

# Whole-Farm Nutrient Management on Dairy Farms to Improve Profitability and Reduce Environmental Impacts



Cornell University  
University of Wisconsin-Madison  
USDA-Agricultural Research Service, Dairy Forage Research Center

April 30, 2004

**Final Report to the National Center for Manure and Animal Waste Management**

**CORNELL UNIVERSITY CROP AND SOIL SCIENCES RESEARCH SERIES R04-1  
UNIVERSITY OF WISCONSIN EXTENSION PUBLICATION A3794**



## **Whole-Farm Nutrient Management on Dairy Farms to Improve Profitability and Reduce Environmental Impacts**

*A joint project among Cornell University, the University of Wisconsin-Madison, and USDA-Agricultural Research Service, Dairy Forage Research Center (USDFRC) funded by the National Center for Manure and Animal Waste Management.*

The National Center for Manure and Animal Waste Management determined that a large body of knowledge exists about livestock waste and nutrient management, but that the development and implementation of manure and animal waste best management practices is limited by lack of integration of research and extension information. A collaborative project was initiated to define and evaluate nutrient management tools developed and used in New York and Wisconsin that are applicable across regions, and tools or models that are region specific but whose approach and structure may be applicable across regions. This document is the final report of the project. It contains outlines of nine nutrient management tools used in New York or Wisconsin and provides readers with comparative reviews of the tools to aid in tool selection. Model developers and agricultural educators can use this information to improve their nutrient management research and teaching efforts.

In addition to software evaluations, this project report describes the dairy production systems and state regulatory environments and gives an overview of three university courses developed to address nutrient management issues in New York and Wisconsin. The primary audiences for this project are researchers, extension personnel and other professionals that generate knowledge and provide assistance to dairy farmers in issues related to feed, fertilizer and manure management.

Find out more about this project by visiting:

<http://www.dfrc.ars.usda.gov/powell/wholefarm.html>



# Whole-Farm Nutrient Management on Dairy Farms to Improve Profitability and Reduce Environmental Impacts

## Final Report

### PROJECT PERSONNEL

Principal investigators	Mark Powell, USDA-ARS Dairy Forage Research Center (USDFRC) Quirine Ketterings, Cornell University
Coordinators	Caroline Rasmussen, Cornell University Leah Nell Adams, University of Wisconsin

---

### AUTHORS

Introduction	Leah Nell Adams and Caroline Rasmussen
New York and Wisconsin dairy industries	
Comparing nutrient management tools	
Additional nutrient management tools	
Conclusions	
New York State nutrient management policies and regulations	Caroline Rasmussen Greg Albrecht, Cornell University Karl Czymmek, Cornell University
Wisconsin nutrient management policies and regulations	Leah Nell Adams
Integrated Farm System Model	Al Rotz, USDA/ARS Richard Muck, USDFRC Caroline Rasmussen
PALMS	John Norman, University of Wisconsin Bill Stangel, Soil Solutions Consulting Leah Nell Adams
Modified Yardstick	Kevin Erb, Wisconsin Cooperative Extension Leah Nell Adams
N-CyCLE	Michele Wattiaux, University of Wisconsin Leah Nell Adams

---

---

CNCPS	Danny Fox, Cornell University Tom Tylutki, Venture Milling Caroline Rasmussen
Cornell Cropware	Caroline Rasmussen Mark Ochs, Ochs Consulting Greg Albrecht Quirine Ketterings Karl Czymmek
New York Phosphorus Index	Karl Czymmek Quirine Ketterings Larry Geohring, Cornell University Greg Albrecht Caroline Rasmussen
Wisconsin Phosphorus Index	Larry Bundy, University of Wisconsin Laura Ward Good, University of Wisconsin Leah Nell Adams
SNAP Plus	Bill Pearson, Wisconsin Cooperative Extension Douglas Marshall, MATC Reedsburg Leah Nell Adams
Educational Tools	Michele Wattiaux Greg Albrecht Leah Nell Adams Caroline Rasmussen

---

## CONTENTS

I.	Introduction	
	Project Background .....	1
	The Video Seminar Series.....	2
II.	New York and Wisconsin Dairy Industries.....	4
III.	Environmental Regulation of Agriculture	
	New York Nutrient Management Policies and Regulations .....	10
	Wisconsin Nutrient Management Fact Sheet .....	16
IV.	Nutrient Management Tools for Research	
	Integrated Farm System Model .....	19
	PALMS .....	30
V.	Nutrient Management Tools for Balancing Nutrients	
	Modified Yardstick .....	36
	N-CyCLE .....	41
VI.	Nutrient Management Tools for Consultants and Farmers	
	CNCPS .....	52
	Cornell Cropware.....	65
	New York Phosphorus Index .....	76
	Wisconsin Phosphorus Index .....	80
	SNAP-PLUS .....	84
VII.	Comparing Nutrient Management Software Tools .....	90
VIII.	Additional Nutrient Management Tools	
	New York Tools .....	91
	Wisconsin Tools .....	92
	Other States Tools.....	93
IX.	Conclusions.....	95
X.	Educational Tools	
	Cornell University: Whole-Farm Nutrient Management .....	96
	University of Wisconsin: Environmental Management of Livestock Operations .....	97
	Other Educational Tools .....	97
XI.	Appendices	
	National Center Matrix.....	99
	Additional Resources.....	101
	Pre-seminar Survey .....	104
	Presentation Outline .....	105
	Using Video Conferences as an Educational Tool .....	107



## I. INTRODUCTION

### Project Background

Agriculture is an important contributor to the economy of both New York and Wisconsin and retaining and supporting these agricultural industries is critical. For a healthy agricultural economy it is essential to implement management strategies that protect air and water quality while maintaining or increasing a farm's profitability.

In past years, software tools were developed to address a range of nutrient management decisions, from optimizing dairy herd and feed management, matching soil and cropping systems, and manure and fertilizer management, to assisting land use planners in issues related to dairy herd expansion. The National Center for Manure and Animal Waste Management determined that although a large body of knowledge exists about livestock manure and nutrient management, the development and implementation of best management practices continues to be limited by lack of dissemination and integration of research and extension information.

Cornell University, the University of Wisconsin, and the USDA-ARS Dairy Forage Research Center initiated a joint project in January 2002 to study nutrient management tools, research applications, and educational efforts for dairy farms in New York and Wisconsin. At each location, interdisciplinary teams are working on research, extension and educational programs to improve farm profitability while protecting the environment but prior to this project, there was little exchange of information and experiences. Through a video-linked seminar series in which software tools were presented and discussed, and follow-up with the developers after the seminars, tool assessments were done.

In this final report to the National Center for Manure and Animal Waste Management, the research and extension teams compare dairy farming and regulations in New York and Wisconsin, describe nine of the nutrient management software tools used in the two states and beyond, and compare teaching tools that are used for undergraduate courses at both universities.

Nutrient management tools were evaluated based on a set of criteria agreed upon at the onset of the project so that farmers and their consultants, as well as researchers, can identify the most appropriate uses for each tool, identify areas where new tools and new functionality are needed, or identify where data can be shared between tools. For the list of the evaluation criteria used for the project, we refer the reader to the Appendix, page 105.

## The Video Seminar Series:

### Nutrient Management Tools for Protecting Environmental Quality While Maintaining Economic Sustainability

In order to present the selected nutrient management tools to people at both locations, Cornell University, the University of Wisconsin and USDFRC featured a series of video seminars open to the public in the fall of 2003. These seminars drew audiences from New York and Wisconsin beyond faculty, staff and students at the universities. We held 6 video seminars (Table 1.1). Five meetings focused on an identified 'type' of nutrient management tool while the final meeting focused on summarizing project findings. From the many nutrient management tools available for use in New York and Wisconsin, we chose to focus on nine specific tools based on where they were primarily developed and used, and what their focus and scale was.

**Table 1.1:** Video conference seminar series schedule, Fall 2003.

Date	Topic	Speakers
September 9	Long-term, whole-farm research: - Integrated Farm System Model	Al Rotz, USDA ARS Rich Muck, USDFRC
September 23	Field-scale research models: - PALMS	John Norman, UW Bill Stangel, Soil Solutions Consulting
October 14	Tools that meet regulatory requirements: - Cornell Cropware - NY phosphorus index	Greg Albrecht, CU Karl Czymmek, CU Mark Ochs, Ochs Consulting
October 28	Farm-level nutrient management tools: - N-cyCLE - Modified Yardstick	Michel Wattiaux, UW Kevin Erb, Wisc. Coop. Ext.
November 18	Tools that meet regulatory requirements: - SNAP - WI phosphorus index	Bill Pearson, UW Larry Bundy, UW Doug Marshall, MATC
December 2	Dairy herd nutrient management tools: - CNCPS	Danny Fox, CU Tom Tylutki, CU
December 16	Software evaluation wrap-up	Mark Powell, USDFRC

There are many tools used in nutrient management research and planning. We were unable to cover every tool available due to time and money constraints. The nutrient management tools we chose to cover in detail fall into three categories: (1) research models, (2) farm level nutrient balancing programs, and (3) tools for consultants and farmers. Some of the tools cover whole-farm applications and others cover nutrient management on a field by field basis.

Sessions in the seminar series alternated in broadcasting location between New York and Wisconsin, with a speaker in one location and a moderator at the second location. For each seminar, we heard from one or two tool developers and one person with experience using the tool in the “real world” with the only exception being the October 28 seminar featuring N-CyCLE and the Modified Dutch Yardstick where a commentator was not included due to time constraints. Seminars were well attended at both locations. The combination of hearing from the developer(s) and having a user of each tool comment on the tool created a very effective means of feedback to the speakers. It generated a lot of discussion both formally, during the video-link, and informal immediately after the meetings. Feedback and discussions frequently pointed towards ways in which the tools could be improved in the future.

The tool evaluation sections in this report are organized following a consistent outline and format. The information reported was compiled from the presentations given in the seminar series and edited by each of the nutrient management tool developers. The sections are written in an easy to follow, bulleted format. If you would like to see more detail on any of the tools, please go to our web site; all presentations and videos of the seminar are archived at <http://www.dfrc.ars.usda.gov/powell/wholefarm.html>.

## II. NEW YORK AND WISCONSIN DAIRY INDUSTRIES

In this project we compared nutrient management tools used in both New York and Wisconsin to identify areas for research collaboration, possibilities for tool integration, and gaps in tool capabilities. A comparison of the dairy industries in these two states is a good place to begin answering questions such as:

- Are New York and Wisconsin dairy systems similar enough to use the same nutrient management tools?
- Are the suite of different tools found in each state justified based on differences in farming, soil type, topography, land use patterns, etc.?

### Importance of Agriculture

In both New York and Wisconsin, agriculture is an important part of the state economy (Table 2.1). The dairy industries are quite similar in size and production, though there are some differences that should be pointed out. In New York, according to the Agricultural Statistical Services (2002), about 25 percent of the state's land area, or 7.6 million acres, are used by 37,500 farms to generate \$3.4 billion in agricultural products (see <http://www.nass.usda.gov/ny>). In Wisconsin, more than 45 percent of the state's land area, 15.9 million acres, produces \$5.3 billion in agricultural receipts on 77,000 farms.

### Dairy Sector

In both New York and Wisconsin, dairy and livestock are the major sectors of the agricultural industry. Dairy products, cattle and calves account for 53% and 62% of farm receipts in New York and Wisconsin, respectively (Table 2.1).

**Table 2.1:** Wisconsin and New York agricultural sector, 2002.

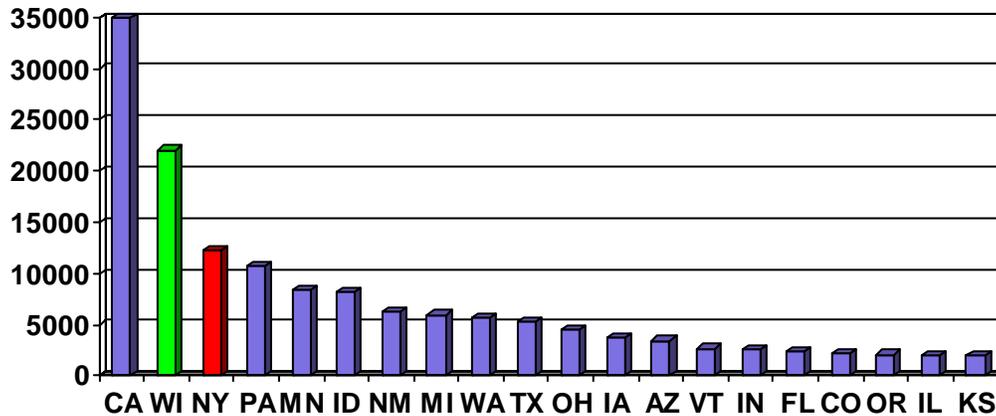
2002	New York	Wisconsin
Land area in agriculture		
% total land area	25	45
acres <sup>1</sup>	7.6	15.9
Agricultural receipts (billion \$) <sup>1</sup>	3.4	5.3
Number of farms <sup>1</sup>	37,500	77,000
Dairy products, cattle & calves <sup>2</sup>		
Value (billion \$)	1.7	3.3
% state total farm receipts	53%	62%
Number of dairy farms, # (US rank) <sup>1</sup>	7,100 (4 <sup>th</sup> )	17,800 (1 <sup>st</sup> )
Average number of cows/farm <sup>1</sup>	102	73
Average annual milk production/cow (lbs) <sup>1</sup>	18,019	17,367

<sup>1</sup> [www.nass.usda.gov](http://www.nass.usda.gov) (2002).

<sup>2</sup> [www.ers.usda.gov/statefacts](http://www.ers.usda.gov/statefacts).

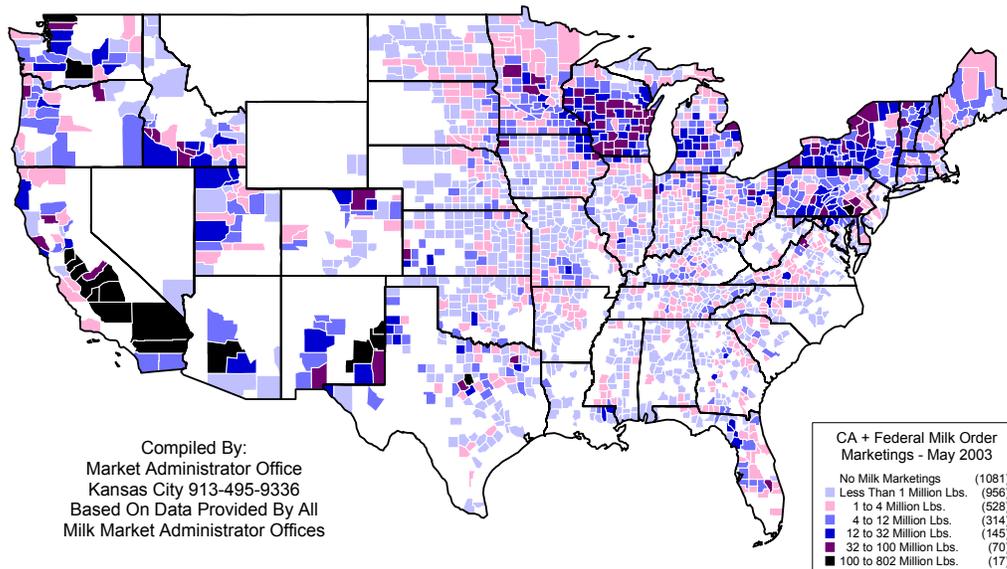
New York and Wisconsin are major dairy production states in the US, consistently ranking 2<sup>nd</sup> (WI) and 3<sup>rd</sup> (NY) in total milk production and number of dairy cattle (Fig. 2.1 and 2.2). Among all US states, Wisconsin ranked 1<sup>st</sup> and New York ranked 4<sup>th</sup> in the number of dairy farms. Wisconsin has almost twice as many milk cows as New York

(1,271,000 versus 678,000) and produces almost twice as much milk (22,074 million lbs versus 12,217 million lbs/year)(USDA NASS, 2002). In general, New York has slightly larger herd sizes and produces slightly more milk per cow (Table 2.1).



**Figure 2.1:** Milk production (millions of lbs) in 2002 (Source: USDA Dairy and Poultry Statistics, 2003).

CA + Federal Order Milk Marketings By County - May 2003



**Figure 2.2:** CA and federal order milk marketings by county – May 2002 (Source: Nicholson, D.R. Marketing Service Bulletin, September 2003).

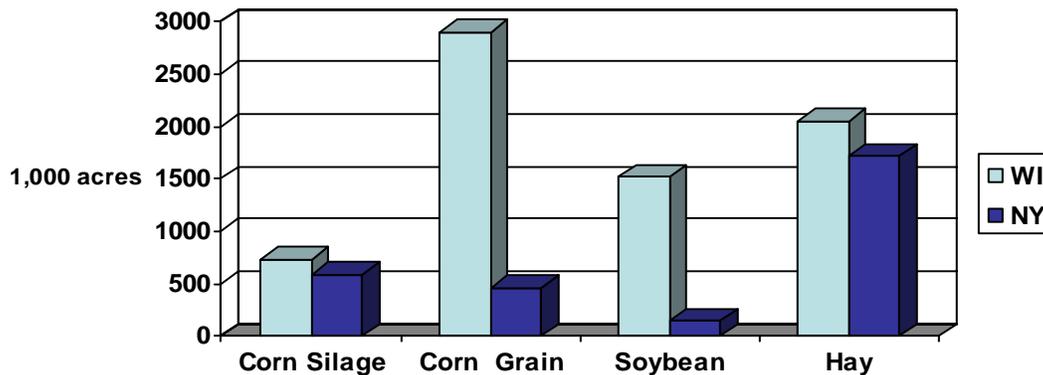
In both New York and Wisconsin, the bulk of farms are mid-sized farms (50-99 cow herds). These farms produce a good proportion of each state’s milk, though in New York, the 200+ cow farms are producing a higher percentage of milk than farms of that size in Wisconsin (Table 2.2).

**Table 2.2:** Wisconsin and New York dairy industry structure in 2002 (Source: Dairy and Poultry Statistics, [http://www.usda.gov/nass/pubs/agr03/03\\_ch8.pdf](http://www.usda.gov/nass/pubs/agr03/03_ch8.pdf))

2002	-----Herd Size, number of milk cows per farm-----						
	0-29	30-49	50-99	100-199	200-499	500+	Total
Wisconsin							
No. of farms	2,600	4,800	7,500	2,000	700	200	17,800
% of farms	14.6	27.0	42.0	11.2	3.9	1.1	100
% of milk	2.5	12.0	35.0	19.0	17.5	14.0	100
New York							
No. of farms	1,200	1,250	2,800	1,200	510	140	7,100
% of farms	16.9	17.6	39.4	16.9	7.2	2.0	100
% of milk	1.5	5.5	25.0	25.0	22.0	21.0	100

### Natural Resources

New York and Wisconsin both have cropping and dairy systems typical of the area around the Great Lakes known as the “dairy belt”. Although the agriculture in this area includes vegetable, fruit, and cash grain production, the majority of crops are grown for feed for dairy cattle. Corn grain and silage, legume and grass hay, hay crop silage, and pasture are dominant crops in both states (Fig. 2.3).



**Figure 2.3:** New York and Wisconsin acres in selected crops in 2002 (Source: New York State Agricultural Statistics 2002-2003 and Wisconsin 2003 Agriculture Statistics).

The growing season in New York varies with altitude and latitude from 100 to 200 days. Wisconsin has a growing season of around 80 days per year in the upper northeast and north-central lowlands to about 180 days in the Milwaukee area. The growing season is 140 to 150 days along the east-central coastal area is of Lake Michigan. Average annual precipitation is about 40 inches per year in New York and about 30 inches per year in Wisconsin.

### New York Soils

The soils of New York are from various parent materials, all showing the effects of glaciation (Fick and Cox, 1995). Many of the soils are shallow and rocky. Soil pH is

commonly low except in the Central Plains where limestone is the parent material. Drainage and sloping topography dictate the choice of crop rotation for many farms. The typical crop rotation involves 3 to 6 years of perennial forage followed by 3 or 4 years of corn.

### Wisconsin Soils

Wisconsin subsoil materials are deep (more than 2 feet thick over consolidated bedrock in 95% of the state). A third of the soil area is derived from glacial outwash sand and gravel, a third from glacial till loams, a tenth from deposits in ancient glacial lakes, and a tenth from bedrock-derived residuum. Wetland soils (both organic and inorganic) cover nearly 10% of the state, but bodies too small to show on state scale soil maps probably more than equal that acreage. About 40% of the land is covered with a foot or more of weathered loess, from which some of the most productive soils have formed. Wisconsin is crossed by a southeast-trending climatic and ecological tension zone that separates cool-summer forest soils on the northeast from warm summer prairie and prairie-forest transition soils on the southwest. Forest soils have formed on two thirds of the area, and prairie and savanna influenced soils have developed on the remaining third. Clayey soils cover about 10% of the state; silty soils, about 40%; loams and sandy loams, 25%; sands, 20%; and peats and mucks, about 5%.

Wisconsin dairy producers grow more farm-produced feedstuffs than their New York counterparts (Fig. 2.3). See Table 2.3 for yields of major feedstuff crops.

**Table 2.3.** Average yields of corn, alfalfa, hay and soybeans in NY and WI in 2002 (Source: 2002 WI Agricultural Statistics and NY Agricultural Statistic Service).

Crop	New York	Wisconsin
Corn Silage (tons/acre)	13	16
Corn Grain (bu/acre)	97	135
Alfalfa Hay (tons dry equivalent/acre)	2.3	2.8
Other Hay (tons dry equivalent/acre)	2.2	2.6
Soybeans (bu/acre)	35	35

### Nutrient Management

The selection of nutrient management tools depends in part on how well these tools address and facilitate compliance with federal and state environmental regulations (see Section III, page 10). The US Environmental Protection Agency (US EPA) has ruled that farms that meet certain size criteria and/or have the capacity to pollute, are defined as Confined Animal Feeding Operation (CAFO) and subject to legislation associated with point source pollution. According to the most recent US EPA definitions, New York currently has 137 large CAFOs (700+ dairy cows) and 515 medium size CAFOs (200-699 dairy cows). Most but not all of these are dairy farms. Wisconsin currently has 88 registered CAFOs (500+ animal units).

Another aspect that may play a role in nutrient management tool use in the future is animal density and associated farm mass nutrient balance. Producers with large animal to land ratios and excessive nutrient imbalances will likely be under more pressure to actively manage farm nutrient flows. In the 228 dairy farms participating in the “New York

State Farm Business Summary”, the average animal density (1,000 lbs live animal weight/tillable acres) was 0.95. In a recent study of 98 representative dairy farms in Wisconsin, an average of 0.64 animal units per acre of total cropland was recorded (Powell et al., 2002).

A 1997 survey of 470 small and medium (under 1,000 cows) dairy farms in New York showed a reliance on daily spreading of manure (Bills et al., 2003). The average number of days manure was spread on farms in this survey was 263. Forty-six percent of the small farms and 39% of the medium farms had no manure storage. Of the small farms that reported having manure storage, 91% had less than 180 days of storage. Seventy-eight percent of the medium farms with manure storage had less than 180 days of storage. In Wisconsin, approximately one-half of the dairy farms have manure storage. The majority of these producers haul manure year round.

An urbanizing landscape is an issue in both New York and Wisconsin. According to the National Resources Inventory, in the 5 year period of 1992 to 1997, 132,100 acres of agricultural land in New York State (2%) were converted to community developments. For the same time period, Wisconsin lost 126,100 agricultural acres (1%) to development.

Since all of the nutrient management tools described in this report are computer software programs, it is important to know computer usage among our farm operators. In 2001, 58% of all farmers in New York and 56% of the all farmers in Wisconsin owned computers (NASS, 2002).

## **Summarizing Remarks**

Farming in general, and especially dairy farming, forms an important component of the economies of both New York and Wisconsin. These two states are part of the “dairy belt” surrounding the US Great Lakes. The states’ natural resources, agricultural products, and farming practices have many similarities although Wisconsin has more animals and more farms than New York. On average, New York dairies depend on a greater proportion of purchased feed than their Wisconsin counterparts. Purchased feed, a potential source of excess nutrients, could be addressed with more widespread use of tools that focus on animal diets. Smaller farms may be challenged to invest capital resources necessary for some nutrient management strategies. The agricultural regulatory laws and structures are specific to each state. Nutrient management tools that are state-specific (i.e. in regards to soils, regulations and crop fertilization recommendations) will, by definition, be used only in that state. Tools which have more global parameters, such as cattle diet manipulation software, mass balance software and risk assessment programs, can be used in both New York and Wisconsin and many other similar states.

## **References**

Bills, N., G. Poe, and P. Wright. 2004. Chapter 11: Agriculture and the Environment. In: New York Economic Handbook, 2004. Department of Applied Economics and Management, E.B. 2003-2. Cornell University, Ithaca NY 14853.

Bills, N., G. Poe, and P. Wright. 2003. Using Voluntary Approaches to Reduce Environmental Damages: Evidence from a Survey of New York Dairy Farms. *Jpn. J. Rural Econ.* Vol. 5, pp 35-50.

Cornell Cooperative Extension. 2004. Cornell Guide for Integrated Field Crop Management. Cornell University, Ithaca NY 14853. 112 pp.

Fick, G.W and W.J. Cox. 1995. The agronomy of dairy farming in New York State. <http://www.css/cornell.edu/forage/agronomy.html>.

Knoblouch, W.A., L.D. Putnam, J. Karszes. 2003. Dairy Farm Management Business Summary New York State 2002. Department of Applied Economics and Management, Cornell University, Ithaca, NY 14853.

Ma, J. 2002. Seminar Presentation, May 29, 2002. Numerical Assessment and Spatial Analysis of Dairy Manure Energy Potential in New York State.

