Private Well	High	Low	Medium	N-based
Rileys Knoll	65-1	38.0	Corn Silage	KbA	KbA	D	Somewhat Poorly	.5 1.5	None	> 60	2.4		Optimum	Medium	Medium	N-based
Rileys Knoll	65-1	38.0	Barley	KbA	KbA	D	Somewhat Poorly	.5 1.5	None	> 60	2.4		Optimum	Medium	Medium	N-based
Rileys Knoll	65-1	38.0	Wheat	KbA	KbA	D	Somewhat Poorly	.5 1.5	None	> 60	2.4		Optimum	Medium	Medium	N-based
Rileys Knoll	65-1	38.0	Wheat	KbA	KbA	D	Somewhat Poorly	.5 1.5	None	> 60	2.4		Optimum	Medium	Medium	N-based
Back of House	65-2	13.5	Grass/le gume, Hay, Estbl.	KbA	Cv	D	Somewhat Poorly	.5 1.5	None	> 60	1.1	Stream	Optimum	Medium	Medium	N-based
Back of Davids	65-4	35.0	Corn Silage	MeA	KbA	C	Somewhat Poorly	1 1.5	None	> 60	0.56	Nieghbor s	Medium	Medium	Medium	N-based

Vermont soil test categories expressed as pounds per acre (lbs./acre, or parts per two million) in elemental form.

(Table 20 from Nutrient Recommendations for Field Crops in Vermont)

	Low	Medium	Optimum	High	Excessive
	lb/acre				
Available P	0–4	4–7	8–15	16–40	>40
K	0–100	101–200	201–260	261–325	>325
Mg	0–70	71–100	101–200	>200	—

## LESSON III-3

### N- or P-Based Management and Manure Spreading Restrictions

**T**he P index is an indicator of the potential for runoff loss of phosphorus from your fields. The P-index will give you a rating for each field: low, medium, high, or very high. From the results of the P-index and your soil test P results, your field is designated as requiring either N- or P-based management. You can find the status of each field by looking at the column “Need N- or P-based management” on the environmental risk worksheet. Whether a field is under N-based or P-based management will affect your approach to meeting crop nutrient needs. In a perfect world, we would be able to create a blend of fertilizer that met the exact needs of each field. Since we are using manure to satisfy crop needs and we can’t easily change the nutrient composition of the manure, we will likely be over-applying or under-applying some nutrients. When using manure as a nutrient source, generally there is a tradeoff between N and P. If you apply enough manure to meet the crop’s N needs, there will usually be a buildup of P over time.

The P-index and your soil tests provide us with a way to figure out which type of management is appropriate in each individual field. Let’s define each type of management:

**N-Based Management.** You are managing the crop based on its nitrogen needs. Manure can be applied at rates needed to meet crop removal rates or soil test N recommendations. However, with this method you must monitor soil test P levels. (N-based management will

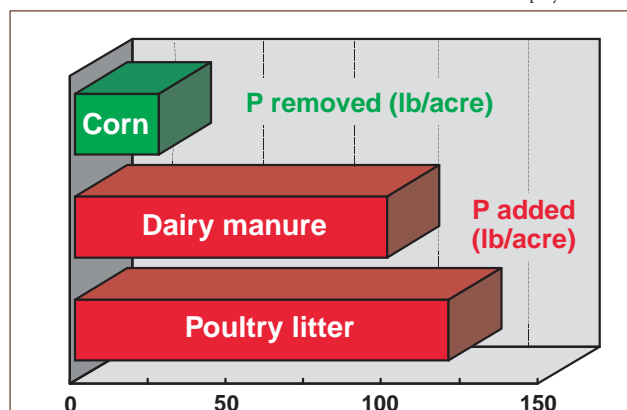
generally result in a buildup of soil P over time, so be sure to continue monitoring soil test P level.)

**P-Based Management.** You are managing the crop based on its phosphorus needs. You may apply only enough manure to meet P crop removal rates or soil test recommendations for P.

#### Manure Spreading Restrictions

On the risk assessment worksheet you will also find a manure spreading restriction code. This code is set up using a stoplight system with red, yellow, and green (see page 71).

Sharpley et al. 2003



Applying manure to meet crop N needs (about 200 lbs. available N/acre) adds much more P than corn removes.



## Manure Spreading Restrictions

### RED

Fields with a very high P-index

No P may be added through manure applications. You have to manage these fields carefully in ways that will prevent P runoff and will draw down soil P levels over time.

### YELLOW

Fields with a high P-index or soil test levels greater than 20 ppm. Even if the P-index is medium, you must manage for P if your soil test exceeds 20 ppm.

Manure and fertilizer applications are based on P recommendations. P-based management means that manure application may not exceed rates of P removal by crops.

### GREEN

Fields with a low to medium P-index

You can apply manure based on N recommendations. Be careful! If you add 10 lbs. of N per 1000 gallons of manure, you will apply 15,000 gallons of manure to get 150 lbs. of N. This also means you are applying 120 lbs. of P. Your P level will rise over time and soil test results will show levels at high or very high. You must manage this before it happens.

## EXAMPLE OF MANURE CALCULATION FOR “YELLOW” MANURE SPREADING RESTRICTION

With a yellow manure spreading restriction, manure application may not exceed rates of P removal by crops. Look at crop removal rates for corn silage:

Let's say your typical yield is 20 tons/acre (see table on page 66).

How many lbs. of  $P_2O_5$  are removed per acre?

Answer:

20 tons x 5 lbs.  $P_2O_5$  removed per ton = 100 lbs.

So how much  $P_2O_5$  can you apply in your manure?

Answer: 100 lbs.

How much manure do you put down to get 100 lbs. of phosphorus? Refer to the table on page 40.

On average there are 8 lbs. of  $P_2O_5$  per 1000 gallons of manure. You are allowed to put on 100 lbs. of  $P_2O_5$  ( $8 \times 12 = 96$ ).

12 x 1000 gallons =  
12,000 gallons of manure per acre

Remember that it is best management to not apply more nutrients than the crop needs. Following the soil test recommendation will minimize nutrient over-application. If you just base your measurements on crop removal then you won't utilize all of the nutrients already in your soil. This is a waste of money. In addition, you'll never bring your phosphorus levels down.

## EXERCISE III-3

### Checklist

**H**ere is a list of items that you should have completed before you go on to the next session. Those items found in goCrop™ are listed in [blue](#).

#### SESSION I

- ☐ [Farm information worksheet](#)
- ☐ Maps (proximity, conservation plan, nitrate leaching, topographic, environmental concerns, soils)
- ☐ Soil fact sheets
- ☐ Soil test results organized
- ☐ Soil test interpretation and planning strategy
- ☐ [Soil test schedule](#)
- ☐ RUSLE2 (with your crop rotation indicated)
- ☐ [Field inventory](#)
- ☐ Manure application schedule

#### SESSION II

- ☐ Animal waste system overview sheet
- ☐ Calculation of amount of manure produced
- ☐ Manure test for each storage
- ☐ [Manure analysis worksheet](#)
- ☐ [Manure storage nitrogen calculations \(one for each manure storage\)](#)
- ☐ [Manure nutrient values](#)
- ☐ [P-index](#)

#### SESSION III

- ☐ [Farm nutrient balance](#)
- ☐ [Risk assessment](#)

SESSION IV  
...  
**Putting It All  
Together**

*What will be covered in Session IV:*

**The Rest of the Story**

LESSON 1: Understanding Potassium

LESSON 2: Secondary Nutrients and Micronutrients

LESSON 3: Understanding Nutrient Recommendations

**Terms to Learn**

- macronutrient
- secondary macronutrient
- micronutrient
- luxury consumption

**Exercise**

1. Field Plan Recommendation Worksheet
2. Checklist

## LESSON IV-1

### Understanding Potassium

**A**long with N and P, potassium (K) is referred to as a macronutrient because it is found in such large quantities in most plants. K is important for plant growth, reproduction, and winter survival of perennial plants. It is involved in over 60 different enzyme systems in plants, helps plants resist the effects of drought and extreme temperatures, and increases a plant's ability to resist diseases. K is generally not considered an environmental problem and therefore we haven't yet covered it. However, managing K is important because it is easily leached and can be costly to maintain. Furthermore, when growing feed for livestock, over-application of K can cause severe herd health issues.

#### Forms of Potassium in the Soil

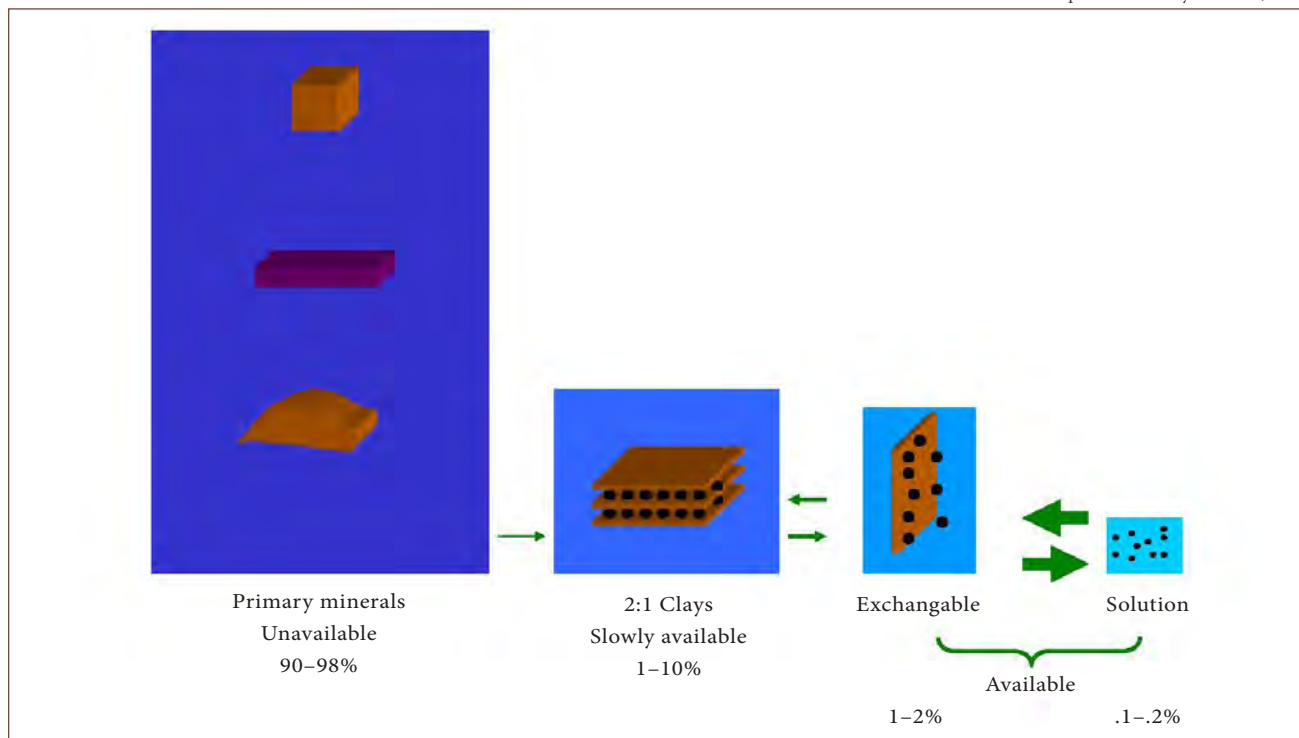
Much of the K in the soil is not available to crops and is tied up in primary minerals. As these rocks and minerals are broken down over time, they release small amounts of K at a very slow rate. This portion of K

(about 10% or less) is referred to as "slowly available." Only a small amount (less than 2%) is available for plant uptake. This is found in the soil solution and is often referred to as "exchangeable" K because the positively charged K ions are constantly moving between the negative charges found in soil particles (the cation exchange capacity, or CEC) and the soil solution. The results you get for K on a soil test report actually reflect what is available and do not account for all the K that is not available.