National Resources Inventory. 2001. <http://www.nrcs.usda.gov/technical/land/nri01>.

New York State Agricultural Statistics 2002-2003 Annual Bulletin. New York State Department of Agriculture and Markets, Albany, NY 12235.

New York State Fact Sheet USDA/ERS. <http://www.ers.usda.gov/statefacts/NY.htm>.

Nicholson, D.R. Marketing Service Bulletin, 2003. <http://www.fmmacentral.com/>.

Powell, J.M., D.B. Jackson-Smith, and L.D. Satter. Phosphorus feeding and manure nutrient recycling on Wisconsin dairy farms. *Nutrient Cycling in Agroecosystems*. 62:277-286.

USDA Dairy and Poultry Statistics. 2003. <http://www.usda.gov/nass/pubs/agr03/03-ch8.pdf>.

USDA NASS. 2003. Farm Computer Usage and Ownership. <http://usda.mannlib.cornell.edu/reports/nassr/other/computer/fmpc0703.pdf>

Wisconsin 2003 Agriculture Statistics. 2003. <http://www.nass.usda.gov/wi/annbull>.

Wisconsin Fact Sheet USDA/ERS. 2003. <http://www.ers.usda.gov/statefacts/WI.htm>.

### **III. ENVIRONMENTAL REGULATION OF AGRICULTURE**

## **New York Nutrient Management Policies and Regulations**

### **History**

#### **Federal Legislation**

Legislative regulation of farm practices began with the implementation of the Federal Water Pollution Control Act (FWPCA 1972) and Clean Water Act (1977). These and subsequent federal laws established policies for the US's navigable waters from both point source and non-point source pollution. Implementation of these laws would fall to the individual states. Discharges from point sources would be identified and regulated by permits from a National (NPDES) or State Pollutant Discharge Elimination System (SPDES). These statutes defined Concentrated Animal Feed Operations (CAFOs) as "point sources".

The 1986 Safe Drinking Water Act Amendments established maximum allowable concentrations of bacteria, turbidity and other contaminants in drinking water and set the stage for major agricultural environmental initiatives in the New York City Watershed. Faced with building a \$6 billion (in 1986 \$'s) filtration plant, and \$300 million annual operating costs, Federal, State and New York City support created watershed wide whole-farm water quality programs.

#### **Local Litigation**

In 1991, a lawsuit based on the Clean Water Act made New York producers and policy makers painfully aware of this legislation. After a three year judicial struggle, the US Court of Appeals ruled that Southview, a large dairy operation in Wyoming County, NY, was a CAFO and therefore a "point-source" and subject to the NPDES permitting process and restrictions (though no such permit was available in NY at that time). In response to this action, a committee of farmers, state agency representatives, and environmentalists started meeting to proactively address issues of CAFO regulation and litigation. This "CAFO work group" met in 1996 and 1997 and drafted a CAFO general permit for New York and established the Agricultural Environmental Management program.

### **New York Agricultural Environmental Regulatory Structure**

#### **Agricultural Environmental Management (AEM)**

AEM is a partnership of state, federal and local agencies, conservation representatives, private sector business and farmers that provides help to farmers to identify environmental risks and solutions on their farms. Currently, nearly 8,000 farms participate statewide. AEM planners follow a five-tiered planning process to guide the development and implementation of agricultural environmental management plans. Tiers I and II document current farm practices and identify environmental concerns. In Tier III a plan for improved environmental management is developed. Tier IV represents the implementation of the plan and Tier V guides the evaluation and continuous improvement of the plan over time. Participation is completely voluntary and producers move through the tiers as resources allow. The "State Soil and Water Conservation Committee" develops policy for the statewide AEM program and administers programs

through staff and various groups associated with the interagency AEM Steering Committee. AEM also serves as a link between interested stakeholders – policy makers, university researchers, extension educators, producers and agribusiness. AEM provides a platform for research and conservation payment funding discussions and decisions.

### Who is Regulated?

The criterion that defines what farms are regulated by federal and state laws has changed over the years and has been interpreted differently by different states. An Animal Feed Operation (AFO) is defined as a facility where animals are fed and confined for a total of 45 days or more in any twelve (consecutive) month period and where crops, vegetation, forage growth, or post harvest residue are not sustained in the animal confinement area. The US EPA has designated AFOs to be CAFOs based on the animal numbers and the ability to convey waste to surface water. An AFO is called a CAFO if it qualifies for any of the following criteria:

- More than 1000 animal units (AU=1000 lbs live weight).
- Between 300 and 999 AU with the capacity to discharge to surface waters either through a man-made ditch, flushing system or other man-made device.
- Deemed to be polluting (any size farm).
- Located in a sensitive watershed (any size farm).

On December 15, 2002, the US EPA revised the National Pollutant Discharge Elimination System Permit Regulation and Effluent Limitation Guidelines and Standards for Concentrated Feeding Operations (also known as “The Final Rule” FR68 (20): February 12, 2003). The December 2002 EPA “Final Rule” on CAFOs moved away from animal units and defined the number of animals that would constitute a CAFO for each animal type (Table 3.1). The NY CAFO workgroup is currently determining how New York will incorporate the new EPA rules into the State permitting process. It is expected that public hearings and comments will be completed and a permit will be reissued before July 1, 2004. For further information, see the NY Department of Environmental Conservation (DEC) website (<http://www.dec.state.ny.us/website/dow/cafohome.html>) or the US EPA website (<http://www.cfpub.epa.gov/npdes/afo/cafofinalrule.cfm>).

**Table 3.1:** Proposed animal categories NY CAFO permit program (Source: Bills et al., 2004).

Animal Category	Medium CAFO Threshold	Large CAFO Threshold
Mature dairy cows	200	700
Beef cattle, beef or dairy heifers	300	1,000
Swine (>55 lbs.)	750	2,500
Swine (<55 lbs)	3,000	10,000
Ducks (liquid manure system)	1,500	5,000
Ducks (other manure system)	10,000	25,000
Layers (liquid manure system)	9,000	30,000
Layers (other manure system)	25,000	83,000
Veal calves	300	1,000
Horses	150	500

If a farm is deemed a CAFO, a NPDES or SPDES permit is required. In New York the permit is managed by the DEC. Of the approximately 7,000 dairy operations in New

York, 137 large CAFOs and 515 medium CAFOS have filed SPDES permits. There may be 200 or so medium CAFOs that have not begun the permitting process. DEC is preparing a compliance strategy to address gaps in the permitting process.

**What is Required?**

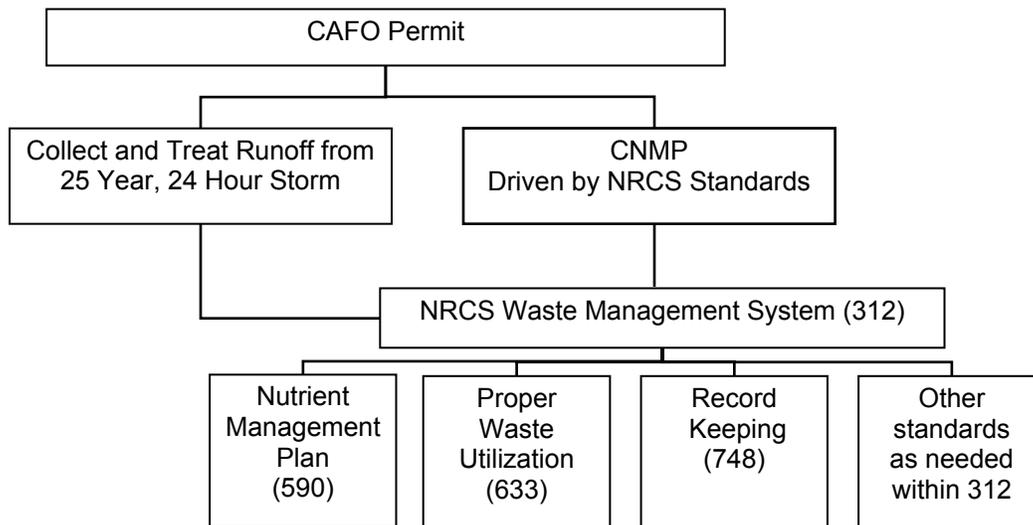
Non-CAFO farms are urged to participate in AEM and use the tiered approach to assess and improve environmental quality. CAFO farms must go through a series of steps: (1) Notice of Intent, (2) Notice of Animal Waste Management Plan Certification (CNMP), and (3) Notice of Complete Plan Implementation. The timeline associated with each of these steps depends on the CAFO size designation. Large CAFOs had to have a notice of intent filed by January 1, 2000, have their CNMP filed by 2002, and implementation completed by the end of 2004. Medium CAFOs must have filed notice of intent and their CNMP by June 2004 and are expected to have their CNMPs implemented by the end of 2004. The new rule changes being considered will change these timelines, probably moving implementation schedules to 2009 in some circumstances.

**CAFO (SPDES) Permit Basics**

The basic requirements of the New York SPDES permit are:

- Effluent guideline: collect and treat dirty farmstead runoff resulting from all storms up to and including the 25 year, 24 hour storm (about 4.5 inches in NY).
- Develop and implement a Comprehensive Nutrient Management Plan (CNMP). This plan must be created and implemented within the guidelines of the NY NRCS standards (Fig. 3.1).

The CNMP must be prepared in accordance with NY NRCS standards and as specified by a Certified Nutrient Management Planner. Planners can be from the private or public sector. To be a CNM Planner, individuals must achieve and maintain Certified Crop Advisor status (CCA certification from the American Society of Agronomy), take the CNMP Certification Training Course, take the NRCS CNMP Home Study Course, and have three CNMPs approved by a CNM Planner Review Team.



**Figure 3.1:** New York State CAFO permitting process organizational chart.

**CNMP Development Steps**

1. File “Notice of Intent” with DEC.
2. Vision, mission and business plan.
3. Site assessment (AEM Tiers I and II).
  - Management of farmstead facilities.
    - Does clean water remain clean?
    - Is dirty water handled/treated (up to 25 yr 24 hr storm)?
  - Management of fields (NY NRCS Standard 590 and 633).
    - Follow Land Grant University guidelines for crop and field management.
    - Evaluate risk: runoff, erosion, (RUSLE and NY Phosphorus Index) and leaching (NY Nitrate Leaching Index) for each field. Implement best management practices (BMPs) and limit nutrient application based on risk indices for each field.
    - Account for all sources of nutrients.
    - Determine crop nutrient requirements.
    - Plan manure and fertilizer applications based on crop nutrient requirements.
    - Identify hydrologically sensitive areas.
    - No spreading manure within 100 feet of surface water unless BMPs in place. No spreading within 100 feet of wells.
  - Recordkeeping (NY NRCS Standard 748).
    - Soil and manure tests.
    - Equipment calibration (planters and spreaders).
    - Crop data – yields, planting dates, etc.
    - Field treatments – sprays, etc.
    - Manure applications, rate, timing, field conditions.
    - Rainfall.
4. Assemble plan and certify (AEM Tier III).
  - 1st General Permit: 7/1/1999 – 6/30/2004.
    - Large CAFO – 1/1/2002 (was 6/30/01).
    - Medium CAFO – 6/30/04 (was 1/1/02).
5. Fully implement plan (AEM Tier IV).
  - 2nd General Permit: 7/1/2004 – 6/30/2009.
    - Large CAFO – expected 12/31/2006.
    - Medium CAFO – expected 6/30/09.
6. Maintain, evaluate and update (AEM Tier V).

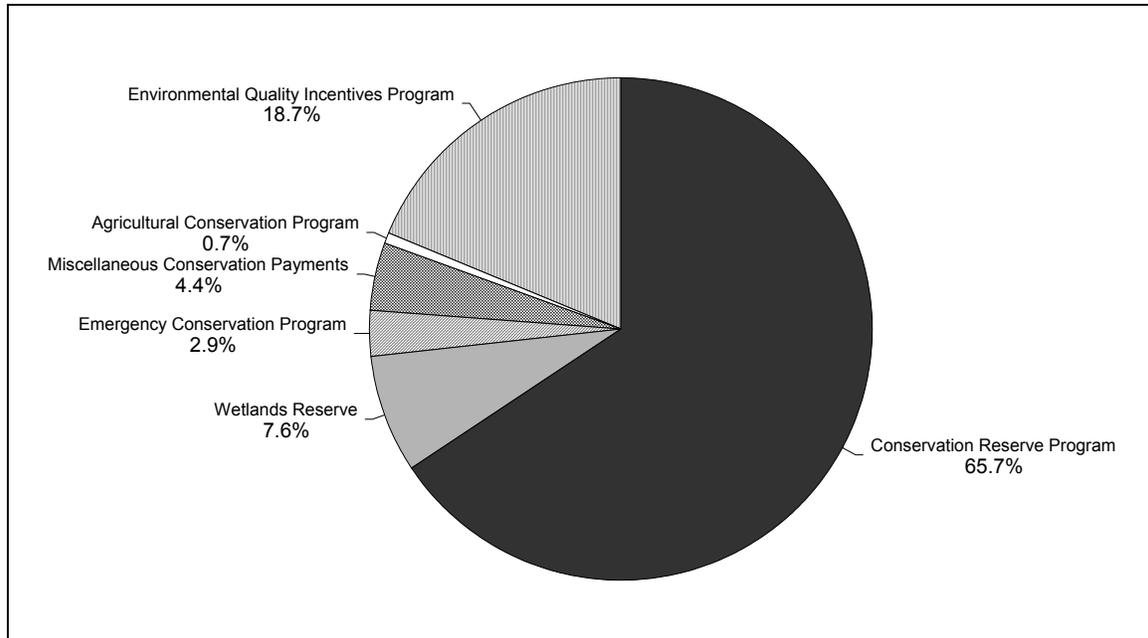
**Some Incentives**

Environmental policy in New York is not all “stick”; some “carrots” (incentives) are available to farmers. Farm land preservation programs, agricultural district legislation and right to farm laws are all part of Federal and State policy in New York. These programs will not be discussed here as they do not relate specifically to environmental protection.

In 2002, New York landowners received over 9 million dollars in federal compensation for conservation programs (Fig. 3.2, Bills et al., 2004). The bulk of these payments were by the Federal government through the Conservation Reserve Program (CRP). Created by the 1985 farm bill, the CRP retires farm land from environmentally sensitive areas for

10 to 15 years. Depending on the stipulations of the program, landowners are paid an incentive payment, an annual rental fee and a share of the cost of conservation practices. As of December 2003, over 58,000 acres of farmland were enrolled in the CRP in New York (<http://www.fsa.usda.gov/dafp/cepd/stats/Dec2003.pdf>).

An additional program under the auspices of the CRP is the Conservation Reserve Enhancement Program (CREP). This program is a state and federal partnership that targets specific environmental conservation projects. New York State has three CREP programs targeting protecting major watersheds including the New York City Watershed and 13 other major watersheds.



**Figure 3.2:** Distribution of USDA conservation payments in New York, 2002. Data from Environmental Working Group, 2003 (Bills et al., 2004, Figure 11-8).

The 2002 farm bill promises to expand spending on farm conservation programs in the future. The Environmental Quality Incentives Program (EQIP) has been broadened to cover a greater variety of farm sizes and geographic areas. EQIP funding may be used, in part, to cover the CNMP costs required by CAFO regulations.

## References

Agriculture Environmental Working Group. 2003. EWG Farm Subsidy Database. <http://ewg.org/farm/regionaldetail.php?fips=36000&summllevel=2>.

Agricultural Environmental Management. <http://www.nys-soilandwater.org>.

Bills, N., G. Poe, and P. Wright. 2004. Chapter 11. Agriculture and the Environment. In *New York Economic Handbook, 2004*. Department of Applied Economics and Management, E.B. 2003-2. Cornell University, Ithaca NY 14853.

DiMura, J. 2004. NYSDEC develops a general SPDES permit for concentrated animal feeding operation (CAFOs). <http://www.dec.state.ny.us/website/dow/article2.pdf>

Poe, G. 1995. The evolution of federal water pollution control policies. Department of Agricultural, Resource and Managerial Economics, E.B. 95-06. Cornell University, Ithaca NY 14853.

USDA FSA. 2004. Conservation Reserve Program Monthly Summary December 2003.

## Wisconsin Nutrient Management Fact Sheet

*Adapted from the Wisconsin Department of Agriculture, Trade, and Consumer Protection document at <http://www.datcp.state.wi.us/arm/regulation/prop-rules/pdf/NMfactshandout.pdf>.*

The Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCP) is adopting rule ATCP 50 which establishes nutrient management standards for farms. This rule (ATCP 50) functions to implement performance standards adopted by the Wisconsin Department of Natural Resources (WDNR) in NR 151.

### NR 151

Cropland Performance Standards:

- Control erosion to meet tolerable soil loss (T).
- Apply nutrients to crop needs (Nutrient Management Technical Standard).

Livestock Performance Standards:

- Construct manure storage facilities to standards.
- Divert clean water around feedlots in water quality management areas 300 feet from streams and 1,000 feet to lakes (Clean Water Diversions Technical Standard).
- Manure Management Prohibitions.
- No overflow of manure structures.
- No unconfined manure stacks in Water Quality Management Areas.
- No direct runoff from feedlots.
- No unlimited livestock access to waters of the state so that adequate sod cover cannot be maintained.

NOTE: No county or local livestock ordinance may exceed state standards unless DATCP or DNR finds that the ordinance is needed to protect water quality. A livestock operator may challenge an ordinance in court if the operator believes that it exceeds state standards and has not been approved by DATCP or DNR.

### Nutrient Management Standards

Farmers applying nutrients must have and follow an annual nutrient management plan if required by a municipality or if cost sharing is offered. Nutrient sources include manure, legumes, organic byproducts and commercial fertilizer. The plan must comply with WI NRCS standard 590 and must include every field on which the farmer mechanically applies nutrients.

Under WI NRCS standard 590:

- Soil must be tested a minimum of once every 4 years by an approved soil test laboratory.
- Nutrient applications may not exceed the amounts required to achieve crop fertility levels recommended by the University of Wisconsin Extension publication A-2809 Soil Test Recommendations for Field, Vegetable and Fruit Crops (1998),

- unless the nutrient management planner documents a special agronomic need for the deviation.
- No manure or organic byproducts may be applied:
    - In waterways, or on frozen slopes greater than 9% (12% for contoured areas with all crop residue remaining).
    - Within 200 feet of groundwater conduits such as sinkholes, fractured bedrock or wells unless incorporated into the soil within 72 hours.

NOTE: The federal government (NRCS) has proposed a phosphorus-based nutrient management standard. DATCP will modify its rules to incorporate the new federal standard by 2005.

### **Qualified Planner**

A qualified nutrient management planner must prepare each nutrient management plan. Persons holding one of the certifications below are presumptively qualified to prepare a nutrient management plan:

- Certified as crop consultants by the National Alliance of Independent Crop Consultants.
- Certified as crop advisors by the American Society of Agronomy, Wisconsin Certified Crop Advisors Board.
- Registered as crop scientists, crop specialists, soil scientists, soil specialists or professional agronomists with the American Registry of Certified Professionals in Agronomy, Crops and Soils.
- A farmer may prepare his/her own nutrient management plan if he/she has completed a DATCP-approved training course within the preceding 4 years, or is otherwise qualified under this rule.

### **Effective Date**

By 2008, all “existing” farming operations must meet the nutrient management performance standard. Farms must comply by 2005 if they are offered 70% cost share and are located in or near outstanding or impaired resource waters, or within a source water protection area. “New” farming operations are not required to receive cost sharing and can be required to comply within one year after the effective date of the rules.

### **New versus Existing Cropland and Operations**

**New** – This includes fields without a crop history from any time in the last 10 years and changes to non-complying cropping practices at and after the effective date of NR 151. New operations also include newly constructed portions of the facility to accommodate a change in livestock, replaced manure storage liner, or a 20% increase in volume or capacity of the facility. New operations may be required to comply with the performance standard without cost sharing.

**Existing** – This includes cropland and livestock operations in existence at the effective date of the performance standard and that are not in compliance with the performance standard. Existing operations may be required to comply with the performance standard if an offer of cost sharing is made to the producer.

### **Cost-Sharing**

Counties typically use cost-share grants to encourage voluntary compliance. In return for a cost-share grant, a farmer agrees to implement nutrient management for a specified number of years. The county and farmer are free to negotiate the contract terms, including the cost-share amount. Different cost-share requirements apply if a county or local government requires a farmer to implement nutrient management practices that change an “existing” farming operation. In these cases, the county or local government must offer cost-sharing. If cost-sharing is required, the cost-share offer must cover at least 70% of the farmer’s annual cost to implement nutrient management (90% if there is an economic hardship). The farmer may accept an alternative flat payment of \$7 per acre per year. If a county or local government cost-shares nutrient management for at least 4 years, it may require the farmer to continue this practice at the farmer’s expense. A county or local government may continue to cost-share if it chooses to do so.

### **Bulk Fertilizer Sales**

A person selling bulk agricultural fertilizer to a farmer must record the name and address of the person who prepared the farmer’s nutrient management plan. This rule does not prohibit sales to farmers who do not yet have plans.

### **Soil Testing Laboratories**

A nutrient management plan must be based on soil tests conducted by a DATCP certified laboratory:

- UW Soil and Plant Analysis Lab – Madison, WI.
- UW Soil and Forage Lab – Marshfield, WI.
- Rock River Laboratory – Watertown, WI.
- Dairyland Laboratories – Arcadia, WI.
- Agsource Soil & Forage Lab – Bonduel, WI.
- A&L Great Lakes Laboratories – Fort Wayne, IN.

### **USDA - NRCS Comprehensive Nutrient Management Plans**

The USDA Natural Resources Conservation Service (NRCS) will be providing cost-share funds for the development of comprehensive nutrient management plans (CNMP) that comply with a new 590 nutrient management standard finalized in the fall of 2002. The new 590 standard contains more nitrogen and phosphorus restrictions than the previous standard and incorporates the use of a phosphorus risk assessment tool. A CNMP has three components that will require development or approval by a certified person:

1. A certified conservation plan where all sheet and rill erosion is controlled to tolerable soil loss along with controlling ephemeral and classic gully erosion.
2. Properly functioning barnyard runoff systems, manure storage facilities, and waste transfer systems that are installed with proper adherence to technical standards and specifications. The plan must also contain properly designed, constructed, and inspected storm water management around the livestock facility.
3. Proper management of nutrients from legumes, organic byproducts, manure, and fertilizer with proper adherence to the NRCS 590 nutrient management technical standard (August 2002).

## IV. NUTRIENT MANAGEMENT TOOLS FOR RESEARCH

### Integrated Farm System Model

<b>Tool Name</b>	Integrated Farm System Model (IFSM) and Dairy Forage System Model (DAFOSYM).
<b>Tool purpose</b>	IFSM and DAFOSYM are research and teaching tools for long-term evaluation of farm production systems.
<b>Developers</b>	C.A. Rotz, U.S. Gupta, D.R. Buckmaster, T.M. Harrigan, L.R. Borton, R.E. Muck, D.R. Mertens, L.D. Parsch, P.H. Savoie and others.
<b>Contacts</b>	C.A. Rotz, USDA/ARS, Building 3702, Curtin Road., University Park, PA, 16802; email: <a href="mailto:alrotz@psu.edu">alrotz@psu.edu</a> .

#### Stage of Development

The first version of DAFOSYM was released in 1989. Numerous additions and refinements were made since that time. Recently, the model was expanded and renamed the Integrated Farm System Model (IFSM). IFSM includes the same algorithms used in DAFOSYM plus the ability to simulate beef farms and crop farms without animals. IFSM is available at: <http://pswmru.arsup.psu.edu/software/ifsm.htm>.

#### Focus

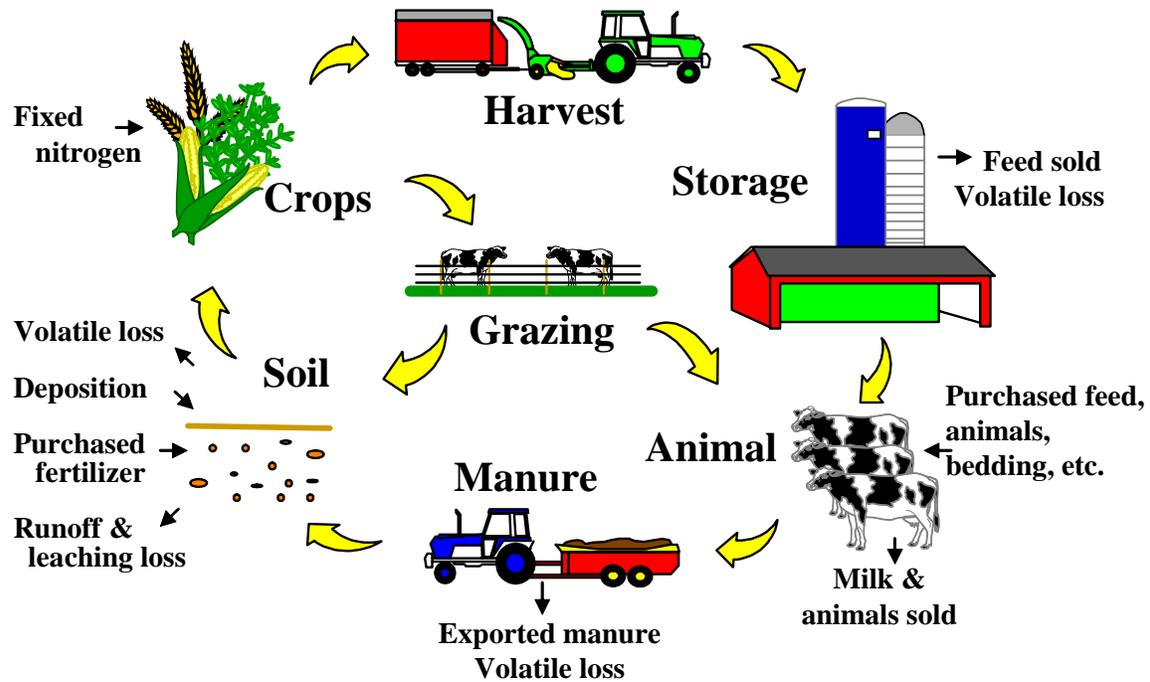
IFSM simulates whole-farm (soil, crops, animals, equipment) processes, allowing users to evaluate the impact of alternative management strategies and technologies on farm production, profitability and nutrient losses.

#### Scale

This software works on a whole-farm scale.

#### Area of Concern

The IFSM model is a whole-farm simulation model of dairy, beef or crop production systems. Farm systems are simulated over many weather years to determine long-term performance, environmental impact, and economics of the farm. As such, the model is a long-term or strategic planning tool. All of the major processes of crop production (harvest, storage, feeding, animal production, manure handling, and crop establishment) are simulated, as well as the return of manure nutrients back to the land (Fig. 4.1). By simulating various alternative technologies and/or management strategies on the same representative farms, the user can determine those alternatives that provide the desired level of farm production, environmental impact, or profit.



**Figure 4.1:** The Integrated Farm System Model simulates material and nutrient flows for various farm systems over many years of weather to determine the long-term performance, nutrient losses, and economics of the farm.

The nutrient management areas of concern are whole-farm nitrogen losses (volatilization, leaching and denitrification), and the phosphorus balance. Based upon simulated farm performance, IFSM calculates key farm economic measures including feed production costs, manure handling costs, purchased feed costs and net farm income.

### Tool Application: Users

IFSM and its predecessor DAFOSYM have primarily been used as research tools for evaluating alternative technologies and management strategies for dairy farms across the Northern US, Canada, and Northern Europe. In addition to its primary purpose as a research tool, IFSM is also an effective teaching aid. Students in Bio-Systems Engineering, Agronomy, and Dairy and Animal Science can use the model to learn more about the complexity of the many interactions that occur within a crop and livestock production system. Students may study the effects of relatively simple changes such as the size of a tractor or other machines. Such a change influences the timing of field operations, fuel and labor requirements, the quality of feeds produced, and milk production as well as the costs of production and farm profit. More complex problems may be studied such as maximizing the profit of a given size farm or evaluating the cropland, machinery, structures, and animals used on a farm. Extension field staff, private consultants, and producers may use the model to study the impacts of various technological changes on farms in their area. With some experience, the model can be used to assist with strategic planning; it could provide useful information on the selection of crops, facilities and animal numbers for optimal farm performance or expansion. Various cropping systems and feeding

strategies can also be compared along with numerous other options in farm management to determine more economical and environmentally friendly production systems.

### **Tool Application: Format**

The program operates on computers that use Microsoft Windows® 95 or higher operating systems. A Windows® version of the Integrated Farm Systems Model is available from the website of the Pasture Systems and Watershed Management Research Unit (<http://pswmru.arsup.psu.edu>). Instructions for downloading and setting up the program are provided on the website.

### **Tool Application: Documentation**

The software contains an integrated help system, which includes a “User Guide” and “Reference Manual”. The User Guide contains guidance on input, output, and use. The Reference Manual includes details of the internal functions and algorithms of the model as well as references.

### **Knowledge and Data Transferability: Geographic Transferability**

Geographic transferability is limited by climate data and plant species selection. DAFOSYM was primarily developed and validated for the northern temperate regions of the US. It has also been used for several locations in Canada and Europe. IFSM can now simulate areas in temperate climatic regions of the southern hemisphere as well, and evaluation of the model for these regions is underway.

### **Data Sharing**

IFSM is a structured program that uses numerous objects or subroutines to represent various processes on the farm. There are nine major submodels that represent these major component processes: (1) crop and soil, (2) grazing, (3) machinery, (4) tillage and planting, (5) crop harvest, (6) feed storage, (7) feed allocation and animal performance, (8) manure handling, and (9) economic analysis. The model shares data within this structure but does not share data with other programs.

### **Data Inputs**

- Farm parameters:
  - Crop types and areas.
  - Predominant soil type.
  - Equipment and structures used.
  - Number of animals at various ages.
  - Animal feeding and maintenance strategies.
  - Harvest, tillage and manure handling strategies.
  - Prices for various farm inputs and outputs.
  
- Machinery parameters:
  - Size.
  - Age.
  - Initial cost.
  - Field speed.
  - Operating capacity.

- Power requirements.
- Repair factors.
- Weather data:
  - Daily data for solar radiation, maximum and minimum temperature, and precipitation.
  - Weather files are available for many locations across the northern US, and a few locations in Canada and Europe.
  - Weather files can be created for other locations.

## Tool Outputs

Example output reports are shown in Tables 4.1, 4.2, 4.3, 4.4, 4.5 and 4.6.

- Performance output:
  - Crop yields and quality.
  - Feeds produced.
  - Feeds bought and sold.
  - Milk or meat produced.
  - Manure produced.
  - Labor, fuel and equipment use.
- Environmental output:
  - Volatile N loss.
  - Leaching N loss.
  - Denitrification N loss.
  - N concentration in groundwater.
  - P balance.
  - K balance.
- Economic output:
  - Manure handling costs.
  - Feed production costs.
  - Other farm costs.
  - Income from milk, meat and animals sold.
  - Net return or profitability.
- Optional output:
  - Daily values of crop growth and development.
  - Pasture availability by month.
  - Suitable days for fieldwork by month.
  - Daily values of forage harvest operations.
  - Annual summaries of machine, fuel, and labor use.
  - Animal group characteristics and diets.

**Table 4.1:** Average crop yields and nutritive contents over a 25 year farm analysis.

	----- Preharvest -----			----- Postharvest -----		
	Yield (ton DM/ac)	Crude Protein	NDF	Yield (ton DM/ac)	Crude Protein	NDF
Alfalfa, 100 acres						
Cutting 1	2.01	21.2	38.1	1.90	21.6	40.2
Cutting 2	1.33	21.4	36.4	1.09	21.5	41.9
Cutting 3	1.24	18.1	40.9	1.15	18.3	43.1
Cutting 4	0.69	17.8	43.1	0.63	18.0	45.7
Total	5.28	20.1	39.0	4.77	20.1	42.2
Corn, 100 acres						
Silage	6.54	8.8	45.8	6.08	8.8	45.8
HM grain	2.72	10.0	10.0	2.62	10.0	10.0
Oats, 20 acres						
HM grain	1.05	13.3	32.0	1.01	13.3	32.0

**Table 4.2:** Feed production and utilization for a 25 year analysis of a farm with 100 cows and 85 young stock on 220 acres of land.

	Unit	Mean	SD
High-quality hay production	ton DM	52	29
Low-quality hay production	ton DM	26	27
High-quality silage production	ton DM	281	42
Grain crop silage production	ton DM	244	1
High-moisture grain production	ton DM	150	50
Forage sold	ton DM	8	63
Grain purchased	ton DM	186	52
Soybean meal, 44% purchased	ton DM	7	3
User defined feed purchased	ton DM	40	5
Mineral and vitamin mix purchased	ton DM	6	0
Average milk production	lbs/cow	20000	0

**Table 4.3:** Nutrients available, used, and lost to the environment for a 25-year analysis of a farm with 100 cows and 85 young stock on 220 acres of land.

	Unit	Mean	SD
Nitrogen imported to farm	lbs/ac	222.1	7.1
Nitrogen exported from farm	lbs/ac	66.9	9.8
Nitrogen available on farm	lbs/ac	329.3	11.5
Nitrogen lost by volatilization	lbs/ac	64.3	2.4
Nitrogen lost by leaching	lbs/ac	30.2	8.4
Nitrogen lost by denitrification	lbs/ac	19.3	5.5
Average nitrogen concentration in leachate	ppm	12.3	5.1
Crop removal over that available on farm	%	51	4
Phosphorous imported to farm	lbs/ac	14.3	1.8
Phosphorous exported from farm	lbs/ac	11.5	0.7
Phosphorous available on farm	lbs/ac	21.2	0.3
Phosphorous loss through runoff	lbs/ac	1.1	0.0
Soil phosphorous build up	lbs/ac	1.7	2.2
Crop removal over that available on farm	%	87	11
Potassium imported to farm	lbs/ac	27.7	6.5
Potassium exported from farm	lbs/ac	20.6	6.4
Potassium available on farm	lbs/ac	122.0	2.9
Potassium loss through runoff	lbs/ac	6.1	0.1
Soil potassium build up	lbs/ac	1.1	11.3
Crop removal over that available on farm	%	88	10

**Table 4.4:** Annual manure production, nutrient availability and handling cost for a 25 year analysis of a farm with 100 cows and 85 young stock on 220 acres of land.

	Unit	Mean	SD
Manure handled	tons	6122	102
Manure applied to alfalfa land	tons	612	10
Manure applied to corn land	tons	3979	66
Manure applied to oats land	tons	1530	25
Manure nitrogen over crop requirement	%	74	9
Manure phosphorous over crop requirement	%	117	15
Manure potassium over crop requirement	%	115	13
Machinery cost	\$	3529	122
Fuel and electric cost	\$	392	7
Custom hauling cost	\$	3057	47
Storage cost	\$	4336	0
Labor cost	\$	1745	31
Bedding cost	\$	3167	340
Total manure handling cost	\$	16226	400
Total cost per mature animal	\$/cow	162	4

**Table 4.5:** Crop production, feeding and manure handling costs and the net return over those costs for a 25 year analysis of a farm with 100 cows and 85 young stock on 220 acres of land.

	Unit	Mean	SD
Machinery cost	\$	43751	497
Fuel and electric cost	\$	4514	224
Feed, manure and machinery storage cost	\$	21647	67
Labor cost	\$	11059	474
Seed, fertilizer and chemical cost	\$	9359	0
Grain drying and roasting cost	\$	0	0
Land rental	\$	0	0
Purchased feeds and bedding cost	\$	41837	7856
Income from feed and bedding sales	\$	3274	3259
Net feed and manure cost	\$	128893	8764
Net cost per unit of milk	\$/cwt	6.65	0.45
Net cost as portion of milk income	%	46.0	3.1
Income from milk sales	\$	279998	0
Net return over feed and manure costs	\$	151106	8764
Net return per mature animal	\$/cow	1511	88

**Table 4.6:** Total production costs and net return to management for a 25-year analysis of a farm with 100 cows and 85 young stock on 220 acres of land.

	Unit	Mean	SD
Total feed cost	\$	115941	6734
Total manure cost	\$	16226	400
Animal facilities cost	\$	21138	0
Milking and milk handling equipment cost	\$	26125	0
Milking and animal handling labor cost	\$	22752	0
Animal purchase and livestock expense	\$	23800	0
Milk hauling and marketing fees	\$	17643	0
Property tax	\$	4676	0
Income from milk sales	\$	279998	0
Income from feed and bedding sales	\$	3274	3259
Income from animal sales	\$	28142	0
Return to management and unpaid factors	\$	63114	8764

## Tool Limitations

Model complexity limits IFSM use by a wider audience. This level of complexity is necessary for the completeness and accuracy of the model in integrating the major processes and process interactions on a farm. On the other hand, model simplifications also limit use. For instance, users sometime request a greater variety of crop, animal species and climate options in the model. There is a need for further validation and verification of some model components.

## Field Validation

DAFOSYM and IFSM have been used to model case study farms in the Netherlands (De Marke), New York, Pennsylvania and Washington. The IFSM model satisfactorily reproduced the long-term feed production and use and the N and P flows of the De Marke dairy farm. Simulation of N conservation technologies on Pennsylvania farms illustrated that N loss, primarily in the form of ammonia emissions could be reduced by 35%. The model was able to show that these nutrient savings came at a cost. For instance, on a 1,000-cow case study farm, annual net return was reduced by about \$80/cow.

Farm level validation of these whole-farm models is very difficult. All of the component models have been carefully evaluated, verified or validated. Numerous journal articles have been published that document components and applications of the model (see References, page 28-29). A more extensive list of publications can be found in the reference manual. Many farms have been represented with the model with reasonable prediction of crop yields, feed production and use, and production costs and profitability.

## Users

It is unknown how many IFSM and DAFOSYM users there are. Thousands of researchers, students and extension educators have been exposed to these models. Over 100 copies are downloaded from the web site each year. These programs are used among others by:

- Researchers.
- Teaching faculty.
- Extension faculty/specialists.
- Machinery industry.
- Producers.

The models have been used in a wide variety of applications including:

- Alternative strategies for manure handling.
- Protein supplementation strategies for dairy cattle.
- Soybean production and feeding on dairy farms.
- Small grain production and use on dairy farms.
- Pasture and confined feeding systems.
- Reduced levels of grain feeding with pasture systems.
- Intensity of pasture management.
- Global climate change.
- Corn silage processing.
- Robotic milking.

### **Is This Tool Useful in Meeting Regulatory Requirements?**

IFSM does not have a direct role in meeting regulatory requirements but it provides a great educational tool that can influence farm design and regulations. However, the use of this model for regulatory purposes could be abused if the user is not knowledgeable enough of farming practices to verify simulation results. IFSM does not produce a nutrient management plan.

### **Future Plans for Tool**

Future plans for IFSM include:

- Validate beef component and evaluate beef production systems.
- Upgrade N volatilization loss prediction.
- Predict P loss (as affected by crops, diet, tillage, etc.).
- Upgrade pasture model to include multiple plant species.
- A carbon balance may be added, but specific plans have not been developed.
- Other crop and animal species could be added if a need arises.

## **Case Study Assessment**

### **Rich Muck, USDA ARS Dairy Forage Research Center**

Rich Muck is a research agricultural engineer at the USDA ARS Dairy Forage Research Center in Madison, Wisconsin. His research interests concern modeling silage fermentation and silage quality. He helped develop DAFOSYM by contributing to the silage storage loss and manure nitrogen loss sub-models.

#### **Tool Use**

Rich uses IFSM and DAFOSYM for research. He has used DAFOSYM to study the effectiveness of specialized bunker silo unloading equipment, wilted versus unwilted alfalfa silage storage, silo management alternatives, and silage operating cost comparisons.

#### **Model Strengths**

The main strength of the model is the interaction of all the parts of the farm including weather, labor, energy and material flows. This is especially important in nutrient management research where the plan implementation depends on the interaction of many factors, including weather, crop selection, labor and the equipment complement. Rich states that IFSM is the only model that he knows of that can integrate all of these important farm components.

He finds the model easy to use in spite of its complexity. The depth of science incorporated and the tremendous output detail available are very valuable for using the model in research. The documentation and layout of the program provide users with the information they need to design research using IFSM and to interpret the results. Al Rotz has been very open to making changes to the program to accommodate specific research projects. Some changes have resulted in permanent improvements to the model; others have provided temporary means to make planned comparisons.

### **Model Limitations**

Because of model constraints, IFSM use is limited to primarily research and teaching for strategic planning. For example, IFSM defines the farmland base as one big field with one soil type, topography, rotation, etc. The programs incorporate only limited field carryover from one year to the next. Also, the time required to set up and adjust for a particular farm limits use. For instance, getting the right complement of machinery is difficult if the user is setting up a simulation from scratch. Using the representative farm data available with the program does facilitate populating the data set. In addition, some data input choices are limited. For example, the user can only select 0, 6 or 12 months of manure storage. The model complexity and sensitivity require that the user carefully look through the simulation results to evaluate if they make sense.

### **Future Opportunities**

Rich would like to see improvements in N and P loss estimates and transformations. More options (such as manure storage choices) will make the program more flexible. He would also like these farm simulation models to allow more than one field per farm (perhaps two or three) so that the user can vary crop rotations by soil type and topography across the farm. This would be valuable from a research perspective as well as allow these models to be more useful to producers and farm consultants.

### **Program References**

The following is a list of publications describing the major components of the model. A more extensive list can be found in the reference manual of the program.

Borton, L.R., C.A. Rotz, H.L. Person, T.M. Harrigan, and W.G. Bickert. 1995. Simulation to evaluate dairy manure systems. *Appl. Eng. Agric.* 11(2):301-310.

Buckmaster, D.R., C.A. Rotz, and R.E. Muck. 1989a. A comprehensive model of forage changes in the silo. *Trans ASAE.* 32(4):1143-1152.

Buckmaster, D.R., C.A. Rotz, and D.R. Mertens. 1989b. A model of alfalfa hay storage. *Trans ASAE.* 32(1):30-36.

Fick, G.W. 1977. The mechanisms of alfalfa regrowth: A computer simulation approach. *Search Agriculture.* 7(3):1-28.

Fick, G.W. and D.W. Onstad. 1988. Statistical models for predicting alfalfa herbage quality from morphological or weather data. *J. Prod. Agric.* 1(2):160-166.

Harrigan, T.M., W.G. Bickert, and C.A. Rotz. 1996. Simulation of dairy manure management and cropping systems. *Appl. Eng. Agric.* 12(5):563-574.

Harrigan, T.M., C.A. Rotz, and J.R. Black. 1994. A comparison of large round bale storage and feeding systems on dairy farms. *Appl. Eng. Agric.* 10(4):479-491.

Jones, C. A. and J. R. Kiniry (Eds.). 1986. *CERES-Maize: a simulation model of maize growth and development.* Texas A&M Univ. Press. College Station, Texas.

Jones, J.W., K.J. Boote, S.S. Jagtap, and J.W. Mishoe. 1991. Soybean development. In *Modeling Plant and Soil Systems*, eds. J. Hanks and J.T. Ritchie. Agronomy Monograph 31, ASA-CSSA-SSSA, Madison, WI.

Mohtar, R.H., D.R. Buckmaster and S.L. Fales. 1997. A grazing simulation model: GRASIM, A: Model Development. *Trans. ASAE*. 40(5):1483-1493.

Ritchie, J.T. and S. Otter. 1985. Description and performance of CERES-Wheat: A user-oriented wheat yield model. Pp 159-175. In *ARS Wheat Yield Project. ARS-38. Natl. Tech. Info. Serv., Springfield, VA.*

Rotz, C.A., D.R. Mertens, D.R. Buckmaster, M.S. Allen, and J.H. Harrison. 1999. A dairy herd model for use in whole-farm simulations. *J. Dairy Sci.* 82:2826-2840.

Rotz, C.A. 1995. Loss models for forage harvest. *Trans. ASAE*. 38(6):1621-1631.

Rotz, C.A., D.R. Buckmaster, D.R. Mertens, and J.R. Black. 1989. DAFOSYM: a dairy forage system model for evaluating alternatives in forage conservation. *J. Dairy Science*. 72:3050-3063.

Rotz, C.A. and Y. Chen. 1985. Alfalfa drying model for the field environment. *Trans. ASAE*. 28(5):1686-1691.

Savoie, P., L.D. Parsch, C.A. Rotz, R.C. Brook, and J.R. Black. 1985. Simulation of forage harvest and conservation on dairy farms. *Agric. Systems*. 17:117-131.

Sinclair, T.T. 1986. Water and nitrogen limitations in soybean grain production I. Model development. *Field Crops Research*. 15:125-141.

Soder, K.J. and C.A. Rotz. 2001. Economic and environmental impact of four levels of concentrate supplementation in grazing dairy herds. *J. Dairy Sci.* 84:2560-2572.

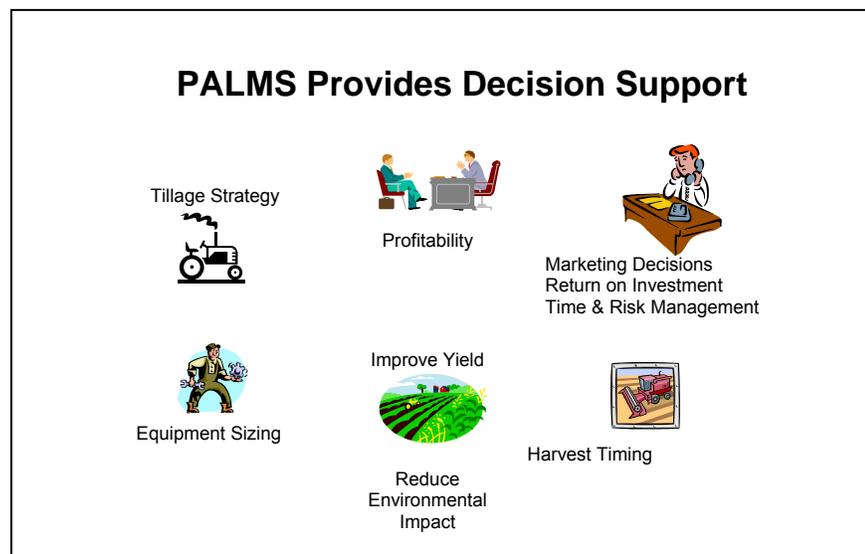
Tsuji, G.Y., J.W. Jones, G. Uehara, and S. Balas (ed.). 1994. *DSSAT version 3*. University of Hawaii, Honolulu, HI.

## PALMS

**Tool Name** Precision Agricultural Landscape Modeling System (PALMS).

**Tool Purpose** The purpose of PALMS is to bring the latest agricultural research to farmers in a meaningful way. PALMS seeks to move away from focusing solely on maximum yield to characterize the tradeoff between productivity and environmental degradation by combining precision modeling with information from precision farming. Spatial variability of soil properties and temporal variability of precipitation are critical pieces of information. These two things are linked together by surface runoff in PALMS.

The developers hope to overcome traditional biases against the usefulness of modeling and form alliances among basic researchers, extension agents, consultants, industry and farmers to create products that will assist in the good management of farms.



**Figure 4.2:** PALMS provides decision support in these areas.

**Developers** Christine Molling, Chris Kucharik, Charles Rodgers, Cristine Morgan, Mark Stelford, John Norman.

**Contacts** Christine Molling, University of Wisconsin, (608) 265-5350, (608) 265-8007, [cmolling@facstaff.wisc.edu](mailto:cmolling@facstaff.wisc.edu). John Norman, University of Wisconsin, (608) 262-4576, [jmnorman@facstaff.wisc.edu](mailto:jmnorman@facstaff.wisc.edu).

### Stage of Development

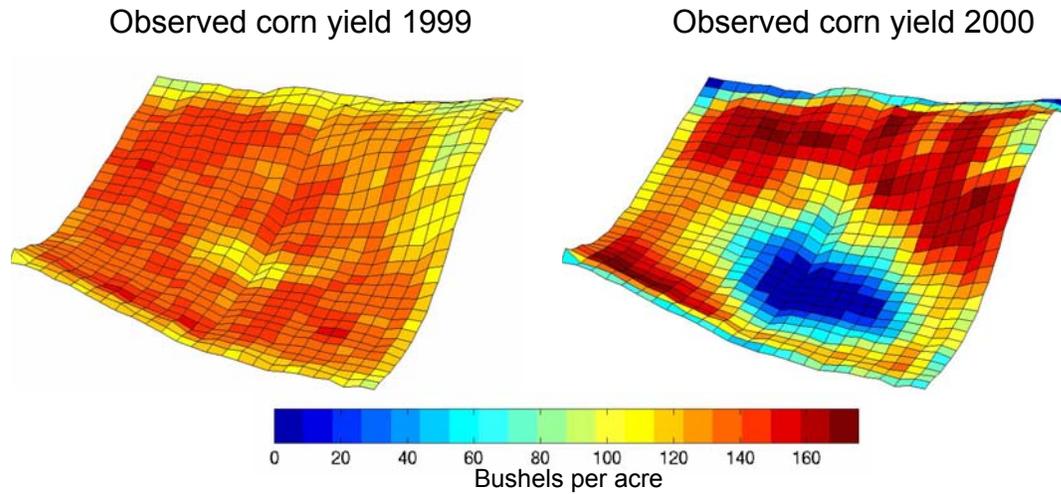
PALMS is in the early stage of product development.

## Focus

Program focus is crops (corn, soybean) and spatial variability of soils over individual fields. Variability is a crucial component. PALMS currently does not include an alfalfa model, but it is being developed.

## Scale

PALMS works primarily at the field scale of up to 100 ha with spatial resolution of about 10 m (Fig. 4.3).



**Figure 4.3:** Landscape variability results in variable yield. But yield varies differently in different years! Note: the blue area on the right indicates a flooded field with dead corn. Traditional crop and hydrologic models cannot simulate variability on this scale. PALMS provides a precision model to go along with our precision farming technology.

CCMolling, 2002

---

## Area of Concern

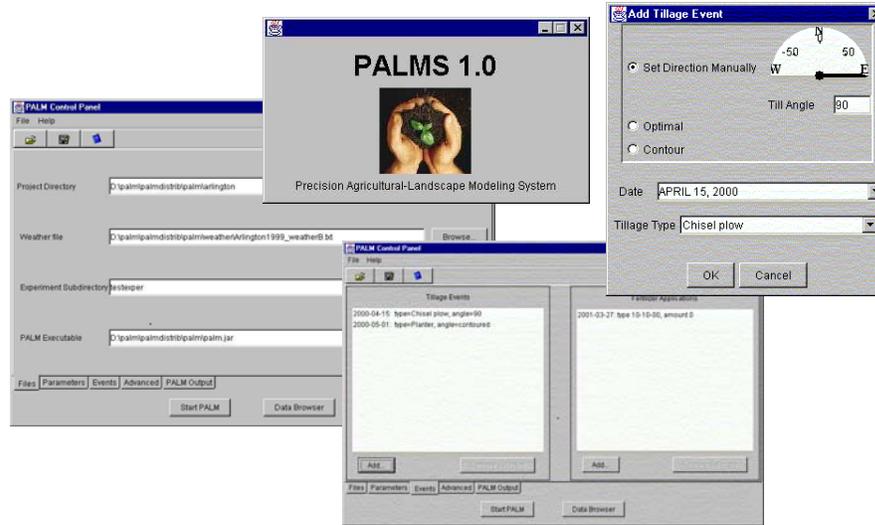
- Environmental impacts of nitrate leaching, P runoff, and erosion.
- Yield, farm logistics related to planting, site-specific management and optimal harvest timing.