#### The Potassium Cycle

The fate of K in the soil can vary. In the soil solution, it can be taken up by the plant or exchanged onto soil particles and/or organic matter. K moves easily with water, so it can also be leached out of a soil if there is water movement due to heavy rains. This most often occurs on very sandy soils that have a low CEC value. K can also be tied up with other minerals and become "fixed" until

Adapted from Brady and Weil, 2002



Forms of K in the soil.

those minerals break down. Soil pH can also influence soil K. As pH increases, the number of exchange sites found on the organic matter also increases, enabling the soil to retain more potassium.

Plants take up K in large amounts. The crop removal rate of K depends on what portions of the plant are harvested. Most of the K in a plant is found in the leaves and stems, therefore, whole plants such as corn silage or hay crops will remove a lot of K. Grain crops remove much less K, as long as the remaining residue is recycled back into the soil. Major sources of K include animal manure and mineral fertilizers (symbolized as  $K_2O$  on fertilizer labels) mostly in the form of muriate of potash (0-0-60), which is also known as potassium chloride. Animal manures can have significant amounts of K but can vary depending on the type of animal, method of storage, and amount of water in the manure.

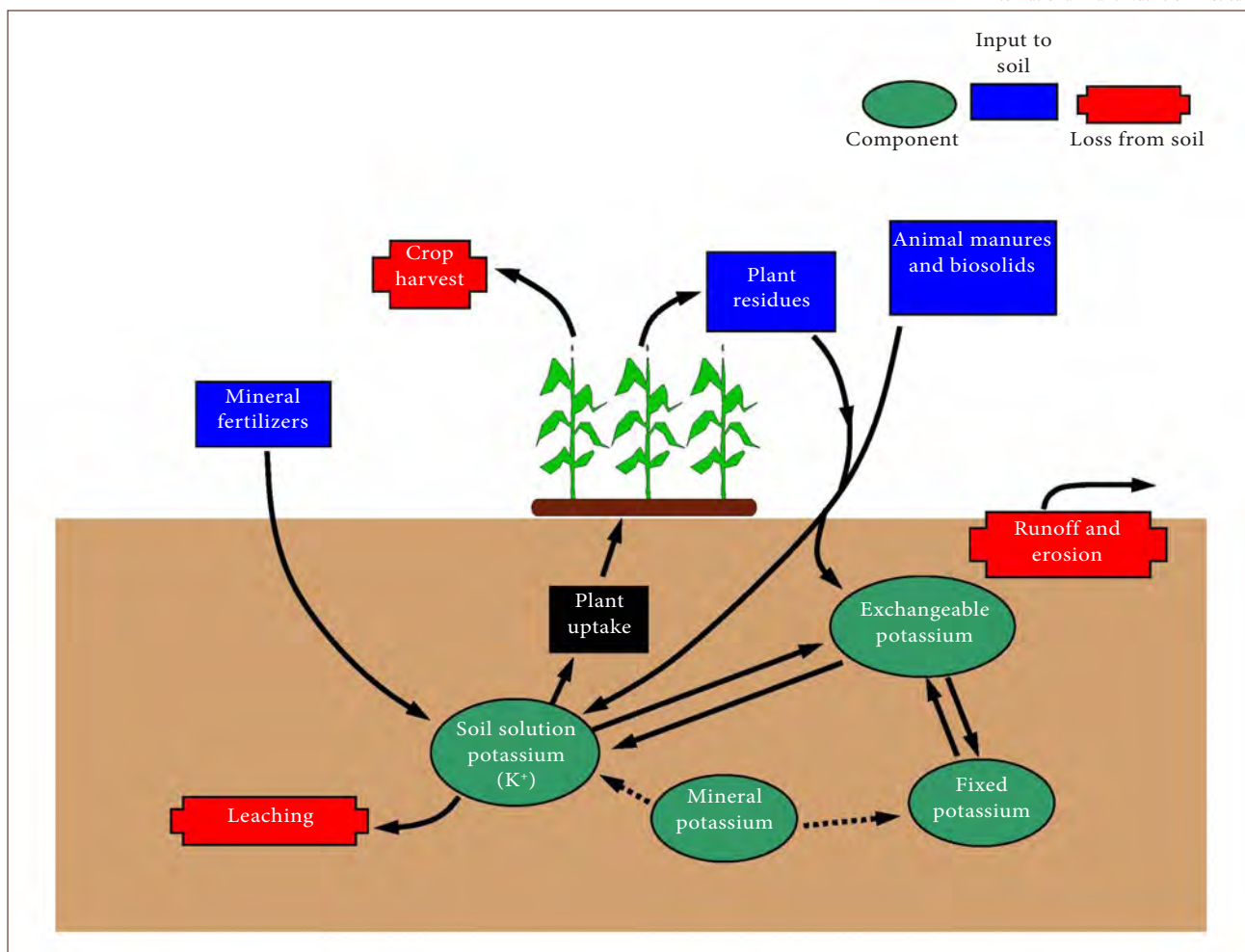
## Potassium Deficiencies

K deficiencies occur when the plant demand for K exceeds what is available in the soil solution. K deficiency symptoms include burned-looking lower leaves, spots near the edges of leaflets, and yellow or dead areas on the edges of leaves. Since K is a mobile nutrient in the plant, deficiency symptoms usually start in lower leaves.

K deficiency can be a problem in soils with low cation exchange capacities, because these soils aren't able to retain potassium ions. These soils tend to be sandy with low organic matter. This problem is usually addressed by splitting K applications.

Alfalfa can remove a large amount of K (250 lbs./acre for a yield of 5 tons) and thus requires that K be replaced to maintain high yields. Adequate levels of soil K are also important for reducing the risk of winter injury in alfalfa.

International Plant Nutrition Institute



The potassium cycle.





K deficiency symptoms of corn.



K deficiency symptoms of soybeans.

Grasses can remove as much K as alfalfa. However, since their fibrous root systems are more efficient miners of K, they are really good at extracting K even from soils testing low for K. In many cases, adding K can improve grass yields since K has to be adequate to get the best yield response out of N fertilization. It is especially important to maintain adequate soil K levels when growing a mixture of grasses and legumes. At low soil K levels the grass will almost always out-compete the legume.

### CONSIDERATIONS IN POTASSIUM FERTILIZATION

- Manure is an excellent source of K and is considered 100% available in one cropping season.
- Generally, hay crops only need one K application a year. However, split applications of K help to reduce luxury consumption and prevent leaching in sandy soils with low organic matter.
- Hay crops generally have their highest levels of K during the first growth of the season, therefore, it is usually best to apply an annual application of K after the first or second cutting rather than in the spring.



Alfalfa winter injury can be exacerbated by K deficiency.

## LESSON IV-2

### Secondary Nutrients and Micronutrients

**W** While N, P, and K are classified as primary macronutrients, magnesium (Mg), calcium (Ca) and sulfur (S) are classified as secondary macronutrients because they are found at intermediate levels in plants. Micronutrients — which include iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), boron (B), chlorine (Cl), molybdenum (Mo), and nickel (Ni) — are found in very small amounts. If you look at a forage report or a plant tissue test, normally you will see that primary and secondary macronutrients are reported as percentages, while micronutrients are reported in parts per million (ppm). To give you a sense of the differences in scale, the table below gives the sufficiency levels of nutrients for field corn used in tissue testing. As you can see, micronutrients are found at much smaller levels in plants than are macronutrients.

Generally, we have not seen deficiency problems with secondary macronutrients or micronutrients in our field and forage crops in Vermont. The exceptions to

The sufficiency levels for corn of most nutrients (measured from the ear leaf at silking time) reported as both percentages and in parts per million.

Nutrient	Percent	PPM
Nitrogen (N)	2.5–3.5	25,000–35,000
Phosphorus (P)	0.25–0.45	2,500–4,500
Potassium (K)	1.7–3.0	17,000–30,000
Calcium (Ca)	0.25–0.50	2,500–5,000
Magnesium (Mg)	0.13–0.30	1,300–3,000
Sulfur (S)	0.21–0.50	2,100–5,000
Iron (Fe)	0.0021–0.025	21–250
Manganese (Mn)	0.0015–0.03	15–300
Zinc (Zn)	0.002–0.01	20–100
Copper (Cu)	0.0006–0.002	6–20
Boron (B)	0.0005–0.0025	5–25

Snyder, 1998

this are B in alfalfa and trefoil and, occasionally, Zn in corn. The infrequency of deficiency problems is probably largely due to the great amounts of animal manure that most of our agricultural soils have received over the years. Manure is a good source of most of these nutrients. In addition, when soil is properly limed to maintain an optimum pH, Ca is usually adequate for most agronomic crops.

There have been some cases of Mg and Zn deficiencies in corn and B deficiency in forage legumes, so some additional discussion of these is found below. Also, there are some concerns about S deficiencies, though most studies in New York and Pennsylvania have not shown widespread problems.

#### Magnesium

On occasion, Mg deficiencies are found, particularly in field corn. The most obvious symptom of Mg deficiency is interveinal chlorosis on older leaves. This means that the veins stay green, but the area between the veins turns yellow. This is fairly distinguishable from the deficiency symptoms of other nutrients. Mg is a fairly mobile nutrient in the plant, therefore symptoms often first show up in the older leaves (similar to N, P, or K). Your soil test should show if a field's Mg levels are low. Deficiencies are sometimes associated with both low soil Mg levels and high K levels. Both being cations, K will compete with Mg for soil exchange sites and for plant uptake levels. This is why the UVM soil recommendation for Mg is based on both factors — a low soil Mg level and a very high soil K level.