## Tool Application: Users

The primary audience is crop consultants who work directly with farmers, but a secondary emphasis is directed toward researchers who could add to the functionality of the tool.

## Tool Application: Format

PALMS is a Fortran program with a Java-based Windows user interface that links program inputs and outputs to a Geographic Information System (Fig. 4.4); currently ARCGIS. PALMS runs on a personal computer.



©CCMolling, 2002

**Figure 4.4:** PALMS graphical user interface.

### Tool Application: Documentation

Documentation is in its earliest stages. PALMS' user manual is intended for the computer literate crop consultant. Currently the documentation does not include equations and references. Publications are being submitted to document new parts of the model, but many aspects of PALMS make use of equations and concepts from the literature.

### Knowledge and Data Transferability: Geographic Transferability

PALMS is a process-level model designed to work in virtually any agricultural field. However, it has not been tested on slopes beyond 30 degrees.

### Data Sharing

Anything in ARCGIS and shapefiles can be used but units might need to be changed or made compatible with PALMS. Sharing with tools compatible with ARCGIS should be possible. Developers would like to be able to easily incorporate other researchers' work to improve predictive capacities. They are looking for easy ways to collect the extensive data input needed.

### Data Inputs

- Weather from an on-site weather station or from the internet: easy; relatively cheap; currently available.
- Crops and Management - record keeping: easy; cheap.
- Topography - a few cm accuracy required, need differential GPS survey: more expensive; currently available.
- 3-D Soil Map – These data are harder to get and more expensive, less available.

### **Tool Outputs: General Information**

PALMS can create an immense amount of output. Trial runs have produced 500 megabytes of output. It is not suggested that so much output needs to be generated for every simulation. The variation across a field can be assessed accurately with a relatively small set of output data.

### **Production Outputs**

- Yield maps.
- Optimal harvest date.
- Plant stress effects.

### **Environmental Outputs**

- Nitrate leaching.
- Drainage.
- Runoff and soon to have erosion and phosphorus loss in runoff.
- Trafficability.
- Soil moisture distribution vertically and horizontally.
- Ice content.
- Ground water levels.
- Soil temperature.
- Crop water use.
- Ponding.
- Aeration stress effects.

### **Economic Outputs**

PALMS does not yet have economic outputs, but the developers intend to include economic costs of various strategies to reduce environmental impact.

### **Tool Limitations**

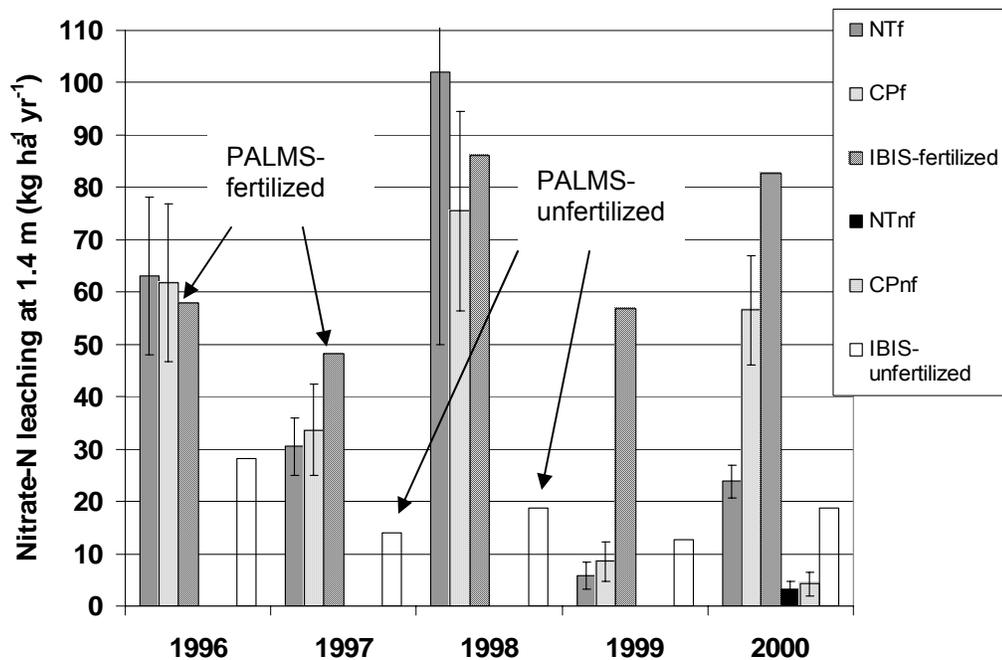
PALMS is not yet available for public use. Extensive inputs are needed especially for the soil and topography but it needs to be released and evaluated by the target audience.

### **Quality of Results**

Only nitrate leaching and phosphorus runoff modules are currently being developed.

### **Field Validation**

Validations of nitrate leaching, soil water distributions, yield, and partial validation of grain moisture content have been done with generally good results. Figure 4.5 provides a comparison of modeled and measured nitrate-N leaching at a depth of 1.4 m in a silt loam soil with economic optimum fertilization of 180 kg/ha under no-till and chisel plow tillage treatments for five years. IBIS is the submodel in PALMS that estimates leaching.



**Figure 4.5:** PALMS modeled and measured nitrate-N leaching.

## Users

The developers have been the only users to date. Potential users have gathered to test the model (See case study assessment, page 35).

## Is This Tool Useful in Meeting Regulatory Requirements?

PALMS does not produce a nutrient management plan, but it is intended to assist with design and placement of buffers to reduce P losses from fields without costing farmers or the public a lot of money.

## Future Plans for Tool

Currently the developers are conducting field measurements of runoff, erosion and phosphorus losses on four farm fields with Discovery Farms to test PALMS and assist the Wisconsin Buffer Initiative. In addition, the model is being used to study runoff, erosion and P losses from four fields at Arlington and working with UW-Platteville on an up-slope, in-field structure to reduce erosion and P losses from a field. This is an ambitious project to assist with the creation of science-based guidelines for the implementation of regulations to limit phosphorus losses from farm fields.

PALMS is well suited to exploiting remote sensing and the developers would like to do more of this.

## **Case Study Assessment**

### **Bill Stangel, Soil Solutions Consulting**

Bill was interested in working with PALMS because he saw it as a great start in attempting to integrate a large number of variables and to express them in a very comprehensive package. He also viewed PALMS as something that farm clients would be able to use. He has used it on a trial basis and is participating in groups involved in looking for funding. Bill believes that models such as this need to be integrated into larger information systems and that PALMS is new enough that opportunity still exists for future integration.

Bill is particularly interested in PALMS ability to address spatial variability and to incorporate what the farmer is actually doing to get predictive scenarios. Bill sees differences between a large-scale research model like DAFOSYM and PALMS: with DAFOSYM, you have to define many of the attributes, essentially build the farm and the land that will grow crops. With the format of PALMS you can potentially overcome the problems of populating a model by utilizing the large body of data the farm may already have, such as spatial yield data and digitized soil surveys used in farm GIS applications.

#### **Other Comments from Bill Stangel**

- Output variables are elegantly expressed in predicted yields, providing a quality of data comparison that is easily checked against a yield monitor.
- The ability to predict runoff and ponding is of great help in reflecting real world situations and provides visual results.
- The ability to play with 'what if' scenarios and to select historic weather conditions (i.e. what if we have another wet/dry year?) is a great feature.
- The model is great for addressing public relations issues.
- Can really talk to a farmer about what his field/operation is contributing rather than saying "Look what's happening downstream".

## V. NUTRIENT MANAGEMENT TOOLS FOR BALANCING NUTRIENTS

### Modified Yardstick

<b>Tool Name</b>	Modified Dutch Yardstick for Wisconsin
<b>Tool Purpose</b>	The Modified Dutch Yardstick is a mass balance tool designed to help farmers identify the sources of nutrients entering and leaving the farm, allowing them to make more informed decisions on how to deal with nutrient loading. It has been used to help Wisconsin farmers find out what their nutrient balances are and how they can reduce positive balances.
<b>Developers</b>	The Modified Yardstick was imported from the Netherlands in the mid 1990's by the Institute for Ag Trade and Food Policy (IATP) in Minneapolis. It was adapted for use in the US by Wisconsin, Minnesota and modified to be easier to use than the original.
<b>Contacts</b>	<p>Mark Muller, Senior Associate Institute for Agriculture and Trade Policy 2105 First Avenue South Minneapolis, Minnesota 55404 phone: (612) 870-3420; fax: (612) 870-4846 email: mmuller@iatp.org</p> <p>Kevin A. Erb University of Wisconsin Cooperative Extension (920) 391-4652 kevin.erb@ces.uwex.edu</p>
<b>Stage of Development</b>	Developed in the Netherlands in 1980's and modified for use in the Upper Midwest in the mid 1990's. The Modified Yardstick is a well-established nutrient balancing tool. It was developed in the Netherlands for use as an Environmental Taxation Tool (i.e. tax penalties or credits based on nutrient surpluses).
<b>Focus</b>	The Modified Yardstick in Wisconsin collects N, P, and K data. Nutrients like sulfur and selenium can be added with modifications.
<b>Scale</b>	The Modified Yardstick focuses on the whole-farm nutrient budget, but animal enterprises can be isolated with some modifications to data collection.
<b>Area of Concern</b>	This software focuses on nitrogen, phosphorus and potassium losses and balances.

### **Tool Application: Users**

The Modified Yardstick is considered simple enough for a farmer to use, but the best method is to work with someone who is trained in data collection and result interpretation.

### **Tool Application: Format**

Excel spreadsheet and paper version.

### **Documentation**

The paper version of the Modified Yardstick has extensive documentation; the electronic version is less detailed.

### **Knowledge and Data Transferability: Geographic Transferability**

The Modified Yardstick can be used on any farm where the farmer has kept decent records. It is targeted to livestock farms, but it is also valid for cash grain operations.

### **Data Sharing**

Most Wisconsin users have added a linked spreadsheet to deal with purchased feeds, and Excel can export data in a number of different formats to fit with other applications.

### **Data Inputs**

Data inputs include the following categories:

- Livestock and animal products.
- Purchased feed products, forages and minerals.
- Sold crops, meat and milk.
- Fertilizers and manure.
- Nitrogen fixated by legumes.
- Environmental inputs.

Figure 5.1 shows example Yardstick input screens.

### **Tool Outputs**

- Basic level: N, P, K surplus (deficit) on a per acre basis.
- Advanced: ability to modify the operation to determine nutrient impacts:
  - How many acres do I need to add to be in a P balance?
  - What happens if I add 50 cows?
  - If I buy hay instead of growing it on my farm, what happens to my overall environmental impact?

Microsoft Excel - blank yardstick.xls

File Edit View Insert Format Tools Data Window Help

Palatino 10 B I U

Table 3 - Estimates for N-Fixing Crops (A3517)

**V. NITROGEN FIXATED BY LEGUMES**  
 Use Table 3 at right to determine the appropriate nitrogen credit for a particular field. Multiply the nitrogen credit by the number of acres. Add all of the legume nitrogen values together to get the total nitrogen fixation on the farm.

TYPE OF LEGUME	ACRES	X	N CREDIT	=	LEGUME N
e.g. alfalfa	100	X	150	=	15000
		X		=	
		X		=	
		X		=	
		X		=	
<b>TOTAL N FIXATION:</b>					

**FORAGES<sup>1</sup>**

Alfalfa <sup>1</sup> : - plants / ft. <sup>2</sup> - - 4 - more (70 - 100%) - 1.5 - 4 (30 - 70%) - 1.5 - less (0 - 30%)	Medium & Fine Soils		Sandy Soils	
	before Sept. 10	after Sept. 10	before Sept. 10	after Sept. 10
	190	150	140	100
	160	120	110	70
	120	90	80	40

Red Clover: ..... 80% of alfalfa credit for similar stands .....  
 Birdsfoot Trefoil: ..... 80% of alfalfa credit for similar stands .....

**GREEN MANURE CROPS<sup>2</sup>**

Sweet Clover (non-harvested): ..... 80 - 120 lbs. N/acre .....  
 Alfalfa: ..... 60 - 100 lbs. N/acre .....  
 Red Clover: ..... 50 - 80 lbs. N/acre .....

Soybeans: 1lb N/acre for each bu/acre of beans harvested up to a maximum credit of 40 lbs N/acre  
 Sweet Clover (harvested): ..... 20 lbs N/acre .....

**LEGUMINOUS VEGETABLE CROPS<sup>3</sup>**

Peas, Snapbeans, & Lima beans: ..... 20 lbs N/acre .....

<sup>1</sup> In the second cropping year following fair and good stands on medium and fine textured soils, you can take a credit of 50 lbs. N/acre.  
<sup>2</sup> The age of the green manure stand should be taken into account when determining what credit to take from the ranges shown. To use red clover as an example, if sown in spring a field where this legume has been seeded one spring and then plowed under the next spring can credit 80 lbs. N/acre. However, if the red clover is summer-seeded, the recommended credit is at the lower end of the range, or 50 lbs. N/acre. If the field has less than 6 in. of growth before tillage, a 20 lbs. N/acre credit is suggested.  
<sup>3</sup> Credit only if residue is left on the field. No credit on sands, loamy sands.



Ready NUM

Microsoft Excel - blank yardstick.xls

File Edit View Insert Format Tools Data Window Help

Arial 12 B I U

**VII. - NUTRIENT TOTALS**  
 Enter the nutrient totals from the previous pages onto the table below. Then add all N, P, and K inputs and outputs to get the total inputs and outputs and the nutrient balances.

Inputs	N (Lbs)	P (Lbs)	K (Lbs)
Purchased Feed Products (pg. 9)			
Fertilizers and Manure (pg. 13)			
N Fixation (pg. 14)			
Deposition (pg. 15)			
Irrigation (pg. 15)			
<b>Total Inputs:</b>			
Outputs	N (Lbs)	P (Lbs)	K (Lbs)
Animals (pg. 4)			
Animal Products (pg. 5)			
Manure (pg. 6)			
Crop Products Sold (pg. 12)			
<b>Total Outputs:</b>			

Calculate nutrient surpluses by subtracting outputs from inputs.

	NITROGEN	PHOSPHOROUS	POTASSIUM
Total Excess (Lbs)			
Total Land Farmed (Acres)			
Excess/Acre (Lbs/Acre)			

Ready NUM

Figure 5.1: Example input pages from Modified Yardstick.

## Tool Limitations

A mass balance can tell you where the manure is going, but it cannot tell you whether it was applied in an environmentally sound manner. Just because a farm is in balance, it does not mean that nutrients are being applied in the right places at the right rates and the right time.

One of the biggest barriers to effective use of the Modified Yardstick is poor farm records. On 17 farms in one Wisconsin study, the heifer:bull calf ratio created from the farm's records was 7:1. In reality this should have shown up as closer to 1:1, but the farmers were not keeping track of the bull calves. Farmers tended to have tax records available, but tax records are not the same as tonnage records. Most records that were used for the Wisconsin study did not come from the farm, but from the supplier (feed mill, dealer, etc.).

Another barrier to effective use is the time it takes to complete the Modified Yardstick. With excellent records readily available, the Modified Yardstick took only ½ hour to complete. On a farm with poor record-keeping, the completion time was closer to 22 hours. *Having an experienced person who knows what records to look for (and where to find them) pays big dividends.* The goal of the Modified Yardstick is to open farmers' eyes and allow them to see where changes can be made.

## Quality of Results

The main impacts of the Modified Yardstick have been in how livestock are fed. Once producers learned that the main source of excess phosphorus was from purchased protein supplements, significant reductions were made.

## Field Validation

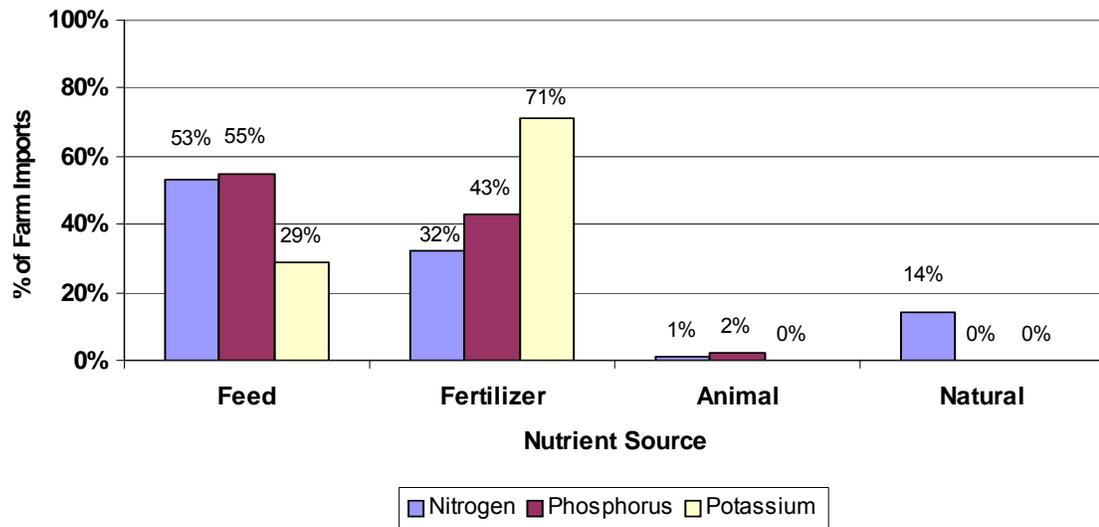
The Modified Yardstick has been used in several studies in the Midwest with accurate results, and the original yardstick has been validated extensively in the Netherlands. The Modified Yardstick was used in several studies in Wisconsin. Figure 5.2 shows a mass balance of nitrogen, phosphorus and potassium on farms in a dairy watershed in Northeastern Wisconsin.

## Users

Farmers have tended to advertise this by word of mouth—it works as a foot in the door, rather than a detailed field analysis. In Wisconsin, potassium data has been the key to getting dairy farmers to use Modified Yardstick results because of fear of milk fever and Ketosis. Crop advisors are currently not using it.

## Is This Tool Useful in Meeting Regulatory Requirements?

A mass balance is currently required by some WPDES large livestock permits, but the Modified Yardstick does not produce a nutrient management plan. There are too many variables to be used in a strict regulatory sense (poor year = low yields = more feed bought). It would be good to look at more than a one year snapshot. It is more important to see the long-term trends.



**Figure 5.2:** Source of nutrients in the Apple-Ashwaubenon Watershed 1997-1998 (Source: Erb, K., 2000).

### Future Plans for Tool

- Integrate the Modified Yardstick functions into Soil Nutrient Application Program (SNAP PLUS).
- Watershed carrying capacity studies.

\*\*\*Please note: there was no case study assessment completed for the Modified Yardstick because of time constraints in the seminar series.

### References

Erb, K., 2000. Mass balance of nitrogen, phosphorus and potassium on farms in a dairy watershed in Northeast Wisconsin. MS Thesis, University of Wisconsin-Green Bay.

Erb, K. and K. Fermanich. 2002. Phosphorus loading per acre versus cow populations in a dairy watershed in northeast Wisconsin. In: SWCS Annual Meeting, July 13-15, 2002, Indianapolis, IN.

Erb, K. and K. Fermanich. 2002. Phosphorus loading per acre vs. cow populations in a dairy watershed in northeast Wisconsin. In: Total Maximum Daily Load (TDML): Environmental Regulations, Proceedings of 2002 Conference, March 11-13, 2002, Ft Worth, TX, ASAE, Miles, MI.

Erb, K. and K. Fermanich. 2002. N, P and K Balances across farm sizes: Do large dairies import more nutrients than small ones? In: Proceedings 2002 WI Fertilizer, Ag Lime and Pest Management Conference, January 2002, Madison, WI.

## N-CyCLE

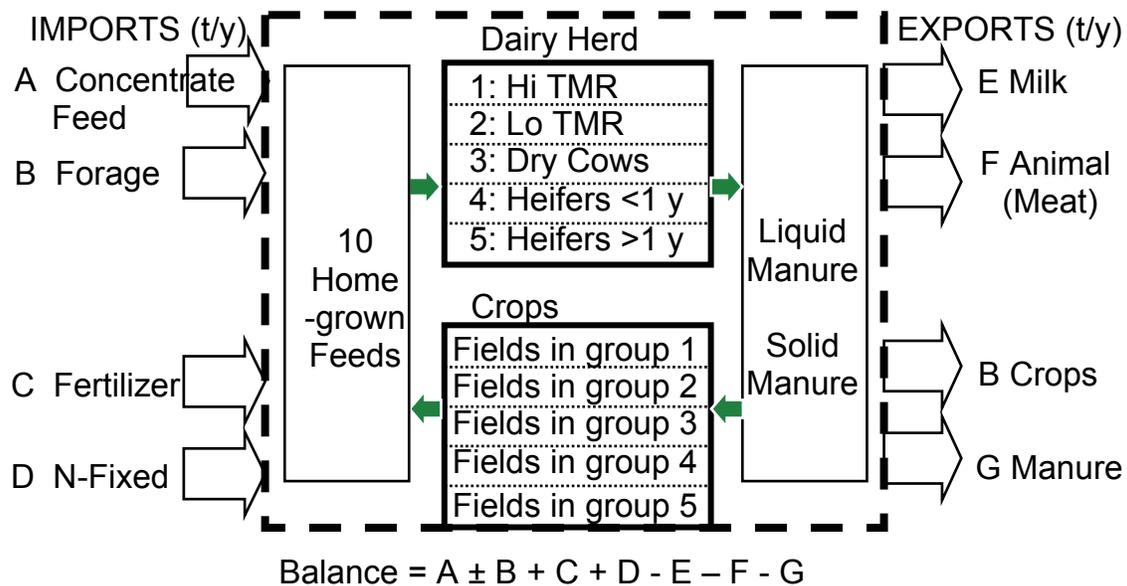
<b>Tool Name</b>	<u>N</u> utrient- <u>C</u> ycling <u>C</u> rops <u>L</u> ivestock <u>E</u> nvironment (Version 2.5).
<b>Tool Purpose</b>	N-CyCLE has evolved through several versions to describe nitrogen and phosphorus flows and balances across the dairy herd, the manure system, the fields, and feed of a farm as a management unit (Fig. 5.3). The latest version of the model finds the best combination of rotations, diets, manure and fertilizer application with the objective of either: (1) maximizing net income, (2) minimizing whole-farm P balance, or (3) minimizing the whole-farm N balance.
<b>Developers</b>	Michel Wattiaux, University of Wisconsin-Madison Doris Pellerin, Université de Laval, Québec, CN Edith Chabornneau, Université de Laval, Québec, CN Sally A. Flis, University of Wisconsin-Madison Vinicius R. Moreira, University of Wisconsin-Madison
<b>Contacts</b>	Michel Wattiaux, Assistant Professor, Dairy Science Department 460 Animal Science Building 1675 Observatory Drive Madison WI 53706 (608) 263-3493 wattiaux@wisc.edu

### Stage of Development

Version one of the tool was an extended least-cost ration formulation model that picked the best combination of crops to grow on a farm when given a land base and the type and amount of purchased feed required to formulate rations to meet nutritional requirement of the herd (Wattiaux, 2001). In addition, N-CyCLE 1.0 estimated manure nutrient production and compared the nutrient requirement of the proposed crops to nutrient availability in manure.

A second version, N-CyCLE 2.0 was constructed as a tool to look at optimizing the flow of N and P in as many as five groups of animals in the herd and five groups of fields (referred to as land management unit) in order to minimize the overall balance on the farm. N-CyCLE 2.0 was capable of optimizing a whole-farm balance rather than just herd nutrition.

N-CyCLE 2.5 provides an economic evaluation of management practices including those related to environmental management of farms such as the cost/benefit of reducing the N balance and the P balance. Version 2.5 also provides a way to compare current practices to an “optimal” set of “Best Management Practices”. A beta version of N-CyCLE 2.5 has been released and is available as a free download at [http://www.dairynutrient.wisc.edu/ncycle/s\\_model.htm](http://www.dairynutrient.wisc.edu/ncycle/s_model.htm). However, the tool is still under construction and any interested user should first contact the developers for details on how to use the model.



**Figure 5.3:** Overview of N-CyCLE v. 2.5, the latest version, showing the farm gate balance across the farm boundary (dotted lines) and the cycling of nutrients between five groups of animals and five groups of fields on a farm.

### Focus

N-CyCLE's focus is on feed, crops, animals and manure as sub-system components that influence the whole-farm economic and environmental performance.

### Scale

The scale is whole-farm.

### Area of Concern

N-CyCLE's objective is to determine the ideal herd feeding program and cropping systems on a farm that minimizes nitrogen and phosphorus surplus and maximize net farm income. As such the tool can be used to explore the relative impact of feeding, cropping, or manure management strategies on economic and environmental performances.

### Tool Application: Users

N-CyCLE was developed as a research and educational tool for teaching, research, extension, and private consultants.

### Format

N-CyCLE was developed on Microsoft® Excel® using *Solver Function* that solves linear and integer models by the *Simplex* algorithm.

## Documentation

The documentation is “in-progress”. The web site (<http://dairynutrient.wisc.edu>) contains three PowerPoint presentations introducing the tool and providing an example of its functionality.

## Knowledge and Data Transferability: Geographic Transferability

The current version of the model can be run for two basic scenarios and sets of conditions (prices, crop rotation and crop yields). One scenario describes the southern Quebec conditions (somewhat similar to conditions in the Northeast, except for prices), and the second scenario describes the conditions prevalent in the Midwest of the USA.