Generally, the least expensive and most practical way to provide Mg to a crop is to add a high Mg lime such as dolomitic limestone when routinely liming. However, if pH is adequate, a fertilizer such as sul-po-mag (S, K, and Mg) can be applied.

Low Mg levels in grass pasture are sometimes associated with grass tetany or hypomagnesemia, a condition in livestock with low blood Mg levels. High N and/or K fertilization can also contribute to the problem. Although fertilization may help correct Mg levels in the



Interveinal chlorosis on older leaves is a symptom of Mg deficiency in corn.

forage, it is usually more economical to supply the animals with Mg in their mineral supplement. In addition, risks associated with this condition can be reduced by avoiding N and K fertilization in early spring, and by encouraging more legumes in the pasture mix.

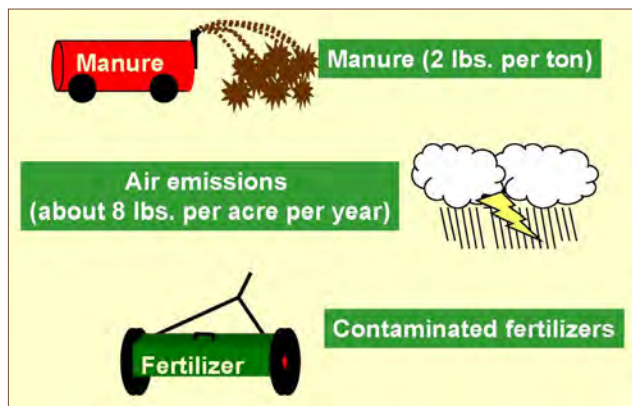
## Sulfur

Although there have been no confirmed reports of S deficiencies in our field crops, many soil fertility specialists warn that this nutrient could become limiting in the future for two reasons. Historically, the two major sources of S were contaminated fertilizers and air pollution. With modern fertilizers formulated more purely and with air pollution reduced, there is a likelihood that S could drop below critical levels for high-producing crops. Research in New York and Pennsylvania has not

shown this to be a problem so far. In Vermont, it may be less likely that we will have S deficiency problems because of our heavy applications of animal manure in addition to air pollution emissions. On average, there are about two pounds of S for every ton of manure. By rough estimate, approximately eight pounds per acre per year may be contributed by air emissions (based on data from two monitoring stations in Vermont).

It is best to be on the lookout for S problems. Deficiencies are most likely to occur in high rainfall areas on sandy soils with low organic matter that receive little or no manure. The best visual symptom is a general yellowing of newest, top leaves (see picture below). If you suspect S deficiency, tissue analysis is one way to confirm the problem. Collect samples from both the suspected area and from “good” areas so you can compare the analyses. If the corn is still in the vegetative stage (25 to 45 days old), collect whole plants. If the corn is at tassel and silk stage, collect several ear leaves for analysis. Sufficient levels at either of these stages should be between 0.18% and 0.40% of dry matter. For alfalfa, sample whole plants. As with corn, sufficient levels should be between 0.18% to 0.40%. You can also look at the N to S ratio for alfalfa. It should be between 12 and 17.

Montana State University



Sources of S.



S deficient corn plant on right.



## Zinc

Cases of Zn deficiency in corn do show up on occasion in Vermont. Usually they show up within the first month of corn emergence. Symptoms appear on the youngest leaves when corn plants are still quite young. Visual symptoms include a unique banded chlorosis on the leaves and stunted plants.

Conditions in which Zn deficiency is most likely to occur include the following:

- Cool spring weather
- Sites that receive little or no manure
- Acid soils that are heavily limed to bring the pH to 7.0
- Soils testing high for P
- Highly eroded high lime soils

The decision to apply Zn as either banded or incorporated is based on both soil test results and past observations of deficiency symptoms. Foliar applications of Zn as a rescue treatment for corn already showing symptoms have had limited success.

## Boron

In the 1950s, University of Vermont soil scientists first demonstrated that alfalfa and bird's-foot trefoil need supplemental B. Our soils tend to be low in B. Based on that early work, the general recommendation has been and still is to apply one to two pounds of B per acre per year to these crops.

B deficiency is most likely to occur on coarse-

textured soils that are easily leached, or when soil pH is above 7.0 (when B becomes highly adsorbed by the soil). You can also get deficiency symptoms during dry periods. Visual symptoms show up first on the youngest leaves as yellow to reddish necrosis appears along the edges of the leaflets. The plants will also be stunted and rosette in shape.

Sometimes symptoms of B deficiency are confused with potato leafhopper damage. Both occur in the summer and cause stunted plants. However, the most striking visual symptom of hopperburn is the V-shaped necrosis at the tip of the leaflet — not damage along its edges.

British Columbia Ministry of Agriculture



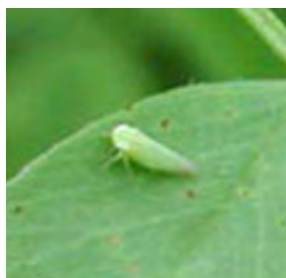
Yellow and red leaf discoloration in alfalfa is typical of B deficiency.

Owen Plank, University of Georgia

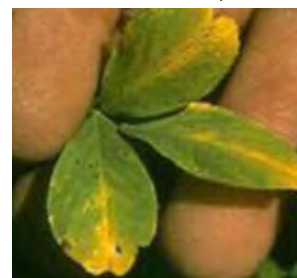


Zn deficiency in corn.

Ohio State University Extension



An adult potato leafhopper.



Hopperburn in alfalfa.

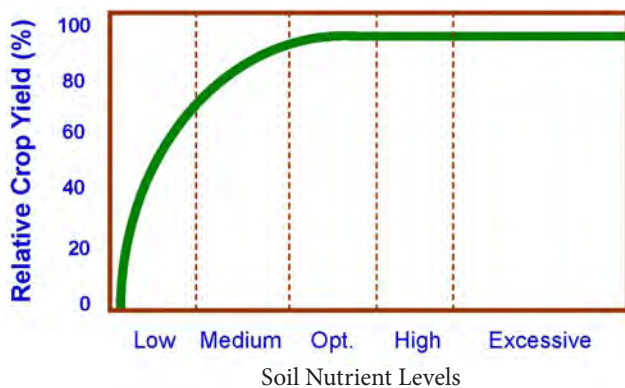
## LESSON IV-3

### Understanding Nutrient Recommendations

#### Approaches for Nutrient Recommendations

When you submit a soil sample for testing, the results and recommendations you get back may vary from lab to lab. It is important to understand both what type of chemical extractant a particular lab uses, and how that lab interprets the soil test results. You should use the same lab whenever possible so that you get consistent results. There are three approaches or philosophies to interpreting soil tests and making fertilization recommendations for P, K, Ca, and Mg. The approach taken can significantly affect the recommendation rate and, thus, fertilizer costs.

**Sufficiency Approach.** This approach is based on maintaining a critical level of exchangeable nutrients in the soil. The assumption is that plant growth is optimized at a certain soil test level if all other nutrients and conditions are adequate for growth. In the following figure, crop yield only reaches its optimum potential once the soil test level is at or above “optimum.” If the soil test is at a low level, then there is a good probability that you would get an increase in yield by adding fertilizer. This research-based approach is most commonly used by university soil labs, and relies on routine soil testing to ensure that your soils are at or above critical

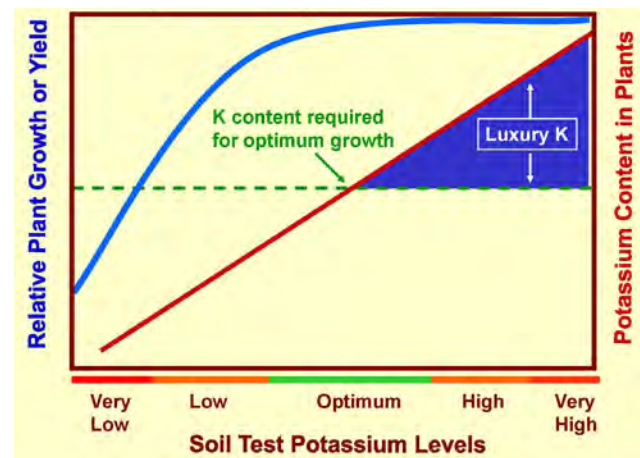


The “sufficiency approach” uses crop yield at different soil nutrient levels to determine fertilization recommendations.

levels.

**Maintenance Approach.** This approach is based on calculating or estimating the replacement value of nutrients removed by the crop. Often, a general fertilization recommendation for a crop that you might read in a fact sheet or crop guide is based on typical removal rates. If you know your crop yield and the nutrient content of your crop, you can simply calculate the removal rate. The assumption is that you need to replace that amount of nutrients to replenish what was taken out of the soil. So, you could approach your fertilization rates without having to do soil tests; however, there is a problem with this approach. For example, plants take up K even if they don’t need it. This is called luxury consumption and can create a false sense of what the crop needs for fertility. The figure below shows plant growth in response to different levels of soil K. At an optimum soil test level the yield levels off; however, the K content in the plant continues to go up even at higher soil test levels.

**Soil Cation Balance Approach.** This approach is based on the maintenance of certain ratios of K, Ca, and Mg. The problem is that field studies across the North-



Luxury consumption occurs when plants take up more K than they need, sometimes resulting in herd health problems when the high K forage is fed.



east and Midwest have not supported this approach when the ratios are maintained within strict ranges. This approach often results in over-fertilization of certain nutrients and in higher input costs. Since extremely high levels of K can interfere with Mg uptake, fertilization recommendations for Mg may be made even if soil test levels of Mg are at a normally optimum level.

**Combination Approach.** On a practical basis, a fertilization program is often based on a combination of approaches. In the case of K, the soil test is important for determining K rates to achieve optimum soil test levels, while estimates of K crop removal are used to adjust rates depending on the yield potential of the soil. For some soils that are inherently high in K, adjustments for Mg are also made to achieve a reasonable ratio.

## Making Your Own Nutrient Recommendations

The very last thing you need to do to finish your NMP is to develop fertilizer and manure application rates for your fields.

If you asked for nutrient recommendations when you submitted your soil samples, you should already have recommendations on your soil test reports. Check each soil test report to make sure that the nutrient recommendation is for the crop that you are growing this coming season. What if you don't have a recommendation or there is an incorrect recommendation on your soil test? In either of these cases, you can make your own recommendation using the tables on the following pages. Below is a step by step process for making your own nutrient recommendations.

## Nitrogen Recommendation

**For Corn and Other Annual Crops.** Use table 4 on page 82 to locate the expected yield and soil drainage class to determine N recommendations. For example, an expected yield of 25 tons of corn silage per acre on well drained soil will require 150 lbs. of N per acre.

**For Perennial Forages.** Use table 8 on page 82 to locate the expected yield on the table to determine N recommendations. For example, an expected yield of

5 tons dry matter per acre will require 50 lbs. of N per acre per cutting. Therefore, if you are harvesting three cuttings of hay then your recommendation is 150 lbs. of N per acre (50 lbs. per cutting).

## Phosphorus Recommendation

**For All Crops.** Use table 9 on page 83 to locate the soil test P level in ppm, then locate soil test aluminum (Al) in ppm. For example, if your soil test P is 1.5 ppm and your soil test Al is 90 ppm, then your recommendation is 105 lbs. of P per acre.

**For Corn.** If you are growing corn, you are finished with your P recommendation.

**For Other Crops.** Use table 10 on page 84 to adjust the recommendation according to the crop you are growing.

For example, if your soil test P is 1.5 ppm and your soil test Al is 90 ppm, then your recommendation is 105 lbs. of P per acre. Then turn to table 10 and make an adjustment for topdressing perennial forages. First determine if your soil test P range is low, medium, or optimum. Then determine the adjustment. The adjustment for this example requires a reduction of 20 lbs. of P per acre. Therefore your recommendation would be 85 lbs. of P per acre.

## Potassium Recommendation

**For All Crops.** Use table 11 on page 85 to locate the soil test K level in ppm. Next, locate the crop to be grown and its corresponding yield. This will give you the K recommendation. For example, if your soil test K is 50 ppm and you are expecting to grow 25 tons of corn silage per acre, then your K recommendation is 200 lbs. of K per acre.

## Recommended nitrogen rates for annual crops (without credit for manure or previous crops).

(Table 4 from Nutrient Recommendations for Field Crops in Vermont)

Corn expected yield		Soil Drainage Class		
		Somewhat poorly to poorly drained	Well Drained to moderately well drained	Excessively drained
Silage <sup>1</sup> (tons/acre)	Grain (bu/acre)	N to apply (lbs./acre)		
15	90	110	90	110
20	120	140	120	140
25	150	170	150	170
30 <sup>4</sup>	180	n/a <sup>2</sup>	180	190 <sup>2</sup>
35 <sup>4</sup>	210	n/a <sup>2</sup>	210	210
Small grains (oats, wheat, barley, rye, millet)				
	45	65	45	65
	60	80	60	80
	90	110	90	110
Sorghum, sorghum-sudan, sudangrass, sunflower		90	70	90
Dry beans, peas, buckwheat		40	30	40
Soybeans		0 <sup>3</sup>	0 <sup>3</sup>	0 <sup>3</sup>

Note: Reduce N rates for previous crop credits (Table 5) and manure application (Tables 15–19).

<sup>1</sup> Silage yields are wet tons/acre (30–35% DM).

<sup>2</sup> 30 tons/acre (180 bu/acre) yield are not considered realistic on these soils. Recommendation for 25 tons/acre yield is provided.

<sup>3</sup> A low rate of N (5–10 lbs./acre) may be applied in a 2"x 2" placed starter band, but do not apply in direct contact with the seed.

<sup>4</sup> Basing a nitrogen application on realistic yield goals is extremely important in order to avoid over applications of N.

## Recommended nitrogen rates for perennial grass and legume-grass forages.

(Table 8 from Nutrient Recommendations for Field Crops in Vermont)

	Nitrogen to apply	
	Per application (N, lbs./acre)	Total per year (N, lbs./acre)
Grass (<20% legume) <sup>1</sup>		
Hay, high-level management (5+ tons/acre)	50–75	200
Hay, medium level (3–4 tons/acre)	50	150
Hay, low level management (2 tons/acre)	40–50	100
Pasture, intensively managed <sup>2</sup>	50	100
Pasture, low-level management	50	50
Conservation planting	40	40
Legume-grass mix (20–60% legume)		
Hay harvest	40	40–80 <sup>3</sup>
Pasture	0	0
Conservation planting	0	0

<sup>1</sup> Yields are dry hay equivalent (12–15% moisture). One ton dry hay is equivalent to 2.5 tons haylage (65% moisture).

<sup>2</sup> Avoid N applications to pasture if over-seeding legumes or to encourage legume growth.

<sup>3</sup> If a spring nitrogen application is made, in some cases, a second application later in the season may benefit mixed hay stands.

Recommended base phosphorus rates for selected available P and Al test values  
(adjust for specific crop based on table on page 85).

(Table 9 from Nutrient Recommendations for Field Crops in Vermont)

Reactive Al	Available P soil test						
	Low		Medium		Optimum <sup>1</sup>	High <sup>2</sup>	Excessive
	ppm						
	0.5	1.5	2.5	3.5	4.1–7	7.1–20	>20
ppm	P <sub>2</sub> O <sub>5</sub> to apply, lb./acre						
10	60	60	40	40	20	0	0
20	65	60	40	40	20	0	0
30	75	55	40	40	20	0	0
40	90	65	40	40	20	0	0
50	100	70	45	40	20	0	0
60	110	80	50	40	20	0	0
70	120	90	55	40	30	0	0
80	120	95	60	40	30	0	0
90	120	105	65	40	30	0	0
100	120	115	70	40	30	0	0
110	120	120	75	40	30	0	0
120	120	120	80	40	30	0	0
130	120	120	85	40	30	0	0
140	120	120	90	40	30	0	0
150	120	120	95	40	30	0	0
160	120	120	100	40	30	0	0
170	120	120	105	40	30	0	0
180	120	120	110	40	30	0	0
190	120	120	115	40	30	0	0
200	120	120	120	40	30	0	0

Note: Table shows selected values within each category. Recommended P application rates are based on the following equation:  

$$P_2O_5 \text{ to apply (lb./acre)} = [(Al + 36) \times (4 - \text{available P})] \div 3.$$

<sup>1</sup> The recommended rate (20 to 30 lb. P<sub>2</sub>O<sub>5</sub>/acre) is best applied as starter/ row fertilizer at planting for corn or broadcast as a blend with other nutrients as a topdress on perennial forages.

<sup>2</sup> A low rate of starter fertilizer (10 to 20 lb. P<sub>2</sub>O<sub>5</sub>/acre) is recommended, especially under conditions of early planting, limited drainage, or conservation tillage.

## Phosphorus (P<sub>2</sub>O<sub>5</sub>) rate adjustments for different crops.

(Table 10 from Nutrient Recommendations for Field Crops in Vermont)

Crop	Available P soil test level	
	Low-medium (0–4 ppm)	Optimum (4.1–7 ppm)
	lb. P <sub>2</sub> O <sub>5</sub> /acre	
Corn	No change	No change
Small grains, soybeans, dry beans/peas, buckwheat, sorghum, sorghum-sudan, sudangrass, sunflower	Subtract 20	No change
Establishment of perennial forages	Add 40	Add 20
Topdress alfalfa (>60%)	No change	No change
Topdress of other perennial forages	Subtract 20	No change
Conservation planting	Subtract 30	Subtract 20 or 30

Note: Add or subtract from values in Table 9, but note minimum rates for Low and Medium P test.

## Recommended potassium rates for field crops.

(Table 11 from Nutrient Recommendations for Field Crops in Vermont)

K, ppm:	K soil test						
	Low		Medium		Optimum	High	Excessive
	<25	26–50	51–75	76–100	101–130	131–160	>160
K <sub>2</sub> O to apply (lbs./acre)							
Corn for silage <sup>1</sup>							
15 or 20 tons/acre	200	160	120	80	60	0 <sup>2</sup>	0
25+ tons/acre	240	200	160	120	80	30	0
Corn for grain							
90 or 120 bu/acre	140	100	60	40	30	0 <sup>2</sup>	0
150+ bu/acre	180	140	100	60	30	30	0
Alfalfa (> 60%) <sup>3</sup> Topdress							
2-40 tons/acre	280	240	200	160	100	40	0
5 tons/acre	320	280	240	200	140	60	0
6+ tons/acre	360	320	280	240	180	80	0
Establishment	240	200	160	120	80	40	0
Clover, trefoil, grass, alfalfa (20–60%) <sup>3</sup> Topdress							
2-4 tons/acre	220	180	140	100	60	0	0
5+ tons/acre	260	220	180	140	100	0	0
Establishment	180	140	100	80	60	0	0
Small grains, soybeans, buckwheat, dry beans/peas, millet	120	100	80	60	40	0	0
Conservation planting	80	60	40	0	0	0	0

<sup>1</sup> Corn silage yields are wet tons/acre (30–35% DM)

<sup>2</sup> 10–20 lb. K<sub>2</sub>O/acre recommended as row-applied starter under conditions of early planting, limited drainage, or conservation tillage.

<sup>3</sup> Yields are dry hay equivalent (12–15% moisture). One ton dry hay is equivalent to 2.5 tons haylage (65% moisture).



## EXERCISE IV-1

### Field Plan Recommendation Worksheet

**T**his is where your NMP really starts to come together. You will fill out one form per field. The risk information for each field will be filled out in the form. This information will help you gauge manure and fertilizer applications. The goal is to apply nutrients to meet the crop needs while reducing environmental risk.

#### HELPFUL TIPS FOR FIELD PLANNING

- Check the soil tests to make sure that each recommendation is for the crop to be grown in the coming season.
- Make a new recommendation (if necessary) using the instructions on page 81.