## Data Sharing

Any other spreadsheet tool could easily be linked to N-CyCLE. A compatible spreadsheet can be used as a means to enter data into N-CyCLE and similarly, any N-CyCLE output values could potentially be linked to and used as an input for another spreadsheet based modeling tool.

## Data Inputs

N-CyCLE uses one input sheet with six input sections: (1) herd description, (2) economic inputs, (3) ration guidelines, (4) feed composition, prices, and losses, (5) land units and crop rotation, and (6) manure nutrient management and fertilizers. Table 5.1 describes possible inputs in more detail.

**Table 5.1:** N-CyCLE inputs.

(1) Herd Description	
<i>Herd Structure</i>	<i>Herd Production</i>
Total # cows	Peak milk production, Kg/d
Mature body weight	Fat, %
Calving interval	Protein, %
Culling rate	Other solids, %
Mortality rate (heifers < 1yr)	Management groups (n ≤ 5):
Age at first calving	Groups (3 for cows 2 for heifer):
Groups (4 for cows 1 for heifer):	Early Lactation
Early Lactation	Mid-late lactation
Mid-lactation	Dry cow
Far-off dry cow	Heifers (< 15 months)
Pre-fresh cow	Heifers (> 15 months)
Heifer	
(2) Economic Inputs	
Milk pricing (component based)	Variable Costs (\$/hl) including:
Meat price (\$/hl equivalent)	Breeding fees
Fixed costs (\$/hl) including	Health (veterinarian)
Labor	Bedding
Taxes and Insurances	Supplies
Depreciation	DHI
Interests	Other Costs

**Table 5.1:** N-CyCLE inputs (continued).

(3) Ration Guidelines (5 groups)	
<i>Fiber/Energy</i> Neutral Detergent Fiber (NDF) Forage NDF Non Fiber Carbohydrates (NFC)	<i>Nitrogen</i> Rumen Undegraded Protein (RUP) Rumen Degraded Protein (RDP) Dry Matter intake NRC, 2001 predictions
<i>Minerals</i> P Ca (K + Na) – (Cl + S)	
(4) Feed Composition, Prices and Losses (n≤20) Inputs	
<i>Home-grown feed (and bedding) defined by crop rotation (n ≤ 10)</i> Field and storage losses (%) Corn silage, alfalfa silage, grass legume mix, grass silage Corn stover, straw Corn grain, wheat (barley), Soybean (for roasting)	<i>Purchased feeds (n ≤ 10)</i> Commodity “shrink losses (%) RUP and RDP sources (e.g. Sbex, Sbsol, Urea) By-products (e.g. CoDi, CGM) Energy sources (e.g. CaFat, WCS) Minerals (e.g. CaCO <sub>3</sub> , Ca <sub>2</sub> PO <sub>4</sub> )
(5) Land Unit and Crop Rotation	
<i>Land Units (n ≤ 5)</i> Areas Distance from facilities Soil test P (maximum application above agronomic needs)	<i>Crop rotations (n ≤ 5)</i> User-defined (e.g., CCC; SCC) Yield of each crop in each rotation N, P, K requirements Adjusted for legume credits Cost of production (\$/ha)
(6) Manure Nutrient Management and Fertilizer	
<i>Type of Manure &amp; Storage Facility</i> Liquid Daily Haul Liquid Storage: Covered Uncovered top loaded Uncovered bottom loaded Solid Bedded Pack Stack Compost Manure Management Costs Cost of production (\$/t 0) Cost for exporting (\$/t 100) Cost of spreading (distance from storage)	<i>Method of Manure Spreading</i> Liquid Broadcast, no incorporation Broadcast, incorporated within 2h Band spreading Injection in open slots Knifing in Solid Box spreader, incorporate within 2h Box spreader, no incorporation Purchased Fertilizers (n=4) User-defined (e.g.: 18-46-0; 27-0-0) Nutrient contents (N, P and K) Variable spreading costs/land unit Market prices

## Objective Functions

- To find the best combination of:
  - Rotations for each of the user-defined land units.
  - Manure allocation and fertilizer application.
  - Diets ingredient mix for each user-defined group of animals.
  
- With the objective (select one) to:
  - Maximize net income (\$).
  - Minimize whole-farm phosphorus balance (kg/yr).
  - Minimize whole-farm nitrogen balance (kg/yr). See Table 5.2.

**Table 5.2:** N-CyCLE objective functions.

Optimization functions		Environmental costs
Net income, \$	75,917	
P balance, kg	4,158	\$25/kg
N balance, kg (w/o fixation, manure export)	24,170	
N balance, kg (w/o manure export)	32,352	\$20/kg
Energy used, MJ	215,069,391	\$0/MJ
	-675,090	

## Land/ Crop Constraints

- Land Use (Land available - cropped area)  $\geq 0$  (i.e., crop required land only)  
 $= 0$  (i.e., crop all available land)  
 crop sold  $\leq$  user defined limit
  
- Crop rotation assignment:
  - If binary constraint: one of five proposed rotation per field.
  - If no binary constraint: fractional rotation per field is allowed (that is, crop rotation is optimized assuming all fields can be treated the same for nutrient management purpose).
  
- Crop requirements:  $0 \leq (\text{N, P, K supplied} - \text{N,P,K needed}) \geq$  Legal limits  
 $\geq$  Agronomic limits
  
- Manure produced - manure used – (manure exported) = 0
  
- Nutritional Need (per animal group basis)
 

Min <	Total amount of DM	< Max
Min <	NDF, NFC, Absorbable P, Absorbable Ca	< Max
Min <	FNDF, RUP, RDP, and K	-----
-----	CP	< Max
  
- Adjustable Losses:
  - Home-grown (Field and storage losses).
  - Purchased feed (Shrinkage losses).
  
- Adjustable feed refusals.

## Tool Outputs

Program outputs include net income, and whole-farm N and P balances, optimal rotation plans, a crop fertilization plan, and a feeding program. Example output reports are shown in Figures 5.4, 5.5 and 5.6.

FARM DESCRIPTORS					
<b>Animals</b>					
<b>Animal units (AU)</b>	588	AU	290	Total cows	
Early	148	AU	104	Cows	Grp 1
Mid-Late	208	AU	145	Cows	Grp 2
Dry Cow	59	AU	41	Cows	Grp 3
Heifers	44	AU	112	Heifers	Grp 4
Heifers	128	AU	121	Heifers	Grp 5
<b>Land</b>			<b>Animals per Unit of Land</b>		
Area available	270.0 ha		<b>Animal Density</b>	2.2 AU/ha	
Land Unit 1	100.0 ha		<b>Milk</b>		
Land Unit 2	100.0 ha		<b>Price</b>	15.0 \$/cwt	
Land Unit 3	70.0 ha		<b>Production Cost</b>	9.3 \$/cwt	
			<b>Sold, Total</b>	2,207 T/year	
			<b>Sold, per ha</b>	8,175 kg/ha/y	
			<b>Sold, per cow</b>	9,651 kg/cow/y	
FARM INCOME AND NUTRIENT BALANCES					
<b>Incomes</b>			<b>Expenses</b>		
<b>Incomes</b>	%of total	\$/year	<b>Costs</b>	%of total	\$/year
Milk income	90%	723,497	Herd fixed + variable	63%	454,476
Animals sold	3%	21,394	Feeds (purchased)	18%	125,936
Crop income	7%	55,547	Feed storage	11%	77,102
			Crops	5%	37,324
			Fertilization	3%	22,283
<b>Total income</b>		800,437	<b>Total expenses</b>		717,120
<b>Farm Net Income,</b>		83,317	\$		
<b>Milk+Animal income over Feed costs,</b>		2.25	\$		
<b>Net over Total income</b>		11.2	%		
<b>Phosphorus Imports</b>			<b>Phosphorus Exports</b>		
Feed (Crop) P purchased kg/yr	5,624		Feed (Crop) P sold kg/yr	1,342	
Fertilizer P purchased kg/yr	0		Milk P sold kg/yr	1,986	
			Meat P sold kg/yr	407	
			Manure P export	Set at 0	
<b>Total Imports</b>	5,624		<b>Total Exports</b>	3,736	
<b>P Balance kg/yr</b>	1,889				
<b>Nitrogen Imports</b>			<b>Nitrogen Exports</b>		
Feed N purchased kg/yr	36,628		Feed N sold kg/yr	9,977	
Fertilizer N purchased kg/yr	0		Milk N sold kg/yr	11,382	
Fixed N kg/yr	23,267		Meat N sold kg/yr	1,431	
			Manure N export	Set at 0	
			<b>Total Exports</b>	22,790	
<b>N Balance (w/o BNF), kg/y</b>	13,838.1				
<b>N Balance(w/ BNF), kg/y</b>	37,105.6				

Figure 5.4: N-CyCLE 2.5 outputs: farm descriptors, income and nutrient balances.

RATIONS						FEED	
Feed (% DM)	Grp 1	Grp 2	Grp 3	Grp 4	Grp 5	Purchased	tons/y
CoSi	18.3	12.0	88.3	2.0	53.5		
AlSi	31.9	19.8	5.0	5.1	27.7		
CoGr	33.1	35.6		42.6	11.6	CoGr	528.9
MxH-60		9.2	3.1	32.6		MxH-60	134.7
CaFat				0.6		CaFat	0.4
CGM	5.5	0.0				CGM	48.5
CoDi	10.4	22.7	2.1	16.6	6.9	CoDi	404.6
Urea			1.4	0.3	0.2	Urea	3.4
Ca-C	0.8	0.7		0.2		Ca-C	14.9
DiCa-P			0.1			DiCa-P	0.1
<b>Total</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>	<b>Home-Grown (Fed)</b>	
						CoSi	847.0
						AlSi	725.4
						SBw	86.1
						CoGr	265.6
						Wheat	142.3
						Straw	83.8
						<b>Feed (Crop) Sold</b>	
						CoSi	50.0
						SBw	86.1
						Wheat	142.3
						Straw	83.8
						<b>Summary</b>	<b>Tons/y</b>
						Home-Grown	2150.2
						Purchased	1135.4
						Sold	362.1
Rations Compositions	Grp 1	Grp 2	Grp 3	Grp 4	Grp 5		
DE1x (Mcal/t DM)	3.25	3.28	2.93	3.25	3.02		
EE, (%DM)	4.4	5.1	3.3	5.0	4.0		
FNDF, (% DM)	17.9	17.0	24.0	23.0	24.0		
NDF, (% DM)	30.0	32.0	44.7	34.0	40.0		
NFC, (% DM)	44.0	42.5	38.0	42.0	39.2		
CP, (% DM)	18.7	16.9	13.9	15.4	14.9		
RUP, (% DM)	7.00	6.00	3.91	5.42	4.48		
RDP, (% DM)	11.8	11.0	10.0	10.0	10.5		
Ca, (% DM)	0.84	0.70	0.36	0.53	0.55		
P, (% DM)	0.38	0.42	0.29	0.38	0.33		
K, (% DM)	1.46	1.33	1.30	1.22	1.60		
Mg, (% DM)	0.20	0.21	0.18	0.19	0.21		
Na, (% DM)	0.05	0.09	0.02	0.09	0.03		
Cl, (% DM)	0.31	0.31	0.31	0.35	0.35		
S, (% DM)	0.24	0.23	0.16	0.23	0.19		
DCAD (meq/kg)	156	142	153	100	202		
Energy used (MJ/t DM)	0.00	0.00	0.00	0.00	0.00		
Price, /t DM	\$93.39	\$92.06	\$70.39	\$101.41	\$73.07		
Storage costs, /t DM	\$26.00	\$22.34	\$34.59	\$17.42	\$32.17		
F:C ratio	50.19	40.99	96.45	39.70	81.19		

**Figure 5.5:** N-CyCLE 2.5 outputs: ration composition for each animal group, purchased feeds and home-grown feeds.

ROTATION, FERTILIZERS AND MANURE APPLICATIONS													
Land Unit		Metric Tons/y						Kg/ha					
		Purchased Fertilizer				Manure		Excess Application Rate			Max Excess allowed		
		18-46-0	27-0-0	0-46-0	0-0-60	Solid	Liquid	N	P	K	N	P	K
Land Unit 1	CCCSWAAA	0.00	0.00	0.00	0.00	0	4,994	49	12	36	50	90	100
Land Unit 2	CCCSWAAA	0.00	0.00	0.00	0.00	767	2,371	40	8	10	50	45	100
Land Unit 3	CCCSWAAA	0.00	0.00	0.00	0.00	378	1,625	0	1	-1	50	0	100
								0	0	0	0	0	0
								0	0	0	0	0	0
Total		0.00	0.00	0.00	0.00	1,145	8,991						

Figure 5.6: N-Cycle 2.5 outputs: rotations, fertilizer and manure application and excess application rates.

- Main outputs:
  - Income (\$).
  - P balance (kg/yr).
  - N balance (kg/yr).
- Optimal rotation:
  - The rotation to use in each pre-defined land unit.
- Crop fertilization plan:
  - Type and amount of purchased fertilizer and manure to apply on each land unit.
  - Amount of manure to export (if allowed).
  - Actual excess nutrient application relative to user pre-defined maximum excess allowed.
- Feeding program:
  - Type and amount of purchased feed and home-grown feed to offer each animal group.
  - Amount of home-grown feed to sell (if allowed).

The optimization worksheet, another type of model output, is developed to find the best combination of rotations for each of the pre-defined land units, manure allocation and fertilizer application, or diet ingredient mix for each pre-defined group of animals, with the simultaneous objective of either maximizing net income (\$), or minimizing whole-farm phosphorus balance (kg/yr), or whole-farm nitrogen balance (kg/yr).

The following farm scenario was used to create the output tables in Figures 5.4, 5.5 and 5.6:

- A 270 ha farm with high soil test P in land unit one (no excess of P application), intermediate soil test P in land unit 2 (45 kg/ha excess P application allowed), and low soil test P (90 kg/ha excess P application allowed).
- A 290 cow herd producing 10,000 kg/lactation.
- The following rotations:
  - Corn silage (CS)-Corn grain (CG)-CG.
  - Soybean-CS-CG.
  - CS-CG-Alfalfa-Alfalfa-Alfalfa.
  - CS-CG-CS-Soybean-CG-Alfalfa-Alfalfa-Alfalfa.
  - CS-CG-CS-Soybean-Wheat-Alfalfa-Alfalfa-Alfalfa.

### **Tool Limitations**

The model does not “automatically” account for restrictions imposed by conservation practices. The tool does not account for the “details” of dairy herd feeding, or the “details” of crop fertilization, or the “details” of the economic analysis of a farm, but it provides the long-term optimal and “Best Management Strategies” when a certain herd is “matched” to a certain land base, under a certain set of price conditions.

The input necessary to run the model is knowledge intensive and not yet user friendly. The model has been tested and “validated” using data from only a limited number of “real farms” and it requires additional validation, including sensitivity analyses of proposed overall management strategies. There is also the inherent limitation of linear programming, where everything must be linear and there are no economies of scale built in. As with any model, “garbage in=garbage out”. Currently, N-CyCLE has incomplete estimates of environmental losses, specifically N leaching.

## Field Validation

N-CyCLE needs more field validation before it is put into wider use, but preliminary results have been encouraging. Validation of the tool is taking place with a current study using N-CyCLE to compare Quebec and Wisconsin dairy farms.

## Users

So far, the only users of the tool have been a small group of researchers and the model developers.

## Is This Tool Useful in Meeting Regulatory Requirements?

N-CyCLE does not produce a regulatory plan, but it can evaluate the economic impact of regulatory policies such as requiring a limited P balance and/or reduced ammonia losses. Because N-CyCLE provides the income and environmental performance (balances and/or losses), the tool can be used to estimate the expected loss/gain of income a farm will incur when changes are made to meet certain regulations. Also, the tool can indicate the cost of implementing a nutrient management plan.

## Future Plans for the Tool

Near future changes that would be easily adapted to the current version are:

- Land use studies:
  - Land requirement for different crop rotation systems.
  - Land requirement for farm of increasing animal density.
- Sensitivity analyses:
  - Change in feed/fertilizer market price on feeding and cropping strategies.
  - Change in BMP to maintain a high N/P ratio in manure.
  - Forage quality.
- Quantify losses and soil build-up:
  - Long term change in soil test P.
  - Ammonia-N losses.

An economic and environmental index (the “E<sup>2</sup> index”) is being included in the model to help users explore the tradeoffs between maximizing net income and minimizing the nutrient balance on farms. The E<sup>2</sup> index is being built as a modified net income discounted for a cost associated with surplus(es) whole-farm N and P balances.

\*\*\*Please note, there was no case study assessment completed for N-CyCLE because of time constraints in the seminar series.

## Program References

Wattiaux, M.A. 2001. A simple model to optimize feeding programs and crop rotation of dairy farms. In: Nutrient Management Challenge in Livestock and Poultry Operations: International and National Perspectives. pp 54-69. Babcock Institute 3<sup>rd</sup> Technical Workshop; The Edgewater, Madison WI, August 21-24, 2001.

Wattiaux, M.A. and D. Pellerin. 2003. Optimization of whole-farm nutrient balance; what you see is not always what you get. Nutrition Professionals Annual Meeting, UW-Madison, May 2, 2003. ([http://www.dairynutrient.wisc.edu/ncycle/s\\_model.htm](http://www.dairynutrient.wisc.edu/ncycle/s_model.htm)).

Moreira, V. R., M.A. Wattiaux, D. Pellerin, E. Charbonneau, and S.A. Flis. 2004. N-CyCLE, a tool to study the feeding and cropping strategies of a farm as a single unit of management. Accepted for the 2004 Midwest American Dairy Science Association annual meeting, DeMoines, IA, March 15-17, 2004.

**VI. NUTRIENT MANAGEMENT TOOLS FOR CONSULTANTS AND FARMERS****CNCPS**

<b>Tool Name</b>	Cornell Net Carbohydrate and Protein System (Version 5.0).
<b>Tool Purpose</b>	The Cornell Net Carbohydrate and Protein System (CNCPS) is the herd nutrition component of the Cornell University Nutrient Management Planning System ( <i>cuNMPS</i> ) that was developed for use in designing whole-farm nutrient management plans. The CNCPS is a nutrition model designed to formulate farm specific feeding programs for all classes of beef, dual purpose and dairy cattle based on consideration of the existing animals, feeds, management and environmental conditions. In addition to evaluating and improving rations for each group in the herd, the CNCPS is designed to predict whole-herd annual feed requirements, nutrient excretion in total and from purchased and homegrown feeds. This information can be used to plan annual home-grown crops and purchased feed requirements, and the impact of various combinations of home-grown and purchased feeds, herd size, and milk production level on annual returns over feed costs and nutrient balances.
<b>Developers</b>	Integrated model: Danny Fox, Luis Tedeschi, Tom Tylutki. Cattle requirements: Danny Fox, Tom Tylutki, Luis Tedeschi, Michael Van Amburgh. Rumen fermentation: James Russell, Ronald Pitt, Luis Tedeschi. Feed composition: Charles Sniffen, Danny Fox, Peter Van Soest, Alice Pell, Larry Chase, Luis Tedeschi, Tom Tylutki. Amino acid requirements: Danny Fox, William Chalupa, Tom Overton.
<b>Contacts</b>	D.G. Fox, Professor Animal Science Department 130 Morrison Hall Cornell University Ithaca, NY 14853 (607) 255-2855 dgf4@cornell.edu

**Stage of Development**

The CNCPS model has been developed by a team of 12 scientists and 40 graduate students over the past 25 years. The CNCPS model equations are used by 3 major computer programs:

- CNCPS VERSION 5.0 ([www.cncps.cornell.edu](http://www.cncps.cornell.edu)).
- CPM DAIRY (Cornell Penn Miner, contact [ejjancze@vet.upenn.edu](mailto:ejjancze@vet.upenn.edu)).
- Dalex computer systems for the feed industry ([www.dalex.com](http://www.dalex.com)).

**Focus**

The focus of the CNCPS is to reduce whole-farm N and P mass balance through precision feeding of the whole-herd and utilization of home-grown feeds. The program computes farm specific nutrient requirements. Whole-herd feed budgets and nutrient excretions are calculated.

**Scale**

The scale is whole-farm.

**Area of Concern**

Purchased feed accounts for the largest volume of nutrients that come onto a dairy farm. Using the CNCPS model to develop farm specific, nutrient-efficient diets has proven to be an effective way to decrease excess farm nutrients. The quantity of ammonia nitrogen, organic nitrogen, phosphorus, and potassium in the urine and feces is modeled. The impact of diet changes on profitability is estimated by program reported income over feed cost values for the whole-farm and each feeding group.

**Tool Application Users**

The users of the CNCPS model have training in ruminant nutrition. Feeding consultants use it to evaluate and improve feeding programs and diagnose feeding related problems. The CNCPS model is also used as a teaching tool for students and consultants. Research use includes setting research priorities and designing and interpreting experiments. Researchers also use the model to apply research results.

**Tool Application Format**

The CNCPS is a stand-alone, Windows-based tool developed in Visual Basic 6.

**Tool Application Documentation**

The CNCPS model is fully documented. Program context sensitive help is available as well as a comprehensive, hard copy, user-manual (Cornell Animal Science Bulletin 213). The manual and in-program help includes all model equations, program logistics, feed dictionaries and references. The CNCPS CD also contains the journal articles relating to the model and six farm and animal type specific tutorials. The model documentation and equations are technical by definition. Program use and tutorial documentation is non-technical. Program use and content support is available from developers via telephone, email and on the Internet (<http://www.cncps.cornell.edu>). The model requires a large set of input data, including animal and group parameters, feed amounts and analyses, and environmental and management conditions.

**Knowledge and Data Transferability: Geographic Transferability**

Inputs and outputs in CNCPS 5 are universal for all cattle types. CNCPS is being used in 42 countries. Major regional variables that need to be determined are certain feed characteristics such as feed chemical analysis information. Feed libraries have been developed to accommodate regional differences (i.e. North America, UK, Brazil, Mexico, South Africa, Korea, Japan). All other variables are site specific and are entered by the user to characterize the animal, group, and farm management and environmental conditions.

## Data Sharing

The CNCPS is a member of a suite of programs, the Cornell University Nutrient Management Planning System (*cuNMPS*). The other currently available *cuNMPS* program is Cornell Cropware. The CNCPS 5.0 is designed to address NY NRCS 592 standards by minimizing excess N and P on the farm through diet manipulation. Cornell Cropware helps nutrient management planners to balance crop nutrient needs with manure and fertilizer availability and to allocate nutrients based on field environmental risk assessments (NY P index and the N leaching index) according to NY NRCS 590. Although the CNCPS and Cropware have compatible data structures and a consistent user interface, the two programs do currently not share data. Data integration and expanded suite development, including a feed management tool, are planned for future versions.

## Data Inputs

Factors used to compute farm specific maintenance requirements:

- Animal body weight.
- Physiological state:
  - Dry.
  - Lactating.
  - Compensating.
- Acclimatization:
  - Previous temperature.
- Heat or Cold stress:
  - External Insulation:
    - Coat Condition.
    - Wind speed.
    - Hide Thickness.
  - Internal Insulation:
    - Condition Score.
    - Age.

Factors used to compute farm specific growth requirements and body reserves:

- Average body weight of the group.
- Average mature size of the group.
- Target age at first calving.
- Body condition score.

Factors used to compute farm specific pregnancy and lactation requirements:

- Expected birth weight and days pregnant are used to predict pregnancy requirements.
- Amount and composition of milk are used to compute lactation requirements.

Feed amounts and analyses to determine energy and protein supplied to the animal:

- Dry matter.
- Ash.
- Neutral detergent fiber (NDF).
- Ether extract.
- Lignin.
- Starch.

- Crude protein.
- Soluble crude protein.
- Non-protein nitrogen.
- NDF protein.
- Acid detergent fiber (ADF) protein.

### **Tool Outputs**

The CNCPS computer program has 3 components: (1) the CNCPS computer model computes nutrient requirements and supply; (2) the feed library contains over 150 feeds with composition values needed to use the CNCPS, and (3) the user's guide provides a tutorial with model equations and case studies. Outputs include calculated animal requirements, nutrients supplied by the diet to meet animal requirements, nutrient balances, nutrient excretion, feed requirements and costs. See example CNCPS outputs in figures 6.1, 6.2, 6.3, and 6.4.

### **Animal Requirements**

- Predicts maintenance requirements for breed type and environmental conditions.
- Computes growth requirements for any mature size.
- Predicts requirements for days pregnant.
- Predicts requirements for target milk amount.
- Predicts energy reserves fluxes to account for positive or negative energy balance.

### **Nutrients Supplied by the Diet to Meet Animal Requirements**

- Computes carbohydrate and protein fractions available for rumen fermentation from each feed.
- Uses a mechanistic rumen model to predict microbial growth and energy and protein absorbed from each feed.

### **Nutrient Balances**

- Energy and protein allowable growth and milk production.
- Nitrogen balances:
  - Rumen ammonia (critical to maximize fiber digestion).
  - Rumen peptides (maximize microbial protein produced from grains).
  - Absorbed amino acids (meet animal tissue and milk requirements).
- Mineral balances.

### **Nutrient Excretion**

- N, P and K excreted for each group.
- N, P, and K excreted by whole-herd.
- % of N, P, and K fed that is purchased.
- Total herd manure production.

### **Herd Feed Requirements and Costs**

- Annual requirement for each diet ingredient:
  - By group.
  - For total herd.
- Daily and annual feed cost and return over feed.