Field Plan Recommendation							
Farm Name		Sample Farm		Plan Date	2012-03-22	Crop Year	2012
Farm Manager		Joe Farmer		Planner	Joe Farmer		
Field Name	Field#1			Drainage Category	Moderately Well		
Tract & Field #	9999-1			Nutrient Mgmt Basis			
Acres	30.0			Phosphorus Index	Not known		
This Crop	Corn Grain			Percent Legume	0-20%		
	Wheat				60-100%		
Last Crop	Corn Silage						
Next year's Crop	Corn Silage						
Expected Yield	180 Bushels						
	2 Tons						
Nutrient Need							
				N	P	K	
Soil Recommendation				190	50	180	
				lb/acre	lb/acre	lb/acre	
Nutrient Credits							
Crop 2 Years Ago				0			
Crop Past Year				0			
Big Pit 1000 gallons / acre							
Manure 2 Years Ago				9	7		
Manure Past Year				6	13		
Fall				9	72	75	216
Spring				0	0	0	0
Summer				0	0	0	0
This Season Total				9			
Total Nutrient Credits				91	75	216	
Fertilizer Needed							
				lb / acre	N	P	K
urea				180	46	0	0
Topdress							
starter				56	7	21	7
Starter Fertilizer							
Total Nutrients					87	14	5
Balance					0	0	0

## Nitrogen credits for previous crops.

(Table 5 from Nutrient Recommendations for Field Crops in Vermont)

Previous Crop		Fertilizer N credit	
		Previous year	Two years ago
		Lb/acre	
Alfalfa	> 60% legume	120	80
	20–60%	80	40
Red clover, trefoil	> 60% legume	90	40
	20–60%	70	30
Grass	Moderate-high level mgmt. (>2 ton/acre yield)	70	30
	Low level mgmt. (2 ton/acre or less)	40	20
Soybeans, dry beans/peas		30	0

1. Fill in the amount of manure you plan to spread on this field. You will need to add the rate applied as well as what storage the manure will come from for the application. Be aware that changing the rate of manure applied will automatically change the rate of manure P application on the P-index.
2. Be aware of the nutrient management basis in the risk assessment portion of the form. If you apply too much manure to a field, these may change to reflect the greater risk of P runoff. Remember that on P-based fields you cannot exceed crop uptake levels of P.
3. Once you apply manure to the fields, you will be able to see the volume of manure left in the storage unit. If there is excess or negative manure quantities, readjust the sheets.

If your farm does not have the land base for the waste produced you need to consider exporting the manure from the farm. If you need nutrients you may consider importing manure from a nearby farm. Regardless of your situation if you are exporting or importing manure you must fill out a form to document the transaction. The import/export form can be found in the class binder.

(Exercise IV-1 is continued on the next page)

Manure drawdown report generated in goCrop™.

Nutrient Management Plan - Manure Drawdown								
Farm Name Farm Manager	Sample Farm Joe Farmer		Plan Date Planner	2012-03-22 Joe Farmer	Crop Year	2012		
Big Pit	Total units to be spread this crop year:				8,789,696 G.			
Giroux Pit	Total units to be spread this crop year:				983,000 G.			
Small Pit	Total units to be spread this crop year:				334,700 G.			
		Big Pit 1000 gallons			Giroux Pit 1000 gallons		Small Pit 1000 gallons	
Field Name	Tract & Field #	Acres	Rate /Acre	Amt. Remain.	Rate /Acre	Amt. Remain.	Rate /Acre	Amt. Remain.
Field#1	9999-1	30.0	9.0	8,520	0.0	983	0.0	335
Small Pieces	60-7	11.0	7.0	8,443	0.0	983	0.0	335
Across Brook	60-8,9,c1	33.0	7.0	8,212	0.0	983	0.0	335
Behind Jacks	60-10	18.0	9.0	8,050	0.0	983	0.0	335
Behind Pond	60-6,11	48.0	0.0	8,050	0.0	983	0.0	335
Rileys Knoll	65-1	38.0	9.0	7,708	0.0	983	0.0	335
Back of House	65-2	13.5	1.0	7,694	0.0	983	0.0	335
Back of Davids	65-4	35.0	9.0	7,379	0.0	983	0.0	335
Gerards Below Hill	67-2	13.0	1.0	7,366	0.0	983	0.0	335
Pieces up back Corn	67-4 Corn	38.0	7.0	7,100	0.0	983	0.0	335
Piece up Back Hay	67-4 Hay	46.0	6.0	6,824	0.0	983	0.0	335
Long Piece next to Rileys	67-16	25.0	8.0	6,624	0.0	983	0.0	335
Coxs big Piece	68-2	34.0	0.0	6,624	0.0	983	0.0	335
Below Brick House- Left	68-3	8.0	0.0	6,624	0.0	983	0.0	335
Below Brick House Right	68-4	7.0	0.0	6,624	0.0	983	0.0	335
11 Acre Piece	69-2	11.0	7.0	6,547	0.0	983	0.0	335
22 Acre Piece	69-3	25.0	0.0	6,547	0.0	983	0.0	335
27 Acre Piece	69-5	35.0	0.0	6,547	0.0	983	0.0	335
3 Pieces up Back	69-9	14.0	8.0	6,435	0.0	983	0.0	335
Point Piece	69-10	17.0	9.0	6,282	0.0	983	0.0	335
Round Piece	69-11	6.0	9.0	6,228	0.0	983	0.0	335
Carols Appletree Piece	69-14	14.0	9.0	6,102	0.0	983	0.0	335
Carols By Bridge	69-15	32.0	0.0	6,102	0.0	983	0.0	335
Carols in back of Pasture	69-18	31.0	7.0	5,985	0.0	983	0.0	335
Pasture	69-19, 21	24.0	0.0	5,985	0.0	983	0.0	335
Lussiers Across Brook	73-1	8.0	9.0	5,813	0.0	983	0.0	335
Lussier Piece Below Barn	73-2,9	22.0	3.0	5,747	0.0	983	0.0	335

- Print out the field sheets and organize them according to nutrient needs.
- Add fertilizer as needed.

Field recommendation report generated in goCrop™.

Nutrient Need								
					N	P	K	
Soil Recommendation					150 lb/acre	40 lb/acre	38 lb/acre	
Nutrient Credits								
Crop 2 Years Ago					0			
Crop Past Year					0			
Big Pit 1000 gallons / acre								
Manure 2 Years Ago					6			
Manure Past Year					10			
Fall					54	75	216	
Spring					0	0	0	
Summer					0	0	0	
This Season Total					9			
Total Nutrient Credits					69	75	216	
Fertilizer Needed								
					lbs / acre	N	P	K
urea Topdress					180	46	0	0
starter Starter Fertilizer					55	7	21	7
Total Nutrients					87	12	4	
Balance					-8	-47	-190	

## FERTILIZER CALCULATIONS

Fertilizer nutrients are usually expressed as a percentage by weight of the total fertilizer. The three numbers you often see on a fertilizer bag, **X-X-X**, are the percentages of N,  $P_2O_5$ , and  $K_2O$ , respectively, regardless of the quantity of the fertilizer (i.e. a 50 lb. bag, a ton, or a 5 ton wagon load). For example, a 12-24-12 fertilizer would be 12% N, 24%  $P_2O_5$ , and 12%  $K_2O$ .

For a list of commonly used fertilizers and their analyses, see table 20 on page 92.

### Working with Percentages

Remember: 1% = one-hundredth = 0.01

For example:

12% N is the same as 0.12

24%  $P_2O_5$  is the same as 0.24

12%  $K_2O$  is the same as 0.12

### How Many Nutrients Come From Fertilizer

For example:

If you apply 300 lbs. of 12-24-12, then how many pounds of each nutrient are you applying?

300 lbs. x 12% (0.12) N =  
36 lbs. of N supplied to plants

300 lbs. x 24% (0.24)  $P_2O_5$  =  
72 lbs. of  $P_2O_5$  supplied to plants

300 lbs. x 12% (0.12)  $K_2O$  =  
36 lbs. of  $K_2O$  supplied to plants

### Calculating Pounds of a Given Fertilizer Needed

To adjust a fertilizer recommendation, divide by the percentage of the nutrient.

For example:

You want to spread urea on a grass hay field. Your nutrient need for the field is 100 lbs. of N per acre. How much 46-0-0 urea fertilizer do you spread to achieve this recommendation?

100 lbs. of N  $\div$  0.46 = 217 lbs.  
of urea needed per acre

Try this for practice:

How much muriate of potash would you need if your soil test recommends 150 lbs. of  $K_2O$  per acre for your alfalfa?

### Calculating Liquid Fertilizer

To determine the amounts of nutrients from liquid fertilizer, you must know the density of the liquid. Multiply the percentage of the nutrient by the pounds of liquid per gallon.

For example:

What is the analysis of a 9-18-9 liquid fertilizer if the weight of one gallon of a liquid fertilizer is 11.4 lbs.?

In each gallon of liquid fertilizer:

11.4 lbs. x 0.09 N = 1 lb. of N

11.4 lbs. x 0.18  $P_2O_5$  = 2 lbs. of  $P_2O_5$

11.4 lbs. x 0.09  $K_2O$  = 1 lb. of  $K_2O$

So if you are applying 5 gallons per acre:

1 lb. x 5 gallons = 5 lbs. of N

2 lbs. x 5 gallons = 10 lbs. of  $P_2O_5$

1 lb. x 5 gallons = 5 lbs. of  $K_2O$

Therefore, to determine how much liquid to apply in gallons, divide the recommended rate by the number of pounds per gallon of the nutrient.

For example:

You want to apply 20 lbs. of  $P_2O_5$  per acre as a starter fertilizer. Using the same liquid in the example above,

20 lbs.  $P_2O_5 \div$  2 lbs.  $P_2O_5$  per gallon =  
10 gallons per acre

At that rate, you'll also be adding 10 lbs. each of N and  $K_2O$ .

## HOW FAR CAN YOU AFFORD TO HAUL MANURE?

Often times, your fields that are nutrient deficient are also far away from the barn, while the fields behind the barn may be high or excessive in nutrients. With today's fertilizer prices it may make more sense to haul manure to these fields than it used to. If you are interested in figuring out how far you should be hauling your manure, the following worksheets can be used to do so.

### Worksheet I - "How Far Can You Afford to Haul Manure?"

#### 1. Calculate the nutrient content and value per unit of your manure.

A "unit" is either a 1000 gallons (liquid/slurry) or a ton (solid/semi-solid).

From Manure Analysis	Manure Type: <input type="text"/>	Availability Factor*	Available Nutrients (lbs/unit)	Fertilizer Equilivant Value** (\$/lb)	Value Per Unit (\$/unit)
Ammonia-N	<input type="text"/>	x <input type="text"/>	= <input type="text"/>	x <input type="text"/>	= <input type="text"/>
Organic-N	<input type="text"/>	x <input type="text"/>	= <input type="text"/>	x <input type="text"/>	= <input type="text"/>
P <sub>2</sub> O <sub>5</sub>	<input type="text"/>	x 1.00	= <input type="text"/>	x <input type="text"/>	= <input type="text"/>
K <sub>2</sub> O	<input type="text"/>	x 1.00	= <input type="text"/>	x <input type="text"/>	= <input type="text"/>
*Refer to Tables on back to determine N availability					Total Value (\$/unit) <input type="text"/>
**See Worksheet II on back					

#### EXAMPLE

From Manure Analysis	Manure Type: <input type="text" value="Liquid"/>	Availability Factor	Available Nutrients (lbs/unit)	Fertilizer Equilivant Value (\$/lb)	Value Per Unit (\$/unit)
Ammonia-N	12.0	x 0.70	= 8.4	x \$0.65	= 5.46
Organic-N	13.0	x 0.36	= 4.7	x \$0.65	= 3.04
P <sub>2</sub> O <sub>5</sub>	8.0	x 1.00	= 8.0	x \$0.62	= 4.96
K <sub>2</sub> O	20.0	x 1.00	= 20.0	x \$0.50	= 10.00
Total Value (\$/unit)					\$23.46

#### 2. Calculate the cost per mile per unit to haul your manure.

This cost is per one-way mile to haul the manure but does account for the return trip.