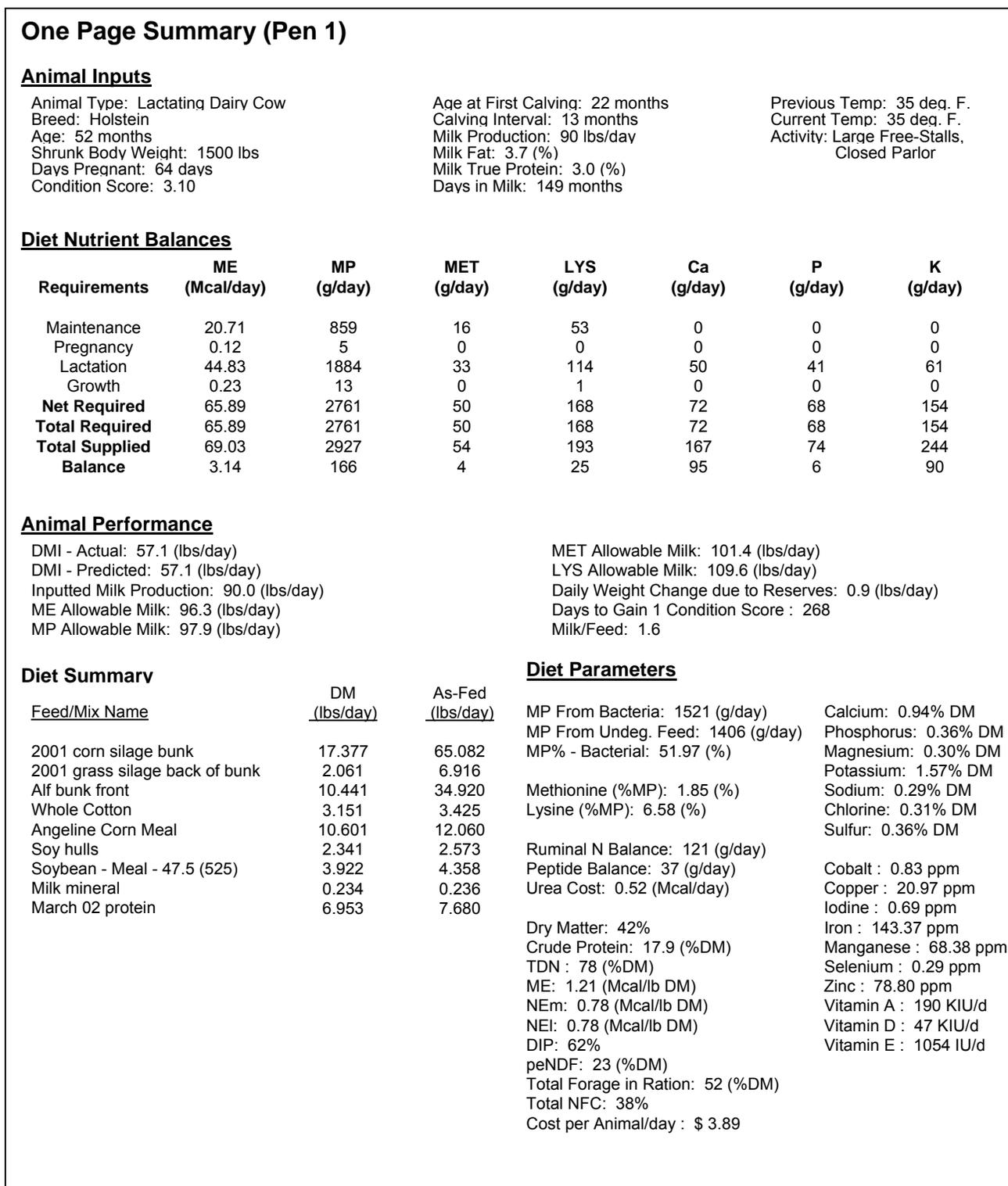


Figure 6.1: CNCPS example output: group one page summary.

## Diet Evaluation (Pen 1)

### Ration Nutrients Supplied and Required

	ME Available	ME Required	ME Balance	MP Available	MP Required	MP Balance
	(Mcal/day)			(g/day)		
Total	69.03	65.89	3.14	2927	2761	166
Percent Difference			104.77%			106%
Maintenance	69.03	20.71	48.32	2927	859	2068
Pregnancy	48.32	0.12	48.20	2068	5	2063
Lactation	48.20	44.83	3.37	2063	1884	179
Gain	3.37	0.23	3.14	179	13	166
Reserves	3.14	0.00	3.14	166	0	166

### Intake and Performance Predictions

Predicted Dry Matter Intake : 57.1 (lbs/day)  
Actual Dry Matter Intake : 57.1 (lbs/day)

Predicted Maximum Forage Intake : 31.9 (lbs/day)  
Entered Forage Intake : 29.9 (lbs/day)

Target ADG (with Conceptus) : 0.05 (lbs/day)  
ME Allowable Gain (with Conceptus) : 0.05 (lbs/day)  
MP Allowable Gain (with Conceptus) : 0.76 (lbs/day)  
MET Allowable Gain (with Conceptus) : 0.97 (lbs/day)  
LYS Allowable Gain (with Conceptus) : 1.71 (lbs/day)  
Days to Gain 1 Condition Score : 268  
Milk/Feed: 1.6

Entered Milk Production : 90.0 (lbs/day)  
ME Allowable Milk : 96.3 (lbs/day)  
MP Allowable Milk : 97.9 (lbs/day)  
MET Allowable Milk : 101.4 (lbs/day)  
LYS Allowable Milk : 109.6 (lbs/day)  
Daily Weight Change due to Reserves: 0.9 (lbs/day)

### Diet Concentrations and Rumen Balances

Physically Effective NDF Req. : 13.1 (lbs/day)  
Physically Effective NDF Sup. : 13.2 (lbs/day)  
Physically Effective NDF Bal. : 0.0 (lbs/day)  
peNDF : 23 (%DM)  
NDF in Ration : 34.5 (%DM)

MP From Bacteria: 1521 (g/day), 52 (% MP Sup.)  
MP From Undeg. Feed : 1406 (g/day), 48 (% MP Sup.)  
Diet CP : 17.9 (%DM)  
Ration Dry Matter : 42%  
NDF : 1.3 (% Body Weight)

Diet ME : 1.21 (Mcal/lb DM)  
Diet NEI : 0.78 (Mcal/lb DM)  
Diet NEm : 0.78 (Mcal/lb DM)  
Diet NEg : 0.51 (Mcal/lb DM)

Total DIP : 61.8 (% CP)  
Soluble Protein : 37.7 (% CP)  
Total NFC in Ration : 37.5 (% DM)  
Total Fat in Ration : 4.5 (% DM)

Ruminal N Balance : 121 (g/day)  
Peptide Balance : 37 (g/day)  
Methionine Balance : 4 (g/day)  
Lysine Balance : 25 (g/day)

Ruminal N Balance : 130 (% of Req.)  
Peptide Balance : 119 (% of Req.)  
Methionine : 108% of Required  
Lysine : 115% of Required

**Figure 6.2:** CNCPS example output: diet evaluation.

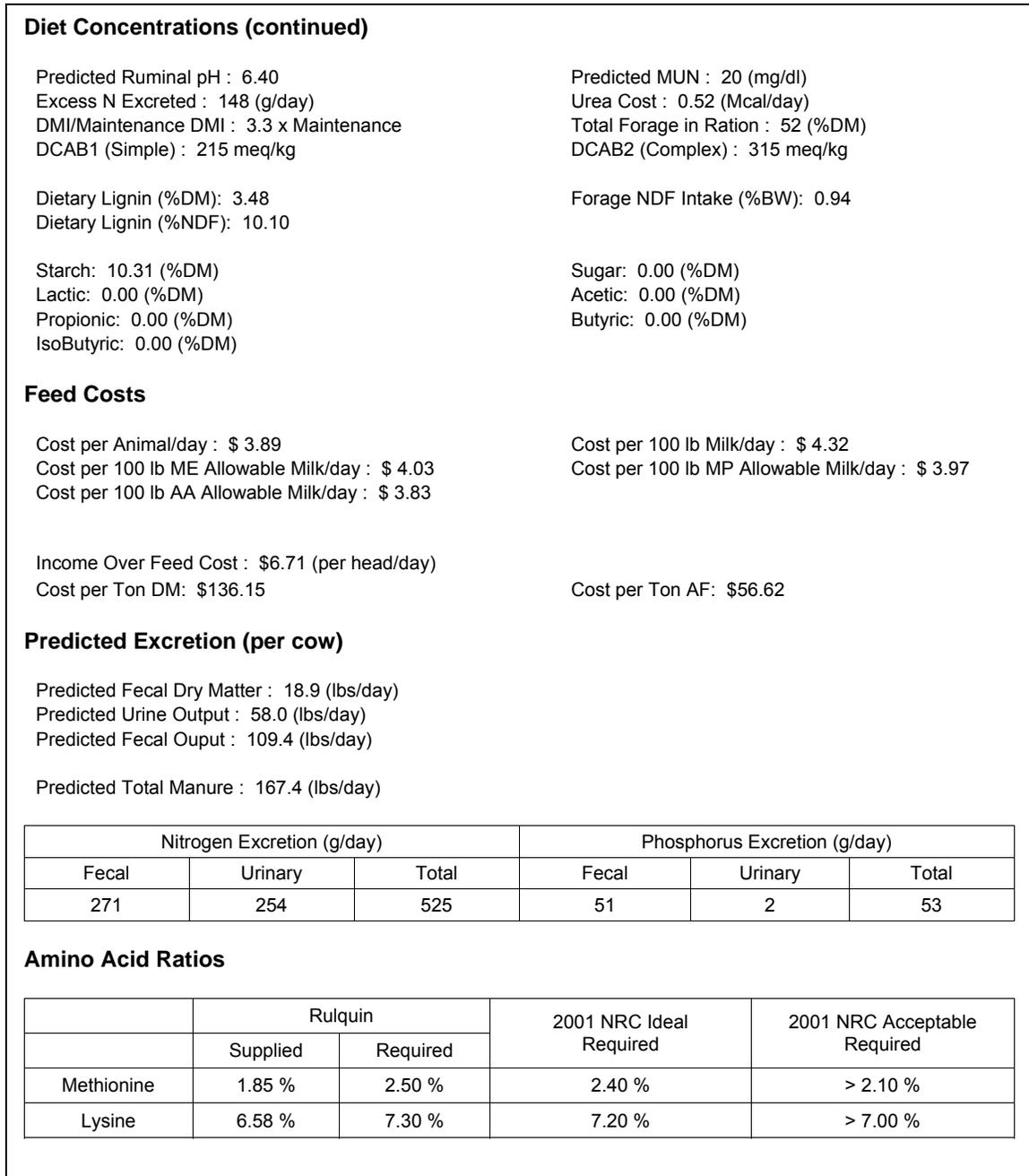


Figure 6.2: CNCPS example output: diet evaluation (continued).

## Whole-Herd Analysis

### Herd Analysis

Number of Cattle in Herd : 914  
 Annual Milk Production : 12,265,826 lbs/yr  
 Average Gain of Growing Cattle : 1.58 lbs/day  
 ME Balance (All Groups) : 0.37 Mcal/cow/day  
 ME Required (All Groups) : 39.71 Mcal/cow/day

Daily Milk Production : 33,605 lbs/day  
 Average Milk Production of Lactating Cattle : 77.3 lbs/day  
 Average Shrunk Body Weight of All Cattle : 1165 lbs  
 ME Balance (Lactating Groups) : 0.31 Mcal/cow/day  
 ME Required (Lactating Groups) : 59.83 Mcal/cow/day

### Rations

Percentage of Home-grown Feeds : 61.3 %  
 Average Ration Cost for Milk Production : 6.39 \$/cwt  
 Total Ration Cost of Herd : 2,146.17 \$/day

Percentage of Purchased Feeds : 38.7 %  
 Average Ration Cost for Gain : 3.48 \$/lb  
 Total Ration Cost of Herd : 783,351 \$/yr

### Nutrients

	Nitrogen	Phosphorus	Potassium
Average Percent Purchased	51 %	47 %	25 %
Excreted (lb/yr)	227,350	27,288	183,261
Urinary (lb/yr)	99,742	930	152,620
Fecal (lb/yr)	127,608	26,358	30,641
Product (lb/yr)	70,764	14,560	18,959
Efficiency of Nutrient Use	24 %	35 %	9 %

### N, P and K Content of Farm Produced Feeds

	Nitrogen (Tons/yr)	Phosphorus (Tons/yr)	Potassium (Tons/yr)
Farm Produced Feeds	75.5	10.9	76.0
Excreted - Farm Produced	38.1	2.7	15.7

### Manure (Wet)

Predicted Fecal Output : 11,044 Tons/yr      Predicted Total Manure : 17,989 Tons/yr  
 Predicted Urine Output : 6,945 Tons

### Whole-Herd Feed Requirements (Metric Tons, As-Fed/yr)

Feed Name	Fresh	High	Group Total
Corn Sil. 40% GR - Medium grnd (308)	541.8	0.0	935.2
Alfalfa Sil - M. Bloom (218)	470.5	0.0	812.1
Orchardgrass - Hay, L. bloom (107)	192.3	641.2	973.0
Corn Gnd. - Grain56 (407)	101.6	161.0	410.1
Soybean - Meal - 49 (525)	99.3	173.8	417.4
Cottonseed - High Lint (507)	4.9	88.7	93.6
Protein Mix	226.4	0.0	378.3
Weighbacks	0.0	0.0	0.0
Medium Mineral	0.0	0.0	2.4
Dry Cow Mineral	0.0	0.0	0.0
Heifer Mineral	0.0	0.0	0.0
Prefresh Mineral	0.0	0.0	0.0
Calcium - Carbonate (805)	0.0	18.2	18.2
Dicalcium - Phosphate (810)	0.0	0.0	0.0
Totals	1636.9	1082.9	4040.2

Figure 6.3: CNCPS example output: whole-herd analysis.

## Tool Limitations

Tool limitations are discussed in more detail by Tom Tylutki in the Case Study Assessment on page 62. The primary tool limitations cited by Tylutki and other users are the large number of data entries needed, the sensitivity of the model to key inputs, such as dry matter intake, and the cost of the detailed feed analyses required for accurate model use.

## Field Validation

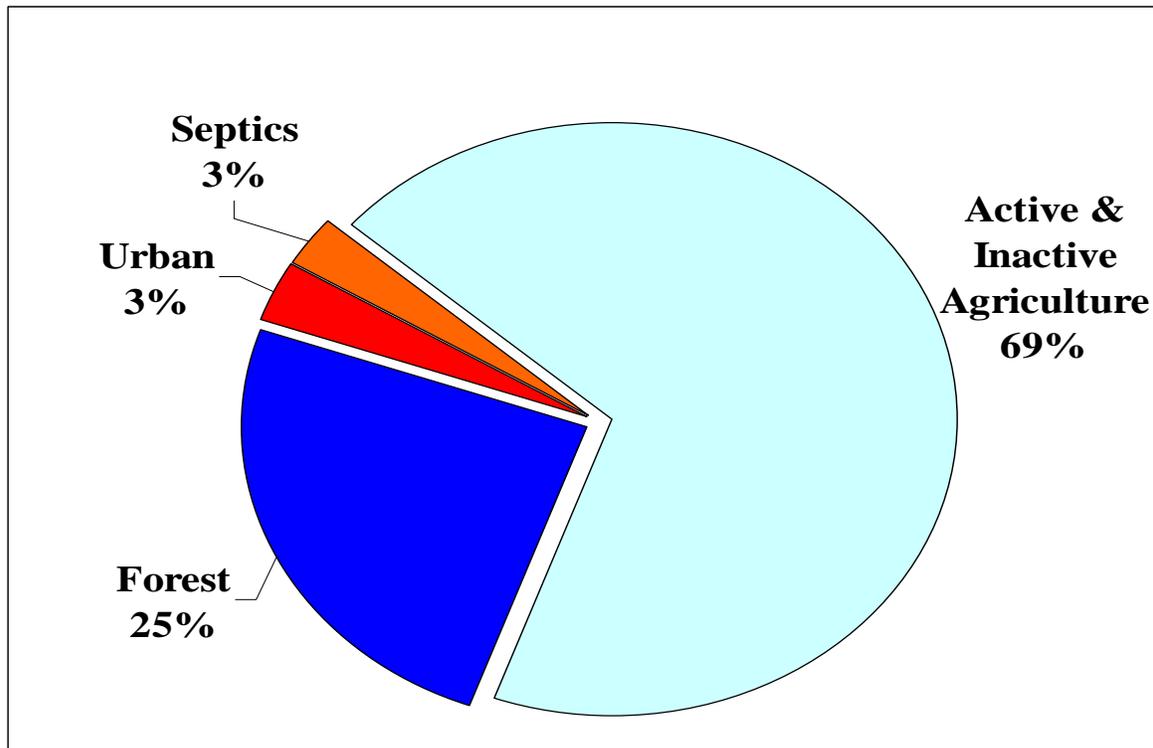
Feeding consultants have found that with accurate inputs, CNCPS can predict actual milk production within 1 to 2 lbs/day. Users typically report an increase in milk production of 4 to 9 lbs/head/day when the CNCPS is used to identify factors that are limiting milk production. Evaluations of the CNCPS have been reported in 19 peer-reviewed papers (<http://www.cncps.cornell.edu/cncps/main.htm>). The whole-farm components including feed use and excretion have been evaluated on several case study farms (Klausner et al., 1998; Tylutki and Fox, 1997; Tylutki et al., 2003; Wang et al., 2000a, 2000b; Fox et al., 2004). Generally, using CNCPS on the case study farms has resulted in reduction of N and P in the manure by one third and reduced feed costs \$50 to \$130/cow/year. A 5 year study (Tylutki et al., 2004) evaluating the implementation of the CNCPS and Cornell Cropware on a case study farm had positive nutrient management and farm profitability impacts (Table 6.1).

**Table 6.1:** Potential for precision feed management by implementing *cuNMPS* tools (Tylutki et al. 2002, 2004).

	Purchased feed \$/day	Milk lbs/year	Nitrogen lbs/year	Phosphorus lbs/year
Before	1813	27,622	309,043	43,435
After	1375	40,167	256,349	31,192
% change	-34.2	45	-17.1	-28.2

Farm specific nutrient management guidelines make sense in New York State's diverse landscape. The *cuNMPS* is currently being studied on a watershed-wide project. The objectives of the *Phosphorus Reduction Through Precision Animal Feeding* program underway in the Cannonsville Reservoir Watershed are to investigate and implement strategies to improve the phosphorus mass balance on dairy farms by reducing the imported and excreted (manure) P and improving P cycling within the farm. The Cannonsville Reservoir is part of the drinking water supply for New York City. The US EPA has designated the reservoir "Phosphorus Restricted" resulting in total maximum daily load (TMDL) restrictions. Modeling research has indicated that the major source of phosphorus to the reservoir is agricultural activities (Fig. 6.4).

On the cooperating farms, 18 to 41 kg of feed P was imported per cow annually. When diets were adjusted using the CNCPS, manure P content was reduced 33%. With 7,000 to 8,000 mature cows in the Cannonsville Reservoir Basin, a potential of 9 kg per cow reduction would result in a 64,000 to 73,000 kg reduction in P excreted in manure each year.



**Figure 6.4:** Cannonsville Reservoir non-point phosphorus load sources.

### Users

The estimated number of users of the CNCPS model is over 2000 worldwide, and over 500 users of version 5 and CPM Dairy in New York State. The CNCPS is used primarily by nutritional consultants. The CNCPS model is also used as a teaching tool for students and consultants. Research use includes setting research priorities and designing and interpreting experiments. Researchers also use the model to apply research results.

### Is This Tool Useful in Meeting Regulatory Requirements?

New York CAFO-sized farms and farms that participate in conservation programs are required to follow NY NRCS Standards. The CNCPS addresses the NY NRCS 592 Feed Management Standard, which specifies that producers use Land Grant University recommendations to:

- Meet animal requirements while reducing the N and P excreted in manure.
- Improve net farm income by feeding nutrients more efficiently.
- Optimize use of forages and concentrates grown on the farm to minimize nutrient imports.

### Future Plans for Tool

The CNCPS developers plan to:

- Keep refining the CNCPS to improve accuracy in predicting cattle requirements, feed biological values, and nutrient excretion.
- Improve user friendliness.

- Increase use by the feed industry in NY.
- Integrate with other *cu*NMPS tools (Cornell Cropware and Whole-farm Feed Management).
- Link with whole-farm and watershed management tools.

## Case Study Assessment – Tom Tylutki, Venture Milling

Tom Tylutki works as a research support specialist in the Department of Animal Science, as a consultant to Venture Milling (a subsidiary of Perdue Farms) and as an independent consultant to individual farmers.

### Tool Use

- *Feed industry product development and testing* - Tom uses the CNCPS in his feed industry work for ration formulation, ration evaluation, trial design and product development. Venture Milling has developed feed products based upon the model and subsequently used the CNCPS model to implement these products.
- *Farm consultant* - Tom considers CNCPS to be a powerful tool for a consultant. He uses it for ration formulation, ration planning and trouble shooting. Tom has linked the CNCPS with his own spreadsheet to do forage allocation across the whole-herd. The program is especially powerful when considering “what-ifs” and troubleshooting. Examples of alternatives that he considers are changes in herd size, forage quality and quantity, animal grouping, target feeding, and feed processing. Tom also uses the model to look at a “snapshot” of a herd when there is a problem. In this way, health problems such as acidosis or sub-clinical acidosis, poor forage quality and poor feeding management can be diagnosed and solutions identified. He finds that using the CNCPS to formulate rations typically increases income over feed cost.
- *Whole-farm planning* - Additionally, the CNCPS is used to decrease nutrient excretion. Tom typically does not recommend inorganic P supplements, aiming for lactating diets with 0.32% to 0.37% P in the dry matter in lactating diets. In one of his farms used as a case study on improving the CNCPS, manure P was reduced 30%. At this time, nutrient management is not a primary consideration for the feed industry or private consulting nutritionists. Feed production and ration formulation decisions are driven by maximizing gross farm income by maximizing milk production, milk fat and milk protein. If there is a decrease in milk, there is a decrease in gross income and the consultant loses the client. This is especially important when trying to decrease N excretion. Some excess protein is in the diet for safety factor because the risk of decreased production is too high due to variability in animal requirements and feed composition. However, diet protein quantities can be fine-tuned using CNCPS because the model matches carbohydrates and amino acids to maximize microbial protein production.

### Model Limitations

The primary model limitation is that it requires a substantial investment in time, data gathering and entry, and forage analysis. The time actually required to enter initial data inputs is modest (20 minutes to an hour per farm) if the data are available. However, Tom’s experience is that collecting the detailed data required can initially take 8 to 20

hours per farm. CNCPS also requires a complete analysis for each feedstuff. The CNCPS feed dictionary and feed company provided analyses can be used for purchased feedstuffs but farm produced feedstuffs should be tested by a feed analysis laboratory. The cost of laboratory analysis can vary from \$20 per sample for near infra-red (NIR) analysis to \$100 per sample for wet chemistry analysis that includes volatile fatty acids and NDF in vitro digestibility analysis.

### **Future Opportunities**

In future versions, Tom would like to see the following changes:

- A more efficiently designed interface would allow for the entry of fewer inputs. Currently there are a lot of repetitive inputs between groups. The next version (6) is being redesigned to limit user entry of inputs that remain static from group to group.
- An improved optimizer - the current optimizer in the CNCPS uses a linear solution to minimize feed costs. However, the CNCPS model equations are not strictly linear and the resulting optimal solution is not stable. In addition, it would be useful to optimize across multiple groups. The optimizer should be made more flexible, allowing the user to choose to minimize nutrient excretion or maximize whole-farm income.
- Electronic transfer of inputs. Feed analyses could be electronically transferred from analytical laboratories, and animal parameters and dry matter intake information could be obtained from farm records and feed management records. Environmental data such as temperature, humidity and wind speed can be electronically linked via remote sensing devices.
- More training and user support is needed.
- Economic analyses can be improved and integrated into whole-farm analysis.

### **References**

Cerosaletti, P.E., D.G. Fox, L.E. Chase and D.C. Frazier. 2003. Precision feed management and its role in watershed protection. Proc. 2003 Cornell Nutrition Conference pp. 251-259.

Fox, D.G., L.O. Tedeschi, T.P. Tylutki, J.B. Russell, M.E. Van Amburgh, L.E. Chase, A.N. Pell, and T.R. Overton. 2004. The Cornell Net Carbohydrate and Protein System Model for evaluating herd nutrition and nutrient excretion. *Animal Feed Science and Technology* 112: 29-78.

Houser, J.B., R.E. Pitt, J.L. Hutson and P.E. Wright. 1996. Integrating knowledge to improve dairy farm sustainability VI: Measuring nutrient loads from a drainage basin within the farm boundaries. In: Dairy farm sustainability final report. Cornell University Animal Science Mimeograph Series 188.

Hutson, J.L., R.E. Pitt, R.K. Koelsch, J.B. Houser, and R.J. Wagenet. 1998. Improving dairy farm sustainability II: Environmental losses and nutrient flows. *J. Prod. Agric.* 11:233-239.

Klausner, S.D. 1993. Mass nutrient balances on dairy farms. Pages 126-129 in Proc. Proc. Cornell Nutr. Conf. Feed Manuf., Rochester, NY. Cornell Univ., Ithaca, NY.

Klausner, S.D., D.G. Fox, C. N. Rasmussen, R. E. Pitt, T. P. Tylutki, P.E. Wright, L.E. Chase, and W.C. Stone. 1998. Improving dairy farm sustainability I: an approach to animal and crop nutrient management planning. J. Prod. Agric. 11:225-233.