Spreading Cost (\$/hr)	Average Speed* (mph)	\$/mile	Load Capacity (units)	Hauling Cost (\$/mile/unit)
<input type="text"/>	<input type="text"/>	= <input type="text"/>	+ <input type="text"/>	x 2 = <input type="text"/>
* Average speed of loaded to field and unloaded for return trip.				

#### EXAMPLE

Spreading Cost (\$/hr)	Average Speed* (mph)	\$/mile	Load Capacity (units)	Hauling Cost (\$/mile/unit)
\$110.00	15	= \$7.33	+ 5.2	x 2 = \$2.82

#### 3. Calculate breakeven distance. (How far you can travel one-way and breakeven on costs.)

Total Value (\$/unit)	Hauling Cost (\$/mile/unit)	Breakeven Distance (miles)
<input type="text"/>	<input type="text"/>	= <input type="text"/>
EXAMPLE: \$23.46	EXAMPLE: \$2.82	EXAMPLE: 8.3

#### 4. Calculate breakeven travel time. (How long can you travel one-way and breakeven on costs.)

Breakeven Distance (miles)	Average Speed (mph)	Breakeven Travel Time (minutes)
<input type="text"/>	<input type="text"/>	x 60 = <input type="text"/>
EXAMPLE: 8.3	EXAMPLE: 15	EXAMPLE: 33



## Worksheet II - Calculating Fertilizer Nutrient Value

### 1. Calculate the value of nitrogen (N) per pound using urea

Urea analysis: 46-0-0 (920 lbs N per ton)

Fertilizer Cost (\$/ton)	lbs N per ton	N Value (\$/lb)
	920	

#### EXAMPLE

Fertilizer Cost (\$/ton)	lbs N per ton	N Value (\$/lb)
\$600	920	\$0.65

### 2. Calculate the value of phosphate (P<sub>2</sub>O<sub>5</sub>) per pound using MAP

MAP analysis: 12-52-0 ( 240 lbs N and 1040 lbs of P<sub>2</sub>O<sub>5</sub> per ton)

Fertilizer Cost (\$/ton)	lbs N per ton	N Value (Step 1.) (\$/lb)	Value of P <sub>2</sub> O <sub>5</sub> per ton	lbs P <sub>2</sub> O <sub>5</sub> per ton	P <sub>2</sub> O <sub>5</sub> Value (\$/lb)
	240			1040	

#### EXAMPLE

Fertilizer Cost (\$/ton)	lbs N per ton	N Value (Step 1.) (\$/lb)	Value of P <sub>2</sub> O <sub>5</sub> per ton	lbs P <sub>2</sub> O <sub>5</sub> per ton	P <sub>2</sub> O <sub>5</sub> Value (\$/lb)
\$800	240	\$0.65	\$643	1040	\$0.62

### 3. Calculate the value of potash (K<sub>2</sub>O) per pound using muriate of potash

Muriate of Potash analysis: 0-0-60 (1200 lbs K<sub>2</sub>O per ton)

Fertilizer Cost (\$/ton)	lbs K <sub>2</sub> O per ton	K <sub>2</sub> O Value (\$/lb)
	1200	

#### EXAMPLE

Fertilizer Cost (\$/ton)	lbs K <sub>2</sub> O per ton	K <sub>2</sub> O Value (\$/lb)
\$600	1200	\$0.50

Organic-N Availability*		
(In First Year)		
Percent Dry Matter of Manure	Soil Drainage Class	Availability Factor
< 20%	Well Drained - tilled in	0.36
< 20%	Poorly drain - tilled in	0.24
< 20%	Well Dr. - surface appl	0.24
< 20%	Pry. Dr. - surface appl	0.16
> 20%	Well Drained - tilled in	0.30
> 20%	Poorly drain - tilled in	0.20
> 20%	Well Dr. - surface appl	0.20
> 20%	Pry. Dr. - surface appl	0.14

\* Source: Nutrient Recommendations for Field Crops in Vermont (W. Jokela), Un. of Vermont

Ammonia-N (NH <sub>4</sub> -N) Availability*		
Season of Spreading	Days From Spreading To Incorporation	Availability Factor
Spring	< 1 hr	0.80
Spring	1 to 8 hrs.	0.70
Spring	1 day	0.55
Spring	2 days	0.50
Spring	3 to 4 days	0.45
Spring	> 4 days	0.40
Spring	Unincorporated	0.40
Fall	Within 2 days	0.30
Fall	Unincorporated	0.15

Prepared by Sid Bosworth, UVM-Extension, 2/96 (revised 2/08)

These worksheets are also available online in spreadsheet form in the "Nutrient Management" section of the Vermont Crops and Soils website: <http://pss.uvm.edu/vtcrops/>.

## Nutrient content and other properties of fertilizer materials.

(Table 22 from Nutrient Recommendations for Field Crops in Vermont)

Fertilizer Material	Chemical formula <sup>1</sup>	%N	%P <sub>2</sub> O <sub>5</sub>	%K <sub>2</sub> O	Other nutrient, % <sup>2</sup>	Equiv. acidity <sup>3</sup>	Salt index <sup>4</sup>
Nitrogen sources							
Anhydrous ammonia	NH <sub>3</sub>	82	0	0		148	47
Urea	(NH <sub>2</sub> ) <sub>2</sub> CO	46	0	0		84	75
Ammonium nitrate	NH <sub>4</sub> NO <sub>3</sub>	33–34	0	0		63	105
Urea-ammonium nitrate (UAN)	(NH <sub>2</sub> ) <sub>2</sub> CO + NH <sub>4</sub> NO <sub>3</sub>	28–32	0	0		54	74
Ammonium Sulfate	(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>	21	0	0	24 S	112	69
Phosphorus sources							
Diammonium phosphate (DAP)	(NH <sub>4</sub> ) <sub>2</sub> HPO <sub>4</sub>	18–21	46–53	0		74	34
Monoammonium phosphate (MAP)	NH <sub>4</sub> H <sub>2</sub> PO <sub>4</sub>	11–13	48–52	0		65	30
Ammonium polyphosphate		10	34	0		53	-
Ordinary superphosphate	Ca (H <sub>2</sub> PO <sub>4</sub> ) <sub>2</sub> + CaSO <sub>4</sub>	0	20	0	14 S, 20 Ca	0	8
Triple superphosphate	Ca (H <sub>2</sub> PO <sub>4</sub> ) <sub>2</sub>	0	46	0	1.5 S, 14 Ca	0	10
Potassium, magnesium, sulfur sources							
Muriate of potash	KCl	0	0	60–62		0	116
Potassium sulfate	K <sub>2</sub> SO <sub>4</sub>	0	0	50	18 S	0	46
Potassium nitrate	KNO <sub>3</sub>	13	0	45		-26	74
Potassium hydroxide	KOH	0	0	70		-89	-
Magnesium sulfate	MgSO <sub>4</sub>	0	0	0	10–16 Mg, 14–21 S	0	
Magnesium oxide	MgO	0	0	0	45 Mg		
Sulfate of potash magnesia (Sul-Po-Mag or K-Mag)	K <sub>2</sub> SO <sub>4</sub> MgSO <sub>4</sub>	0	0	22	11 Mg, 22 S	0	43
Calcium sulfate (gypsum)	CaSO <sub>4</sub>	0	0	0	15–18 S, 19–22 Ca	0	
Micronutrient sources							
Borate	Na <sub>2</sub> BO <sub>4</sub>				20 B		
Solubor	Na <sub>2</sub> BO <sub>4</sub>				21 B		
Iron (ferrous) sulfate	FeSO <sub>4</sub>				20 Fe, 12 S		
Manganous sulfate	MnSO <sub>4</sub>				28 Mn, 16 S		
Zinc sulfate	ZnSO <sub>4</sub>				36 Zn, 18 S		
Zinc oxide	ZnO				50–80 Zn		
Zinc chelate	Zn chelate				6–14 Zn		

<sup>1</sup> Water of hydration (H<sub>2</sub>O) not included in formula.

<sup>2</sup> Actual analysis varies with specific product formulation. B = boron, Ca = calcium, Fe = iron, Mg = manganese, Zn = zinc.

<sup>3</sup> Pounds of calcium carbonate equivalent/100 lb of fertilizer material. Positive number indicates that the material increases soil acidity, that is, lowers soil pH. Negative numbers indicate that the material reduces acidity, that is, raises soil pH.

<sup>4</sup> Salt index of equal weights of the fertilizer material compared to sodium nitrate which equals 100. Useful for comparing the salt effect of different fertilizer materials.

## EXERCISE IV-2

### Checklist

**H**ere is a list of items that you should have completed before you go on to the next session. Those items found in goCrop are listed in [blue](#).

#### SESSION I

- ☐ [Farm information worksheet](#)
- ☐ Maps (proximity, conservation plan, nitrate leaching, topographic, environmental concerns, soils)
- ☐ Soil fact sheets
- ☐ Soil test results organized
- ☐ Soil test interpretation and planning strategy
- ☐ [Soil test schedule](#)
- ☐ RUSLE2 (with your crop rotation indicated)
- ☐ [Field inventory](#)
- ☐ Manure application schedule

#### SESSION II

- ☐ Animal waste system overview sheet
- ☐ Calculation of amount of manure produced
- ☐ Manure test for each storage
- ☐ [Manure analysis worksheet](#)
- ☐ [Manure storage nitrogen calculations](#) (one for each manure storage)
- ☐ [Manure nutrient values](#)
- ☐ [P-index](#)

#### SESSION III

- ☐ [Farm nutrient balance](#)
- ☐ [Risk assessment worksheet](#)

#### SESSION IV

- ☐ [Nutrient Planning](#)
- ☐ [Manure drawdown](#)
- ☐ Manure import/export form and alternative manure utilization form (if applicable)



SESSION V  
...  
**Future Success**

*What will be covered in Session V:*

**Developing a Sustainable NMP**

LESSON 1: Making Use of Your Plan

LESSON 2: Recordkeeping

LESSON 3: Reporting to State and Federal Agencies

LESSON 4: Updating the Plan

**Terms to Learn**

- Medium Farm Operation (MFO)
- Large Farm Operation (LFO)
- Environmental Quality Incentives Program (EQIP)

**Exercise**

1. Checklist



## LESSON V-1

### Making Use of Your Plan

**C**ongratulations! You have written your own NMP. Now what? The NMP is not just a stack of paper-work to be filed away in a desk drawer until next year. Instead, it is a working plan that you should refer to throughout the growing season, especially before planting, spreading manure, or fertilizing crops. Chances are that you are not going to carry the whole plan with you in your tractor, but rather you will leave it somewhere safe and out of the elements. For this reason, you can print out the Plan Summary in your workbook and put it in the tractor or truck for easy reference. The Plan Summary shows manure and fertilizer applications for the cropping season. It also indicates fields that need to

be soil tested this year.