Tylutki, T.P. and D.G. Fox. 1997. Application of the Cornell Nutrient Management Planning System: Optimizing herd nutrition. Proceedings of Cornell Nutrition Conference for Feed Manufacturers, Rochester, NY. pg: 54-65.

Tylutki, T.P., D.G. Fox and M. McMahon. 2004. Implementation of nutrient management planning on a dairy farm. Professional Animal Scientist 20:58-65.

Valk, H., J.A. Metcalf, and P.J.A. Withers. 2000. Prospects for minimizing phosphorus excretion in ruminants by dietary manipulation. J. Environ. Qual. 29:28-36.

Wang, S.-J., D.G. Fox, D.J.R. Cherney, L.E. Chase, and L.O. Tedeschi. 2000a. Whole-herd optimization with the Cornell net carbohydrate and protein system. II. Allocating home-grown feeds across the herd for optimum nutrient use. J. of Dairy Sci. 83:2149-2159.

Wang, S.-J., D.G. Fox, D.J.R. Cherney, L.E. Chase, and L.O. Tedeschi. 2000b. Whole-herd optimization with the Cornell net carbohydrate and protein system. III. Application of an optimization model to evaluate alternatives to reduce nitrogen and phosphorus mass balance. J. of Dairy Sci. 83:2160-2169.

## Cornell Cropware

<b>Tool Name</b>	Cornell Cropware Version 2.0 (released July 2003).
<b>Program purpose</b>	Cornell Cropware is a software tool developed to help nutrient management planners and the producers they work with make more efficient use of manure and fertilizers. Cropware is used by farmers and their advisors to develop nutrient management plans in accordance with the NRCS standard for nutrient management (New York NRCS 590). Cropware integrates the following for effective nutrient management planning: the Cornell crop nutrient guidelines for a full range of agronomic and vegetable crops; nutrient credits from many sources, including manure, soil, sod, and fertilizer; equations for the conversion of soil test values from other laboratories into Cornell Morgan equivalents; environmental risk indices, including the NY P Index (NY PI) and the Nitrate Leaching Index; on-farm logistics, such as manure production, storage, and inventories; and report generation for guiding on-farm implementation.
<b>Developers</b>	Q.M. Ketterings, G.L. Albrecht, C.N. Rasmussen, K.J. Czymmek and V.M. Durbal.
<b>Contacts</b>	Greg Albrecht (gla1@cornell.edu), 607-255-1723. Caroline Rasmussen (cnr2@cornell.edu), 607-255-2875. Quirine Ketterings (qmk2@cornell.edu), 607-255-3061. <a href="http://nmsp.css.cornell.edu">http://nmsp.css.cornell.edu</a>

### Stage of Development

A tool was needed for nutrient management plan development in accordance with the NY NRCS 590 Standard. Cropware 1.0 was released in August 2001. The first version of Cropware was funded by NY NRCS, NY Department of Agriculture and Markets (DAM), and NY Department of Environmental Conservation (DEC). Based on feedback gained through workshops and extensive use in the field, and with funding from NYS NRCS, Cropware 2.0 was released in July 2003. Cropware is free to all NY users. The program and documentation can be downloaded from the Nutrient Management Spear Program website: <http://nmsp.css.cornell.edu>.

Cornell Cropware is developed and supported by the Nutrient Management Spear Program at Cornell University (<http://nmsp.css.cornell.edu>). Cropware is a component of the Cornell University Nutrient Management Planning System (*cuNMPS*). The *cuNMPS* is a suite of decision aid tools that aid in whole-farm nutrient management. In addition to Cropware, *cuNMPS* is currently comprised of the Cornell Net Carbohydrate and Protein System (CNCPS) for bovine and ovine production and nutrient management.

### Focus

Cornell Cropware aims to help people develop nutrient management plans according to the NRCS 590 Nutrient Management Standard. This includes:

- Providing Land Grant University (Cornell) guidelines.

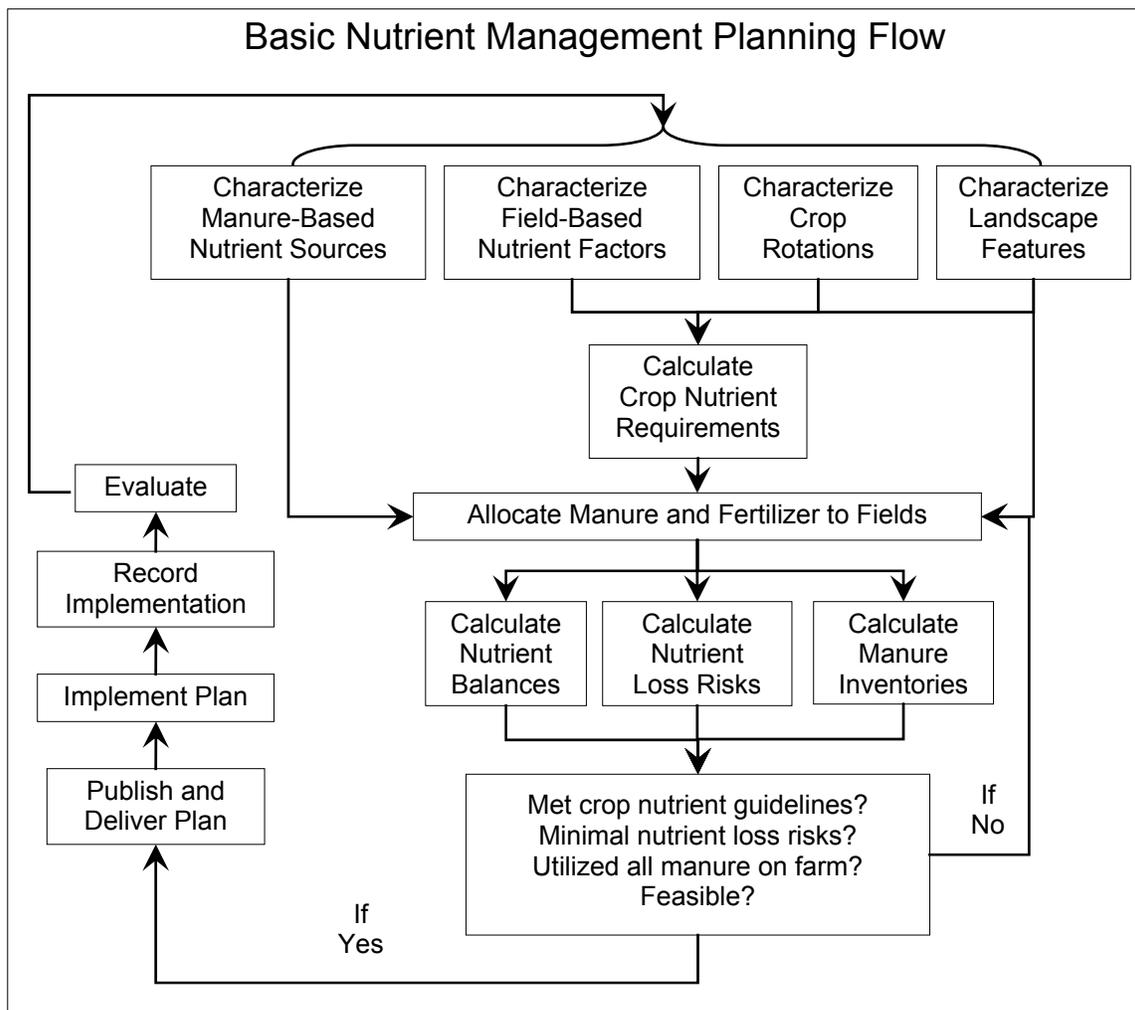
- Accounting for nutrients from all sources.
- Planning manure applications based on crop nutrient requirements.
- Calculating the NY PI and Nitrate Leaching Index for each field.
- Developing plans that consider all of the above factors across the entire farm.

## Scale

Cropware addresses management at the whole-farm and individual field levels.

## Area of Concern

Cropware calculates the nitrogen, phosphorus and potassium balances for each crop field. Nutrient credits are from many sources including manure, soil, sod and fertilizer (Fig. 6.5). Two risk indices (the NY PI and the Nitrate Leaching Index) prescribe best management practices based on index values calculated for each field.



**Figure 6.5:** Cornell Cropware basic nutrient management planning flow.

### **Tool Application: Users**

Cropware users are public and private sector planners, extension educators, farmers, teachers and students.

### **Tool Application: Format**

Cropware is a stand-alone, windows-based tool developed in Visual Basic 6.

### **Tool Application: Documentation**

Cropware has an extensive, built-in Help Section which includes guidance on program operation, the underlying science, and tutorials covering program operation, science, and on-farm logistics. The documentation is a pdf file with many links that move the user to associated topics. The documentation includes all program equations and references. Content documentation is relatively technical. Program use and tutorial documentation is non-technical. Program use and content support is available from developers via telephone, email and on the internet (<http://nmsp.css.cornell.edu>). An extensive set of input data is needed, including detailed soil, crop and manure application histories for each field. However, the information needed is not beyond the scope of crop information normally maintained by farmers and required for NY NRCS 590 standard compliance.

### **Knowledge and Data Transferability: Geographic Transferability**

The concepts of balancing nutrients, applying nutrients based on crop needs, and assessment of risk of phosphorus and nitrogen losses, are transferable to other regions. However equations within Cropware are based on NY conditions and research. The crop nutrient guidelines are based on a NY, soil-specific database of yield potentials, fertilizer use efficiencies, and soil and sod N credits. The organic N mineralization and ammonia volatilization rates for manure are based on NYS research given local climate and soil characteristics. The NY PI and Nitrate Leaching Index were both developed for New York conditions.

### **Data Sharing**

Cropware version 2.0 saves and outputs data in a MS Access compatible file format, allowing links to GIS and many other databases (e.g. \*.mdb, \*.xls, \*.dbf, etc.). Reports are also exportable in \*.rtf file format for inclusion in word processed documents.

### **Data Inputs**

Cropware data inputs include:

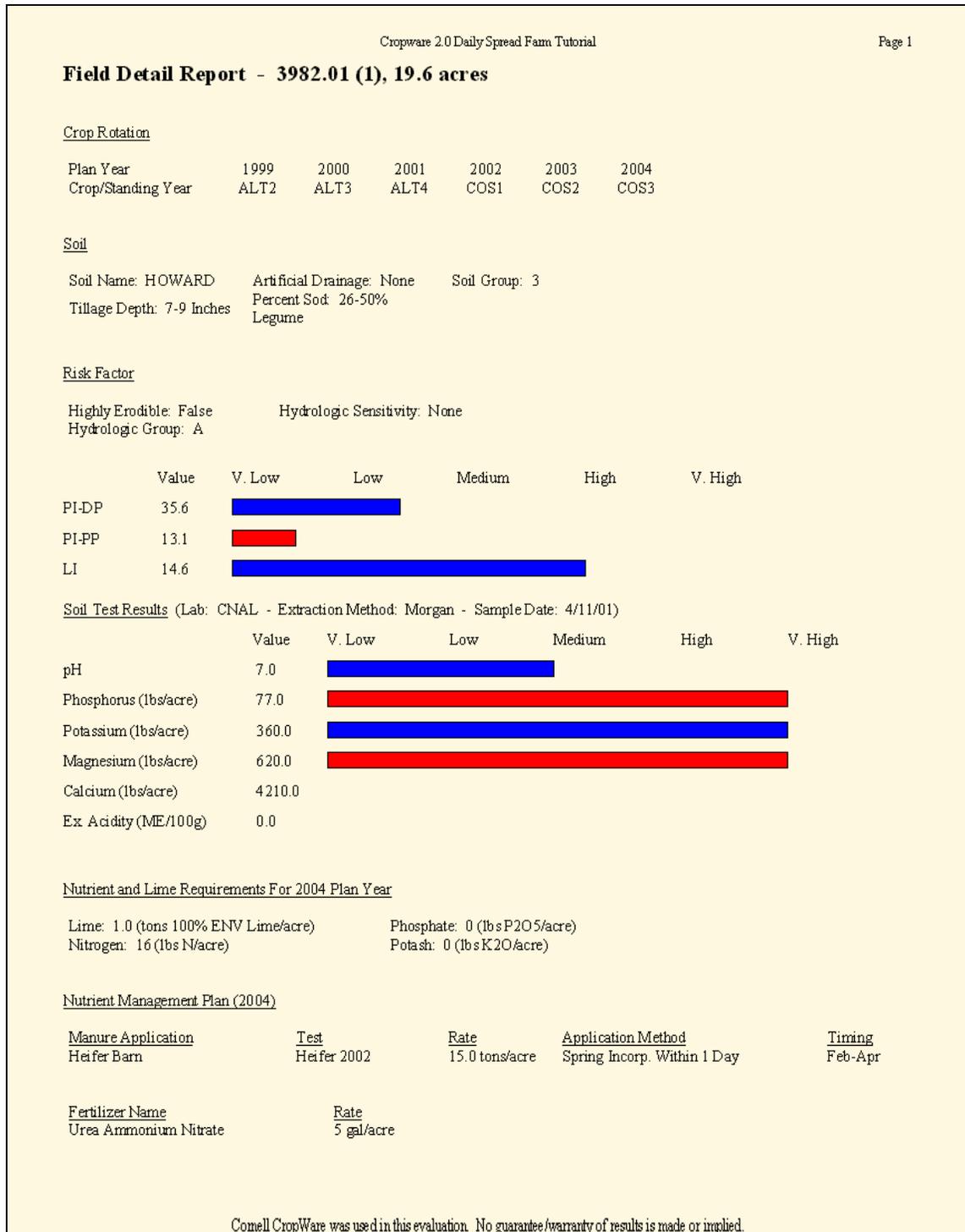
- Producer and planner information - name, address, etc.
- Libraries of crop rotations and fertilizer materials.
- Manure quantities, analyses, and storage capacities.
- Field information:
  - Soil information.
  - Soil nutrient analyses.
  - Crop rotations.
  - Manure and fertilizer application information.
  - Various NY PI and N Leaching Index inputs:
    - Manure and fertilizer application rate, timing and method, RUSLE, flow distance to stream, stream type, precipitation, soil, etc.

- Manure, fertilizer, and lime plan for next year.
- On-farm logistical considerations.

### **Tool Outputs**

The primary outputs of Cornell Cropware focus on presenting a spatial and temporal plan for manure, fertilizer, and lime applications in-line with the NRCS 590 Standard. Custom user-defined reports can be constructed within Cropware. Program reports can be exported to spreadsheet, word processing, database and/or GIS software for additional functionality. Cornell Cropware can be used to generate supporting documentation for development of CAFO compliant Comprehensive Nutrient Management Plans. Outputs include:

- General information:
  - Farm and producer's name and address, planner name and address, county, type of livestock enterprise, number of animal units and age classes.
  - Soil tests results including the soil laboratory and extraction method, soil pH increase and/or maintenance recommendations (Fig. 6.6).
- Production outputs:
  - Fertilizer, manure, and lime recommendations, considering past manure applications, soil nutrients and nutrients in sod (Fig. 6.7).
  - Field number, acreage, land use, RUSLE, and comments about hydrologically sensitive areas for each field.
  - Soil type, crop rotation, timing, and depth of tillage for each field.
  - Crop acreages across the rotation for the whole-farm (Fig. 6.8).
- Environmental outputs:
  - Environmental risk – Nitrate Leaching Index (Fig. 6.9).
  - Environmental risk – NY PI (Fig. 6.9).
  - N, P, K balance for each field and for the farm (Fig. 6.9, Fig. 6.10).
  - Manure/waste utilization – bedding material and quantity, estimate of annual waste production, waste spreading schedule based on the priority nutrient, and a template available to record manure analysis and applications.
  - Manure transfer and storage for existing facilities – storage capacity calculated and reported in terms of volume and time.
- Economic outputs:
  - Fertilizer costs (Fig. 6.11).



**Figure 6.6:** Cornell Cropware field detail report.

Cropware 2.0 Daily Spread Farm Tutorial Page 1

### Fertilizer and Manure Management Report

Field ID	Field Name	Crop	Acres	Manure Application	Manure App. Timing	Fertilizer Application (Qty/Acre)				Lime Req. (tons 100% ENV Lime/acre)	Latest Soil Sample	Comments
						#1	#2	#3	#4			
3982.01	1	ALT3	19.6							0.0	4/11/01	
3982.02	2	CCS2	28.4	Main Barn: 10,000 gal/acre	Nov-Jan	6 gal Urea Ammonium Nitrate				0.0	4/11/01	
3982.03	3	AGT4	24.7	Heifer Barn: 15 tons/acre	Sep-Oct					1.0	3/30/00	
3982.04	4	ALT2	18.2							0.0	4/11/01	
3982.05	5	CCS2	17.9	Main Barn: 6,500 gal/acre	Feb-Apr	9 gal 21-17-0				0.0	4/11/01	
3982.06	6	AGE1	16.5			80 lbs 6-24-24				0.0	4/11/01	
3982.07	7	CCS4	25.6	Heifer Barn: 15 tons/acre	Feb-Apr	6 gal Urea Ammonium Nitrate	15 gal Urea Ammonium Nitrate			0.0	4/11/01	
3982.08	8	GIT19	7.0	Main Barn: 5,000 gal/acre Main Barn: 5,000 gal/acre	Main Barn: May-Aug Main Barn: May-Aug	200 lbs Urea	130 lbs Urea			2.0	11/1/99	

Figure 6.7: Cornell Cropware fertilizer and manure management report.

Cropware 2.0 Daily Spread Farm Tutorial

### Crop Plan Summary

Crop	Plan Year													
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
	----- Acres -----													
Total Corn	80	69	97	80	80	91	79	79	80	52	80	80	96	89
Com Silage	80	69	97	80	80	91	79	79	80	52	80	80	96	89
Total Hay Crop	113	125	96	113	114	103	114	114	113	141	113	113	97	104
Legume Hay	28	48	38	38	38	18	28	28	28	48	38	38	38	18
Mixed Hay	51	43	25	41	42	51	52	52	51	59	41	41	26	52
Grass Hay	34	34	34	34	34	34	34	34	34	34	34	34	34	34
New Seedings*	25	20	18	17	26	9	46	0	25	36	18	0	26	26
Totals	193	193	193	193	193	193	193	193	193	193	193	193	193	193

\* Note: Acres of New Seedings are also included in the Hay acreages above.

Figure 6.8: Cornell Cropware crop plan summary report.

Cropware 2.0 Daily Spread Farm Tutorial Page 1

### Nutrient Management Plan

Field ID	Field Name	Acres	2002 Crop	Residual Soil N	Gross N Req.	Residual Manure N	Total Nutrients Required (lb/a)			Nutrients From Applied Manure (lb/a)			Nutrients From Fertilizer (lb/a)			Nutrient Balance (lb/a)			PI (OP/FP)	LI
							N	P2O5	K2O	N	P2O5	K2O	N	P2O5	K2O	N	P2O5	K2O		
3982.01	1	19.6	ALT3	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0	29 / 11	15
3982.02	2	28.4	CCS2	36	85	10	75	0	0	55	133	250	21	0	0	2	133	250	44 / 22	15
3982.03	3	24.7	AGT4	0	40	14	26	0	0	26	75	120	0	0	0	1	75	120	72 / 66	15
3982.04	4	18.2	ALT2	0	0	22	0	10	0	0	0	0	0	0	0	0	-10	0	6 / 7	15
3982.05	5	17.9	CCS2	24	78	27	51	25	0	36	87	163	21	17	0	6	79	163	47 / 47	5
3982.06	6	16.5	AGE1	0	0	19	0	10	20	0	0	5	19	19	5	9	-1	24 / 30	5	
3982.07	7	25.6	CCS4	0	109	11	98	20	0	26	75	120	74	0	3	55	120	23 / 52	5	
3982.08	8	7.0	GIT19	0	225	22	203	25	83	55	133	250	152	0	4	108	168	30 / 30	9	
3982.09	9	26.9	GIT19	0	225	28	197	0	0	55	133	250	152	0	10	133	250	53 / 8	5	
628.10	10	8.5	CCS2	13	117	17	100	30	0	82	208	370	21	17	0	3	196	370	13 / 65	9

Figure 6.9: Cornell Cropware nutrient management plan report.

<b>Nutrient Balance Report</b>			
	<b>2002</b>	<b>2003</b>	<b>2004</b>
<b>Nitrogen Balance (lbs N)</b>			
<b>Total (Gross) Nitrogen Required</b>	15,205	15,098	17,925
<b>Residual Nitrogen From Sod</b>	1,558	4,001	3,436
<b>Residual Nitrogen From Prior Year's Manure</b>	3,380	3,944	4,129
<b>Nitrogen Available From Manure</b>	15,333	7,859	7,922
<b>Nitrogen Available From Fertilizer</b>	5,711	5,453	5,491
<b><i>Nitrogen Balance</i></b>	<b>10,777</b>	<b>6,159</b>	<b>3,053</b>
<b>Ammonia Loss</b>	14,030	21,507	21,685
<b>Phosphorus Balance (lbs P2O5)</b>			
<b>P2O5 Required</b>	1,562	2,156	1,558
<b>P2O5 Supplied By Manure</b>	19,620	19,615	19,789
<b>P2O5 Supplied By Fertilizer</b>	1,216	1,685	615
<b><i>Phosphorus Balance</i></b>	<b>19,274</b>	<b>19,144</b>	<b>18,846</b>
<b>Potassium Balance (lbs K2O)</b>			
<b>K2O Required</b>	909	1,091	749
<b>K2O Supplied By Manure</b>	35,541	35,547	35,834
<b>K2O Supplied By Fertilizer</b>	317	1,229	306
<b><i>Potassium Balance</i></b>	<b>34,949</b>	<b>35,685</b>	<b>35,392</b>

Figure 6.10: Cornell Cropware nutrient balance report.

Cropware 2.0 Daily Spread Farm Tutorial

### Fertilizer Shopping List

	2002		2003		2004	
	Amt	Cost	Amt	Cost	Amt	Cost
<b>Urea Ammonium Nitrate</b>	708 gal	\$708	350 gal	\$350	478 gal	\$478
<b>Urea</b>	5.6 tons	\$1,398	3.6 tons	\$911	3.6 tons	\$911
<b>21-17-0</b>	238 gal	\$261	238 gal	\$261	161 gal	\$177
<b>6-24-24</b>	0.7 tons	\$165	2.6 tons	\$640	0.6 tons	\$159
<b>Total Fertilizer Cost</b>	---	\$2,532	---	\$2,162	---	\$1,725
<b>Lime*</b>	72.7 tons	---	72.7 tons	---	120.7 tons	---

\* Tons of 100% ENV Lime

Figure 6.11: Cornell Cropware fertilizer shopping list.

## **Tool Limitations**

### ***NY Specific Nutrient Guidelines and Risk Indices***

This tool was developed in response to the need of certified nutrient management planners to account for the many equations and variables associated with the creation of a CNMP. Cropware provides state specific land grant college (Cornell) nutrient recommendations as stipulated by US EPA and NY NRCS guidelines. The NY specific nutrient guidelines and risk indices limits use of Cropware to New York. However, the system of allocating nutrients could easily be applied to other regions with the addition of the appropriate agronomic and nutrient databases.

### ***User Expertise***

Agronomy and nutrient management planning expertise by the user also limit the use of this tool. The software is easy to use but the development of a practical nutrient management plan requires a user with a good working knowledge of agronomy and farming. On the flip side of this “limitation”, Cropware is an excellent teaching tool. It is used to teach students in a joint Animal Science and Crop and Soil Sciences course on whole-farm nutrient management at Cornell University.

### ***Data Intensive***

The data intensive nature of developing nutrient management plans necessitates a somewhat laborious process of entering a great deal of information when first characterizing a farm and its fields. It would be useful to also have a “Cropware Lite” for use when simple crop nutrient guidelines are needed for only a field or two. On-farm crop record keeping systems that record production and input information and communicate directly with Cropware would make nutrient management plan development much more efficient and accurate. There is currently no such software available.

### ***Need for Economic Analysis Capability***

Many nutrient management decisions are associated with farm management decisions and have an impact on farm profitability. There is a need for economic information to be part of the nutrient management planning process.

### ***Better Integration with GIS***

Cropware 2.0 files are saved to a MS Access format (.mdb). These files can be imported into most GIS programs. However, these steps require technical knowledge that many users do not have. Users identified the desire to make farm specific maps within Cropware.

### ***Data Entry Streamlining***

Improvements in the user interface would make Cropware data entry and nutrient allocation more streamlined. Two examples of additions that would increase data entry are: (1) a whole-farm data entry grid option, and (2) an expansion of decision making capacity on the Allocation screen.

### ***Limits to Scientific Knowledge***

Current scientific knowledge and understanding can always be enlarged. Areas where current research may improve Cropware algorithms in the future are:

- Nutrient guidelines with double crops and cover crops.

- Mineralization of organic N over the seasons.
- Ammonia N availability.
- N and P risk indices.

### **Quality of Results**

Like any tool, Cropware's effectiveness is dependent on the accuracy of the data entered and the expertise of the user ("garbage in = garbage out"). Cropware has integrated Cornell research knowledge and has subsequently increased recognition of "all nutrient sources" including sod, manure, soil, and, of course, fertilizer. Program use, along with other efforts, has increased recognition of higher risk management situations.

### **Field Validation**

Cornell nutrient guidelines are based on field experimentation. The evaluation of guidelines and risk indices continues. Although there has been no formal Cropware survey, there has been continuous user input during development, testing, and use. An oversight committee was actively involved in the design of version 1. Two years of field experience, 28 formal Cropware workshops, 12 small group consultations and over 400 phone/email support events helped developers build many enhancements into Cropware version 2.0.

### **Users**

Cropware users are NRCS and Soil and Water Conservation District planners, Cornell Cooperative Extension educators, private-sector planners, farmers, teachers, and students. There are 300 registered copies with approximately 125 regular users producing approximately 600 nutrient management plans.