### Using your NMP to Order Fertilizer

The nutrient management plan that you just created can be a powerful tool on many fronts. Most importantly, the information in the plan can help you in purchasing fertilizer for your farm. During the field by field planning section of the course you entered the nutrient recommendations for your fields (based on soil tests) and you subtracted the amount of nutrients contributed by manure applications. Often you were left with a balance of nutrients that your crops still need. These nutrients

Nutrient Management Plan - Manure Drawdown								
Farm Name	Sample Farm				Plan Date	2012-03-22	Crop Year	2012
Farm Manager	Joe Farmer				Planner	Joe Farmer		
Big Pit	Total units to be spread this crop year:					8,789,696 G.		
Giroux Pit	Total units to be spread this crop year:					983,000 G.		
Small Pit	Total units to be spread this crop year:					334,700 G.		
		Big Pit 1000 gallons		Giroux Pit 1000 gallons		Small Pit 1000 gallons		
Field Name	Tract & Field #	Acres	Rate /Acre	Amt. Remain.	Rate /Acre	Amt. Remain.	Rate /Acre	Amt. Remain.
Field#1	9999-1	30.0	9.0	8,520	0.0	983	0.0	335
Small Pieces	60-7	11.0	7.0	8,443	0.0	983	0.0	335
Across Brook	60-8,9,c1	33.0	7.0	8,212	0.0	983	0.0	335
Behind Jacks	60-10	18.0	9.0	8,050	0.0	983	0.0	335
Behind Pond	60-5,11	48.0	0.0	8,050	0.0	983	0.0	335
Rileys Knoll	65-1	38.0	9.0	7,708	0.0	983	0.0	335
Back of House	65-2	13.5	1.0	7,694	0.0	983	0.0	335
Back of Davids	65-4	35.0	9.0	7,379	0.0	983	0.0	335
Gerards Below Hill	67-2	13.0	1.0	7,366	0.0	983	0.0	335
Pieces up back Corn	67-4 Corn	38.0	7.0	7,100	0.0	983	0.0	335
Piece up Back Hay	67-4 Hay	46.0	6.0	6,824	0.0	983	0.0	335
Long Piece next to Rileys	67-16	25.0	8.0	6,624	0.0	983	0.0	335
Coxs big Piece	68-2	34.0	0.0	6,624	0.0	983	0.0	335
Below Brick House- Left	68-3	8.0	0.0	6,624	0.0	983	0.0	335
Below Brick House Right	68-4	7.0	0.0	6,624	0.0	983	0.0	335
11 Acre Piece	69-2	11.0	7.0	6,547	0.0	983	0.0	335
22 Acre Piece	69-3	25.0	0.0	6,547	0.0	983	0.0	335
27 Acre Piece	69-5	35.0	0.0	6,547	0.0	983	0.0	335
3 Pieces up Back	69-9	14.0	8.0	6,435	0.0	983	0.0	335
Point Piece	69-10	17.0	9.0	6,282	0.0	983	0.0	335
Round Piece	69-11	6.0	9.0	6,228	0.0	983	0.0	335
Carols Appletree Piece	69-14	14.0	9.0	6,102	0.0	983	0.0	335
Carols By Bridge	69-15	32.0	0.0	6,102	0.0	983	0.0	335
Carols in back of Pasture	69-18	31.0	7.0	5,885	0.0	983	0.0	335
Pasture	69-19, 21	24.0	0.0	5,885	0.0	983	0.0	335
Lussiers Across Brook	73-1	8.0	9.0	5,813	0.0	983	0.0	335
Lussier Piece Below Barn	73-2,9	22.0	3.0	5,747	0.0	983	0.0	335

The plan summary provides a concise version of your NMP. Print a copy and keep it handy in your tractor or truck.

## CUSTOM APPLICATORS AND NUTRIENT MANAGEMENT PLANS

If you hire a custom applicator for spreading manure on your farm, you need to make sure that the equipment operators and the supervisor are aware that you are following a NMP. Do not just hand your plan to the custom operators and expect them to interpret it. Instead, give a clear list of the manure application rate for each field and the total number of loads that each field should get. Have them keep a tally as they spread, to see how close they come to the amount you requested.

Humboldt RCD



Give the custom applicator clear instructions about how much manure to spread on each field.

can be added to the soil in the form of fertilizer. Of course, you can't purchase different blends of fertilizer for each field. This is unrealistic from both practical and economic standpoints. Once you know the remaining nutrient needs of your fields, you should start to group together fields that have similar needs. In most cases, a farm can group the fields into five or fewer categories. First a farm might group fields based on crop type (corn, grass hay, legume hay). Within these crops, the fields will be further partitioned into fields with high nutrient needs and those with lower requirements.

Once the groupings are complete you can make an estimate of the type of fertilizer you might need for those fields. This information can then be brought to the fertilizer dealer, who can help develop the best blend for the crop fertility needs.

For example:

### Group 1: Corn Fields

Making sure that crop nutrients are applied in the correct amounts where they are needed can save money.



#### Subgroup 1a:

Corn with nutrient needs around  
150 lbs. N - 100 lbs. P - 200 lbs. K

#### Subgroup 1b:

Corn with nutrient needs around  
150 lbs. - N 40 lbs. - P 100 lbs. K

### Group 2: Grass Hay

#### Subgroup 2a:

Grass with nutrient needs around  
150 lbs. N - 50 lbs. P - 120 lbs. K

#### Subgroup 2b:

Grass with nutrient needs around  
150 lbs. N - 0 lbs. P - 60 lbs. K

These simple groupings of fertilizer needs for your fields will enable your salesman to formulate some blends that work well for your farm.

## THE PRE-SIDEDRESS NITRATE TEST

Nitrogen is often a limiting nutrient in agriculture, yet it is not measured by standard soil tests. This is because it is difficult to predict how much nitrogen will be available for a crop based on a soil sample taken weeks or months before the time of peak nitrogen demand. In your NMP you credited N from manure you spread before the crop was even planted. However, if there are several straight days of rain before topdress of corn, you can make a pretty good guess that much of that manure N will no longer be available for your corn. The tool developed in Vermont for fine tuning sidedress N amounts based on field conditions is called the pre-sidedress nitrate test (PSNT). The PSNT is not required by NMPs, but is a way to save money and take nutrient management to the next level.

The PSNT is performed shortly before topdress (when corn is 8 to 12 inches tall) and measures the plant-available nitrogen (nitrate) in the top 12 inches of soil. Because N is so prone to changing form, the soil sample must be dried or refrigerated after it is taken,

and delivered to the testing lab the same day. Turnaround is quick (within 24 hours on business days) so that you can get your fertilizer on in a timely fashion.

As with any test or recommendation, there are some limitations. The main one is that the PSNT cannot account for unexpected changes in conditions after soil sampling. For example, if unusually heavy rains occur a few days after

sampling, significant nitrate can be lost to leaching or denitrification. If this occurs and if there is time, resample the field. If not, adjust the recommended N rate based on your best judgment to account for suspected losses.

In 2017, the cost for the PSNT was \$8.00 at the UVM Agricultural Testing Lab. Many farmers have found that the PSNT can save them money on fertilizer. For more information, contact UVM Extension or the UVM Agricultural Testing Lab, or visit the following website: <http://pss.uvm.edu/vtcrops/?Page=articles/PSNTTest.html>.

University of Wisconsin



The pre-sidedress nitrate test is done when the corn is 8 to 12 inches high, just before its major vegetative growth occurs.

## LESSON V-2

### Recordkeeping

**R**ecordkeeping is a critical part of nutrient management planning. Not only is it important to know what you planned to do, but also what you actually did. Maybe you had to reallocate some of the manure being spread because access to a field was limited due to wet weather. Or maybe you decided not to plow under the alfalfa field that you were planning to plant with corn this year. In other words, the weather doesn't always cooperate and sometimes plans have to change. You are responsible for keeping a record of that change. Keeping records will also make the plan more useful over time. Recordkeeping will help you refine the plan and make the recommendations more accurate.

The state and federal recordkeeping requirements are to:

- Keep an updated copy of the NMP itself at your farm.
- Provide copies of current soil tests (check your soil test schedule to see which fields need

updated soil samples) and waste tests (one for each waste storage facility per year).

- As you update your plan, keep the old records on file for five years.

There are also record keeping requirements if you transfer manure off your farm. Maintain records showing the date and amount of manure, litter, or process wastewater that leaves the permitted operation, and record the name and address of the recipient. Keeping the import/export agreement will satisfy this requirement.



Figure out a record-keeping system that works for you and stick to it.

There's an app for that.....

## CALCULATING FORAGE YIELDS

**Y**ield measurements are extremely important in nutrient management planning. Knowing average yields will allow you to choose nutrient applications of manure and fertilizer that minimize costs, maximize fertilizer efficiency, and reduce potential environmental problems. Yields are also critical as a measuring tool to evaluate new products, improve management techniques, and allow you to make more informed decisions concerning feeding practices for your livestock. Knowing your forage supplies for the year in the fall allows you to buy or sell forage at the time of year that is most financially rewarding to your operation.

Various methods of measuring yields are available to producers. The most accurate is to weigh truck or wagonloads going into a silo or barn, and to take dry matter samples then. This is often not feasible due to limitations of time and necessary equipment (scales). Other methods of yield checks include field sampling and documenting estimated weights of loads.

### Measuring Wagonloads

Measuring yields by wagonload is probably the most common method used by producers. Ideally you should weigh average loads to get a representative load weight. It is important to know the dry matter of the forage to get an ac-

curate measure of the actual nutrient harvest.

Some recent work in Wisconsin found that wagon loads in the 30 to 50% dry matter range averaged around 5 pounds of dry matter per cubic foot of wagon. Surprisingly, the forage density did not vary greatly with forage type (corn silage or haylage).

Working with this information, we can now estimate the load on a wagon by multiplying volume by density.

For example:

A wagon measures 16 ft. long by 7.25 ft. wide and is filled to a depth of 6 ft.

$$16 \text{ ft.} \times 7.25 \text{ ft.} \times 6 \text{ ft.} = 696 \text{ cubic ft.}$$

$$\begin{aligned} 696 \text{ cubic ft.} \times 5 \text{ lbs. dry matter per cubic ft.} &= \\ 3,480 \text{ lbs. dry matter or} & \\ 1.74 \text{ tons of dry matter yield per acre} & \end{aligned}$$

If we want to calculate actual weight, we need to divide this figure by the dry matter of the forage (28%).

$$\begin{aligned} 1.74 \text{ tons} \div \text{by } 28\% &= \\ 6.96 \text{ tons of feed on the wagon} & \end{aligned}$$



Truck scales can be used to weigh crop yields.

Adapted from by Sid Bosworth <http://pss.uvm.edu/vtcrops/articles/CalculatingForageYields.pdf>



## LESSON V-3

### Reporting to State and Federal Agencies

**A**t the end of each season the state and/or federal government require that you report on your nutrient management for the previous year. Whether you report to state or federal agencies or both will depend on your farm size and the NRCS programs you have enrolled in. The agency you report to wants to know what you did and why you did it. Use this step by step process when you are ready to fill out paperwork and gather necessary information to meet reporting requirements.

#### Required Forms

Depending on your program enrollment, you may need to send your plan to NRCS and/or the Vermont Agency of Agriculture, Foods and Markets.

**Large Farm Operation (LFO).** The State of Vermont defines a LFO as a farm with more than 700 mature dairy cows (whether milking or dry), 1000 beef cattle or cow/calf pairs, 1000 youngstock or heifers, 500 horses, 55,000 turkeys or 82,000 laying hens (without a liquid manure handling system). Unlike the MFO program, LFO permits are individual to each farm. Refer to the Vermont Agency of Agriculture website (address on page 104) for additional information on requirements for compliance.

**Medium Farm Operation (MFO).** The State of Vermont defines a MFO as a dairy with 200-699 mature animals, whether milking or dry. Other MFOs include beef operations (300-999 cattle or cow/calf pairs), youngstock and heifer operations (300-999 youngstock or heifers), horse operations (150-499 horses), turkey operations (16,500-54,999 turkeys), and egg facilities (25,000-81,999 laying hens) without a liquid manure handling system. The State of Vermont requires an annual compliance form. Refer to the MFO general permit for other reporting requirements or refer to the website address given on page 104.

**Certified Small Farm Operation (CSFO).** The State of Vermont defines a CSFO as a farm growing

more than 50 acres of annual cropland (e.g. corn, sweet corn, soybean, or pumpkin), or growing more than 50 acres of vegetables or that house and manage at least the following animal numbers; 50 mature dairy cows, 75 youngstock or heifers, 75 veal calves, 75 cattle or cow/calf pairs, 188 swine weighing over 55 pounds, 750 swine weighing less than 55 pounds, 40 equines, 750 sheep or goats, 4,125 turkeys, 2,250 laying hens or broilers or 375 ducks (w/ liquid manure system), 6,250 laying hens or broilers or 2,500 ducks (w/out a liquid manure system), A combination of animals with total live weight exceeding 90,000 pounds.

**Small Farm Operation (SFO).** SFO fall under the CSFO threshold and do not need to certify annually but are still required to follow the Required Agricultural Practices.

**Environmental Quality Incentives Program (EQIP).** This program, administered by NRCS, is a voluntary conservation program for farmers and ranchers that promotes agricultural production and environmental quality as compatible national goals. EQIP offers financial and technical help to assist eligible participants install or implement structural and management practices on eligible agricultural land. If you are enrolled in EQIP, NRCS requires crop records from the previous crop year.

#### Records

Both state and federal agencies require that a farm keep records. You can use the forms provided in the binder or make your own.

**Recordkeeping Summary Sheet.** Document discrepancies between what you planned to do and what you actually did on the farm last season. If you did not follow your plan, explain why (i.e. weather). The recordkeeping summary sheet can be found in the class binder. A sample is shown on the next page.

## NUTRIENT MANAGEMENT RECORDKEEPING SUMMARY

### General Information

Producer:

Crop Year:

### Seasonal Events

*Describe any unexpected weather, pest, equipment, material availability, or labor problems that occurred this year that caused you to change your nutrient applications or cropping patterns from what you had planned:*

### Nutrient Application Changes

*Describe how your applications or cropping were different because of these events; on which fields were applications higher / lower than planned? How do you think this will impact the fields' overall nutrient balance? Do any rotations need to be adjusted to maintain adequate erosion control?*

### Implications for Next Year

*Do you need to alter your plans for next year to compensate for events this year? Do soil or manure tests need to be repeated sooner than expected? Do fields need to be reseeded ahead of schedule, or rotations adjusted?*

Name of Nutrient Management Records Reviewer:

Date of Review:

Recommendations Resulting From Records Review

The recordkeeping summary sheet is found in the NMP binder.

## LESSON V-4

### Updating the Plan

If there have been any changes on your farm since last year's NMP, you will need to record these changes on the updated NMP. Did you lease a neighbor's farm to increase your acreage? Did you add more animals to your herd? Below is an outline of specific sections of the NMP that may require updating.

### How and When to Modify Each Section

**Farm Information Sheet.** Change this sheet if you have increased your herd size, increased your acreage, changed rotations, changed tillage systems, or if there has been any other major change on your farm.

**Maps.** Add or modify maps if you have added additional farms, tracts, or fields. Contact NRCS or NRCD to make these changes.

**Soil Information.** Add additional soil information sheets if you have added additional farms, tracts, or fields. You will only need to change this section if you added new maps. Contact NRCS or your local Natural Resource Conservation District to make these changes.

**Soil Analysis.** Update this section with new soil tests. Check your soil sampling schedule and modify it

if necessary. Remove old tests and replace them with new versions, archiving old tests to monitor soil P levels.

**Manure Production.** Update this section if you have added additional animal units or have modified your storage units. If you have changed this section you will need to:

- Modify the animal waste overview page
- Modify the sheet for manure nutrients available for crop production
- Reallocate manure on individual field sheets if necessary

**Manure Analysis.** Update this section with manure tests from the past year. You need at least one manure sample analysis per year.



**Field Information.** Update this section if you have added new fields. Update the crop history section.

**Field by Field Planning.** Fill out new field by field nutrient management sheets if necessary. New field sheets will be needed if there are new soil tests.

**RUSLE2.** Change to correct rotation.

## ADDITIONAL RESOURCES FOR NUTRIENT MANAGEMENT PLANNING

The University of Vermont Extension  
Saint Albans office: (802) 524-6501  
Soil, Nutrient and Manure Management  
[www.uvm.edu/extension/cropsoil/soil-health-and-nutrient-management](http://www.uvm.edu/extension/cropsoil/soil-health-and-nutrient-management)

goCrop™ Nutrient Management Planning  
[www.gocrop.com](http://www.gocrop.com)

Northwest Crops and Soils Homepage  
[www.uvm.edu/extension/cropsoil](http://www.uvm.edu/extension/cropsoil)

Nutrient Recommendations for Field Crops  
in Vermont  
[pss.uvm.edu/ag\\_testing/VTNutrientRecFieldCrops1390.pdf](http://pss.uvm.edu/ag_testing/VTNutrientRecFieldCrops1390.pdf)

Agricultural and Environmental Testing Lab  
[pss.uvm.edu/ag\\_testing/](http://pss.uvm.edu/ag_testing/)

USDA Natural Resources Conservation Service  
in Vermont  
State office: (802) 951-6795  
[vt.nrcs.usda.gov](http://vt.nrcs.usda.gov)

Vermont Soil Survey Information  
[websoilsurvey.nrcs.usda.gov/app/websoilsurvey/.aspx](http://websoilsurvey.nrcs.usda.gov/app/websoilsurvey/.aspx)

Key to the Soils of Vermont  
[efotg.nrcs.usda.gov/treemenuFS.aspx?Fips=50001&MenuName=menuVT.zip](http://efotg.nrcs.usda.gov/treemenuFS.aspx?Fips=50001&MenuName=menuVT.zip)

NRCS Manure Screening Tool  
[www.vt.nrcs.usda.gov/technical/Nutrient\\_Management/](http://www.vt.nrcs.usda.gov/technical/Nutrient_Management/)

Vermont Agency of Agriculture, Food and Markets  
(802) 828-2430 [vermontagriculture.com](http://vermontagriculture.com)  
Vermont Required Agricultural Practice (RAPs)  
[agriculture.vermont.gov/water-quality/regulations/rap](http://agriculture.vermont.gov/water-quality/regulations/rap)

Vermont Large Farm Operations (LFO)  
[agriculture.vermont.gov/water-quality/regulations/lfo](http://agriculture.vermont.gov/water-quality/regulations/lfo)  
Vermont Medium Farm Operations (MFO)  
[agriculture.vermont.gov/mfo](http://agriculture.vermont.gov/mfo)  
Certified Small Farm Operations (CSFO)  
[agriculture.vermont.gov/sfo](http://agriculture.vermont.gov/sfo)

Vermont Association of Conservation Districts  
[www.vacd.org](http://www.vacd.org)

## EXERCISE V-1

### Checklist

**B**efore you submit your nutrient management plan, check through it to make sure that all of the necessary information has been completed.

#### SESSION I

- ☐ Farm information worksheet
- ☐ Maps (proximity, conservation plan, nitrate leaching, topographic, environmental concerns, soils)
- ☐ Soil fact sheets
- ☐ Soil test results organized
- ☐ Soil test interpretation and planning strategy
- ☐ Soil test schedule
- ☐ RUSLE2 (with your crop rotation indicated)
- ☐ Field inventory
- ☐ Manure application schedule

#### SESSION II

- ☐ Animal waste system overview sheet
- ☐ Calculation of amount of manure produced
- ☐ Manure test for each storage
- ☐ Manure analysis worksheet
- ☐ Manure storage nitrogen calculations (one for each manure storage)
- ☐ Manure nutrient values
- ☐ P-index

#### SESSION III

- ☐ Farm nutrient balance
- ☐ Risk assessment worksheet

#### SESSION IV

- ☐ Field plan recommendation worksheets (one per field)
- ☐ Manure drawdown worksheet
- ☐ Manure import/export form and alternative manure utilization form (if applicable)

#### SESSION V

- ☐ For plan updates:
- ☐ Records
- ☐ Revise any applicable parts of computer workbook
- ☐ Recordkeeping summary sheet
- ☐ Any additional forms required by program enrollment