### **Is This Tool Useful in Meeting Regulatory Requirements?**

Cropware creates a CNMP which is compliant with the NRCS 590 Nutrient Management Standard. This standard must be followed by CAFO farms as well as farms receiving public funding.

### **Future Plans for Tool**

#### ***Software Development***

- Data integration with crop record keeping software, NRCS Customer Tool Kit, the CNCPS, and farm accounting software.
- Integration with a crop rotation and crop inventory planning tool.
- Streamline data integration with Geographic Information Systems (GIS).
- Continue to improve user interface for efficient farm characterization, plan development, and report generation.
- Data transfer with acquisition/monitoring devices (PDAs, yield monitors, etc.).

#### ***Areas for Further Research***

- Nitrate Leaching Index.
- Phosphorus Runoff Index.
- Crop nutrient guidelines
- Nitrogen volatilization losses.
- Organic nitrogen mineralization and uptake rates.
- Nutrient guidelines/credits for cover crop and double crop systems.

**Area for Further Use**

Cropware is useful in bringing real-world farm specific information more efficiently and more clearly into teaching and extension activities. Using Cropware with a case-study farm to consider alternative management practices can vividly bring out “a-ha” moments.

**Case Study Assessment - Mark Ochs, Ochs Consulting, LLC.**

Mark Ochs is the sole proprietor of Ochs Consulting, LLC. Mark develops CNMPs and crop management recommendations for 27 clients covering a wide range of farm enterprises and management styles. Except for a summer employee, Mark works alone and therefore he does not have the time to develop software. Mark states that although data collection and entry are onerous, once data entry is complete, Cropware is very flexible and will help the planner produce a CNMP that can be implemented. Cropware’s Land Grant College backing is important to consultants like Mark who, for regulatory and liability reasons, do not wish to make nutrient recommendations without the backing of research results. Mark, through experience, obtained confidence in Cropware’s recommendations and calculations and he considers it an “excellent planning tool that saves his clients money”.

**Tool Use**

Mark uses Cropware to produce multiple CNMPs for each client. He calls this approach “what should you do?”, “what can you do?” and “what did you do?”

- *What should you do?*  
The first plan Mark produces is a plan depicting the ideal agronomic and environmental plan.
- *What can you do?*  
Mark then adjusts the Cropware plan inputs to consider “what-if” scenarios. This gives the client an idea of the options of what they can do while still complying with regulations.
- *What did you do?*  
After a plan has been implemented, Mark enters the plan as it was implemented into Cropware. This plan provides the regulatory requirement showing nutrient sources and field activities. The NY DEC recognizes Cropware as a standard.
- *Planning business expansion needs*  
Mark also uses Cropware to project logistics associated with dairy herd expansion. He is able to forecast the land base and manure hauling needs using Cropware; something that can give his clients “a real wake-up call”.

**Future Opportunities**

- **GIS – Map Interface**  
Mark would like to deliver plans to his clients reported in the form of maps instead of tables or text.

- **Crop Recordkeeping**

A crop recordkeeping system that could be maintained by the grower and that would dovetail to Cropware would be a big time savings for Mark and his clients. It would allow for the efficient collection of information critical to production efficiency and regulatory compliance. This system would ideally work with a PDA for data collection and interface with GIS software for map generation.

## References

Agricultural Waste Management Handbook. Part 651. July 1996.

Cornell Guide for Integrated Field Crop Management. 2004. Cornell Cooperative Extension Publication. Cornell University, Ithaca N.Y. 112 pages.

Czymmek, K.J., Q.M. Ketterings, H. van Es, and S. DeGloria. 2003. The New York Nitrate Leaching Index. Department of Crop and Soil Sciences Extension Series E03-2. Cornell University, Ithaca, NY. 34 pages.

Czymmek, K.J., Q.M. Ketterings, and L.D. Geohring, and G.L. Albrecht. 2003. The New York phosphorus runoff index. User's Manual and Documentation. Department of Crop and Soil Sciences Extension Series E03-13. Cornell University, Ithaca, NY. 64 pages.

Ketterings, Q.M., S.D. Klausner and K.J. Czymmek. 2003. Nitrogen guidelines for field crops in New York. Department of Crop and Soil Sciences Extension Series E03-16. Cornell University, Ithaca, NY. 70 pages.

Ketterings, Q.M., K.J. Czymmek, and S.D. Klausner. 2003. Phosphorus guidelines for field crops in New York. Department of Crop and Soil Sciences Extension Series E03-15. Cornell University, Ithaca, NY. 35 pages.

Ketterings, Q.M., S.D. Klausner and K.J. Czymmek 2003. Potassium guidelines for field crops in New York. Department of Crop and Soil Sciences Extension Series E03-14. Cornell University, Ithaca, NY. 41 pages.

Ketterings, Q.M., K.J. Czymmek, W.S. Reid and R.F. Wildman. 2002. Conversion of modified Morgan and Mehlich-III soil tests to Morgan soil test values. Soil Science 167(12): 830-837.

Livestock Waste Facilities Handbook. MWPS-18. Third Edition, 1993. Midwest Plan Service, Iowa State University, Ames Iowa.

Williams, J.R., and D.E. Kissel. 1991. Water percolation: an indicator of nitrogen-leaching potential. In: R.F. Follet, D.R. Keeney, and R.M. Cruse (Eds.). Managing nitrogen for groundwater quality and farm profitability. Soil Science Society of America, Inc. Madison, Wisconsin. pp 59-83.

## New York State Phosphorus Index

- Tool Name** New York Phosphorus Index Calculator, Version 2.
- Program Purpose** The New York State Phosphorus Index (NY PI) calculator is designed to assist producers and planners in identifying fields or portions of fields that are at highest risk of contributing phosphorus (P) through runoff to lakes and streams. The NY PI assigns two scores to each field based upon its characteristics and the producer's intended management practices. One of the two scores, the Dissolved PI, addresses the risk of loss of water-soluble P from a field, while the Particulate PI estimates the risk of loss of P attached to soil particles and manure.
- Developer(s)** The NY PI was developed by NRCS staff, Cornell faculty and educators, and the New York State Soil and Water Conservation Committee staff. In addition to the primary authors of the calculator, Quirine Ketterings, Karl Czymmek, Greg Albrecht and Kevin Ganoë, the P Index working group consists of: Shawn Bossard (CCE Cayuga County), Dale Dewing (CCE Delaware County and New York City Watershed Agricultural Program), Tibor Horvath and Bill Elder (USDA NRCS), Tammo Steenhuis and Larry Geohring (Department of Biological and Environmental Engineering, Cornell University), and Jeff Ten Eyck (New York State Department of Agriculture and Markets/Soil and Water Conservation Committee). Past members include: Barbara Bellows, Ray Bryant, Fred Gaffney, and Paul Ray.
- Contact Person(s)** Quirine Ketterings (for NY PI calculator questions)  
(607) 255-3061  
qmk2@cornell.edu  
Nutrient Management Spear Program  
<http://nmisp.css.cornell.edu>
- Karl Czymmek (for NY PI questions)  
(607) 255-4890  
kjc12@cornell.edu  
PRODAIRY

### Stage of Development

Version 1 of the NY PI calculator was released in Spring 2002. NY PI Version 2 has the same equations and inputs as version 1 but has enhanced usability. Version 2 was released in the Spring of 2003. NY PI version 2 is an Excel<sup>®</sup> spreadsheet. The same equations and methodology are incorporated into Cornell Cropware (see Cornell Cropware, pg 65).

## **Scale and Tool Focus**

The focus of the NY PI is on phosphorus. The assessment tool addresses P loss on a per field basis within a farm.

## **Area of Concern**

The NY PI scores a field based on its susceptibility to P losses. The NY PI is not a measure of actual P loss but an indicator of potential loss that allows for field comparisons. A high PI score triggers a warning to implement management practices to control P loading and loss for the field in question.

## **Tool Application**

Users: the NY PI was developed for public and private sector certified nutrient planners preparing nutrient management plans for NY farms that are CAFO's or involved in state or federal programs. The NY PI calculator is also used by Cornell Cooperative Extension educators and college classroom instructors for teaching purposes.

## **Format**

The program operates on computers that use Microsoft Excel®.

## **Documentation**

A "User's Manual and Documentation" (with references, model equations, and sample scenarios) is available from <http://nmsp.css.cornell.edu/publications/pindex.asp>.

## **Knowledge and Data Transferability: Geographic Transferability**

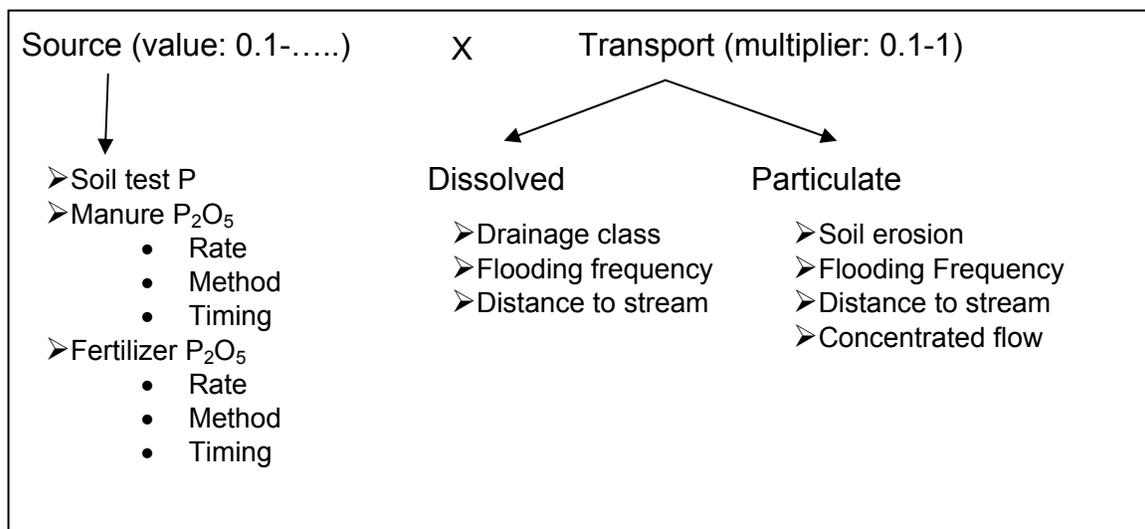
The general framework of the NY PI is based on the National P Index template, modified for NY climate, soils, and farming practices.

## **Data Sharing**

Data generated by the spreadsheet version can be shared to the degree to which Excel® data can be accessed by other programs. Algorithms common to the Excel version are also used in a web based calculator (<http://nmsp.css.cornell.edu/software/pindex/>) as well as in Cornell Cropware, the stand-alone whole-farm nutrient management planning tool for New York.

## **Data Inputs**

The NY PI is separated into two main parts: potential sources of P (source score) and potential movement of P (transport score). The final score is the multiplication of the source and the transport score. Two scores are calculated. The Dissolved P Index (DPI) addresses the risk of loss of water-soluble P and the Particulate P Index (PPI) estimates the risk of loss of P attached to soil particles and manure. Figure 6.12 shows the variables and structure of the DPI and PPI equations.



**Figure 6.12:** New York P index structure.

## Data Outputs

The NY PI outputs are the DPI and PPI scores and management recommendations for the field. Rankings and management implications for final field scores are listed in Table 6.2. Both P indices (dissolved and particulate) are a concern for water quality and should be managed jointly. Both DPI and PPI should be <100. Recommended practices to reduce the score include incorporation of manure, reducing manure and/or fertilizer application rates, adding buffers, changing the timing of manure applications, creating management zones, etc.

**Table 6.2:** New York P index rankings and how they relate to site vulnerability and management implications.

PI Rankings	Site Vulnerability	Management recommendation
<50	Low	N based management.
50-74	Medium	N based management with BMPs.
75-99	High	P <sub>2</sub> O <sub>5</sub> applications not to exceed crop removal.
≥100	Very High	No fertilizer/manure P application.

## Tool Limitations

This tool's use is limited to New York State. The tool's input parameters and weighting factors are based on best available knowledge and its impacts are yet unquantified. Research projects are ongoing to better understand P dynamics and document the impact of the use of the NY PI on manure management options and P losses. The results of these studies will allow for calibration of the NY PI and may lead to changes in the structure of the P index in the future.

Impressions in the field are that the tool is successful in identifying higher risk situations. However, there may be some moderate risk situations that should receive a higher

score. Soil test may play too strong a role in the scoring where transport potential is low, and conversely, the transport factor not strong enough where soil test is low. At present, assessment of the NY PI is required for all fields which involves a modest time-investment by the planner.

### **Field Validation**

Field evaluation of the index is ongoing. A group of researchers from the Northeast and Mid-Atlantic states meet informally at least once per year to discuss P indices.

### **Users**

The NY PI has been used by 100 to 150 planners and Extension Educators in New York State. When used in training sessions, it has proven to be an excellent tool to teach planners concepts of management that impact P runoff risk. Producers and students can easily see how the score can be changed by altering practices. Cropware runs the NY PI "behind the scene"- so once the concepts of the NY PI are well understood, Cropware can be used to generate nutrient management plans for large numbers of fields.

### **Is This Tool Useful in Meeting Regulatory Requirements?**

The NY PI is part of the NYS NRCS 590 standard with which all CAFO farms and AFOs participating in federal or state government programs must comply. A NY PI must be estimated for all fields. The NY PI was designed to meet the federal NRCS expectation that P be allocated in one of three ways: agronomic need, environmental threshold, or P index. This tool does not produce a nutrient management plan but the identical algorithms are contained in Cornell Cropware which does produce a nutrient management plan.

### **Future Plans for Tool**

As mentioned before, field evaluation of the NY PI is ongoing. There is an ongoing study addressing P dynamics and the performance of the NY PI and the PA PI on a farm that straddles the state borders. Other projects are to enhance the basic science regarding the fate and mobility of P, including research with a rainfall simulator and edge of field (buffer) studies. Changes to the NY PI will be made when warranted by evolving knowledge of phosphorus loading and transport risk.

### **References**

Czymmek, K.J., Q.M. Ketterings, L.D. Geohring, G.L. Albrecht. 2003. The New York Phosphorus Runoff Index. User's Manual and Documentation. CSS Extension Publication E03-13. 64 pages.

## Wisconsin Phosphorus Index

<b>Tool Name</b>	Wisconsin Phosphorus Index.
<b>Tool Purpose</b>	The Wisconsin Phosphorus Index (WI PI) is a tool to rank fields based on their potential to deliver phosphorus to surface water bodies. It is designed to rank fields on a farm in order of their risk index so that manure can be applied to the lowest ranking one first. It can also help identify management options to reduce P loss.
<b>Developers</b>	L.W. Good, P. Kaarakka, L. Bundy, and W. Jarrell
<b>Contact</b>	Laura Ward Good, Research Associate Soil Science UW-Madison 152 Soils-King Hall Madison WI 53706 (608) 262-9894 lwgood@wisc.edu

### Stage of Development

The WI PI will be a component of SNAP-Plus in 2004 (See the next chapter for more details on SNAP PLUS).

### Focus

The program focus is soil and water.

### Scale

The WI PI was designed to work on a field-by-field basis, but could be applied to larger scales such as whole-farm or watershed. This would require computation of an acreage weighted value for the larger areas.

### Area of Concern

The WI PI is primarily concerned with phosphorus runoff.

### Tool Application: Users

The WI PI is designed for nutrient management planners, agencies, and farmers.

### Tool Application: Format

Windows based.

### Tool Application: Documentation

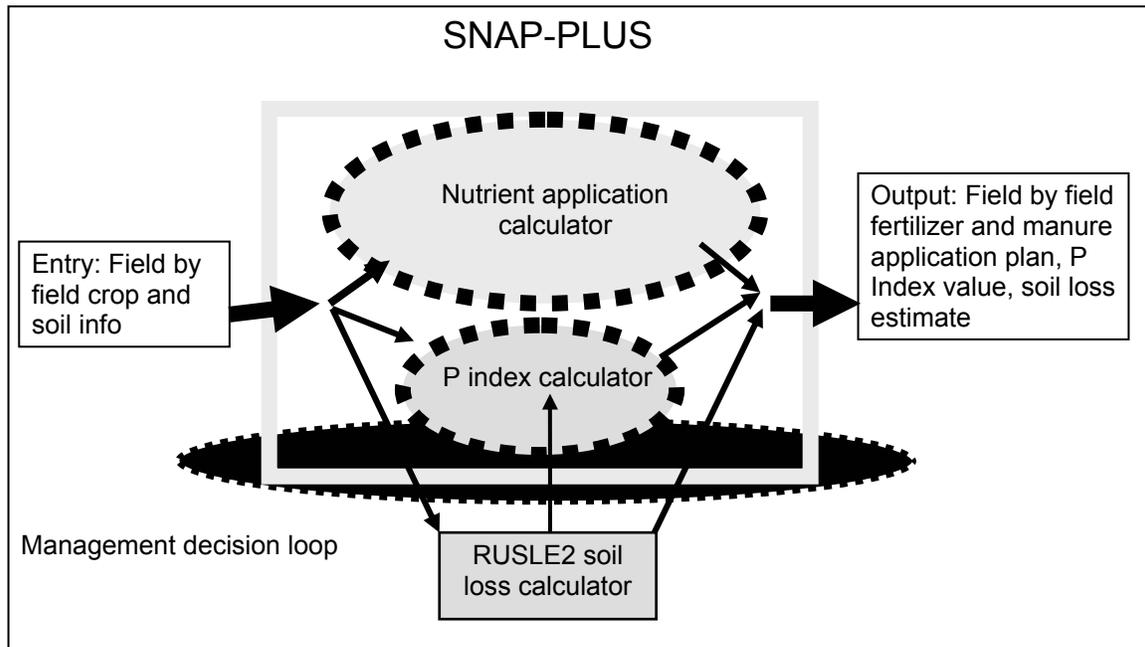
Documentation exists for nutrient management planners, agencies and farmers. Equations are included in the documentation. See <http://wpindex.soils.wisc.edu>.

### Knowledge and Data Transferability: Geographic Transferability

The algorithms in the WI PI are based on Wisconsin or upper Midwest data. It lacks data and algorithms that would make it valid in other regions.

### Data Sharing

The data in the WI PI will be shared and integrated into SNAP-PLUS (Fig. 6.13).



**Figure 6.13:** SNAP-PLUS nutrient management planning flow.

### Data Inputs

The WI PI uses parameters that are readily available or readily calculated. The user is required to enter the following information into the SNAP-Plus program for each field for each year in the crop rotation:

- Soil series.
- Field slope (%).
- Contoured, Terraced, Strip cropped (X).
- Tillage.
- Crop.
- Distance from field to water and average slope (%) of that distance.
- Bray P-1 and %OM from a routine soil test.
- Manure rate and type and fertilizer rate and type (% P<sub>2</sub>O<sub>5</sub>).
- Season of manure application and whether incorporated or not (X).

### Tool Outputs

Environmental outputs include a unit-less PI value based on the estimated P loads (lb/acre/yr) in runoff, in dissolved and particulate forms for each year in the crop rotation. SNAP-Plus also includes an estimate of rotational sediment loss from RUSLE2. The PI

shows the relative effects of different field management practices on P loads (Table 6.3). A three-state group (WI, MN, IA) is sharing information on the structure and basis of individual state P indices.

**Table 6.3:** The interpretation of the Wisconsin PI on a field basis.

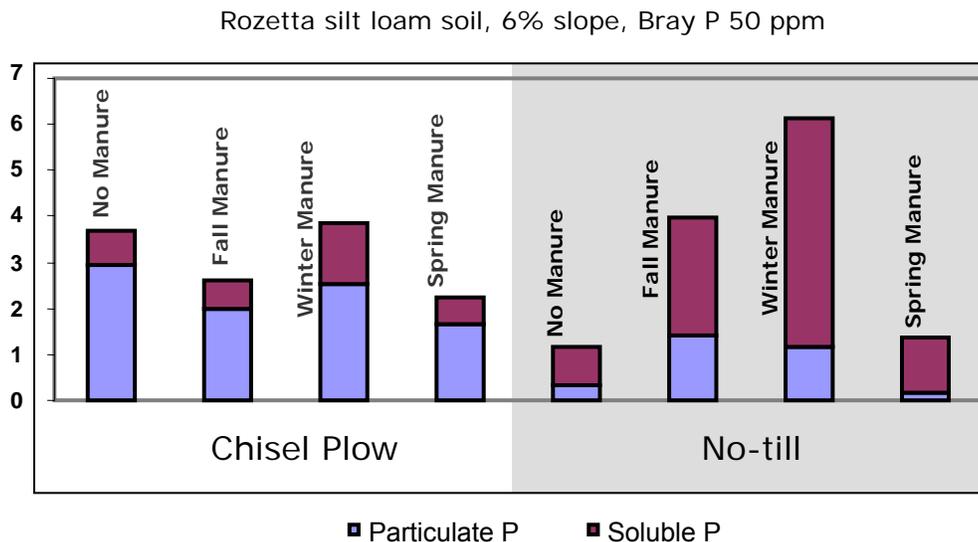
Risk value:	Interpretation
0 - 2:	Minimal risk, N-based management.
2 - 6:	PI should not increase over 4 years or length of average rotation.
6 -10:	Implement plans to decrease PI to <6 over two rotations (max. 6 years).
> 10:	Lower PI to <10 over one rotation or 4 years, <u>and</u> decrease PI to <6 over two additional rotations or 6 years.

**Tool Limitations**

This tool needs calibration against natural runoff data and the influence of buffers needs to be added. In addition, P leaching is not considered nor is the sensitivity of receiving waters addressed.

**Field Validation**

Several field validation projects are underway and more are planned at several levels. Even with relatively low soil test P values, the P index value for a field can still be high if there is tillage leading to a high erosion rate. Figure 6.14 shows corn field P index values under alternative management practices.



**Figure 6.14:** P index values for a Grant County, WI, corn field with various tillage and manure application scenarios. The manure application is 25 wet tons per acre of dairy manure. The Fall and Spring manure chisel plow managements assume that the manure is applied prior to chisel plowing.

**Users**

The tool is not yet in use. Once release, it is estimated to have several hundred users in Wisconsin.

**Is This Tool Useful in Meeting Regulatory Requirements?**

The WI PI provides an option for P-based nutrient management planning. The PI is not the ultimate solution to nutrient management. Balancing nutrient inputs and removals is the ultimate goal. Using the WI PI can minimize environmental problems until balance is achieved. The other option in Wisconsin is to base phosphorus nutrient management on soil test P levels. SNAP-Plus will calculate a WI PI value along with a nutrient application plan.

**Future Plans for Tool**

- Calibrate the P index algorithms based on field-scale monitoring data.
- Continue to incorporate new research findings to improve and refine the WI PI.
- Incorporate P index changes into the SNAP-Plus software program on an annual basis.

## SNAP-PLUS

**Tool Name** SNAP-PLUS

### Tool Purpose

- To manage crop nutrient amounts, source, placement, form, and timing of applications to minimize nutrients entering groundwater and surface water.
- To integrate several nutrient management programs (RUSLE2, Wisconsin P Index, P and K balancing, SNAP2000).
- To simplify/facilitate nutrient management plan development in accordance with the WI NRCS 590 standard.
- To eliminate redundant data entry and have a single interface for data inputs.
- To have a more comprehensive approach to managing manure and P that uses both the P-index and RUSLE2.
- To answer whole-farm level “what if” questions by providing whole-farm views and immediate feedback.

**Developers** Bill Pearson, Kevin Erb, Wes Jarrell, Paul Kaarakka, Larry Bundy, and Laura Ward Good.

**Contacts** For general software questions: Bill Pearson, Kevin Erb and Paul Kaarakka.

Wisconsin P Index: Larry Bundy and Laura Ward Good  
RUSLE2/software programming: Paul Kaarakka, Laura Ward Good.

Bill Pearson – 715-346-4187, Bill.Pearson@uwsp.edu  
Kevin Erb – 920-391-4652, kevin.erb@ces.uwex.edu  
Paul Kaarakka – 608-265-9354, kaarakka@wisc.edu  
Larry Bundy – 608-263-2889, lgbundy@facstaff.wisc.edu  
Laura Ward Good – 608-262-9894, lwgood@wisc.edu

### Stage of Development

SNAP (version 1.0) was released in August of 1996, and version 2.0 was released in August of 2000 incorporating feedback from farmers, University of Wisconsin Extension (UWEX) staff, crop consultants and agency personnel. SNAP-PLUS is currently in development with beta version available in early 2004.

### Focus

SNAP’s focus is soils, crops and animals.

### Scale

SNAP-PLUS works on either a field by field basis for creating a nutrient management plan, a manure plan, P and K balance, rotational soil loss, record-keeping, and P index, or a whole-farm basis for creating a nutrient plan, manure plan, fertilizer plan, record-keeping and P index. See Figure 6.13.

### **Area of Concern**

SNAP-PLUS primary areas of concern are P runoff, soil loss, and nutrient application rates to crop needs. Most important is the ability to identify problems to facilitate management changes by producers.

### **Tool Application: Users**

Snap's intended users are farmers (large and small), NRCS and state employees, University of Wisconsin Cooperative Extension staff, crop consultants, teachers and students.

### **Tool Application: Format**

- Development environment: Borland Delphi.
- Database: currently FlashFiler, an open source relational database product. In the future it will probably switch to xml.
- Lookup data: in xml, searched using XPath.
- NRCS Rusle2 model: obtain soil loss and potentially other parameters (for example runoff volumes).

The software will eventually be made available for downloading from the University of Wisconsin Soils Department web site.

### **Tool Application: Documentation**

Help screens and a manual will be included with SNAP-PLUS. The documentation is intended to be non-technical for use by farmers and others with limited computer knowledge.

### **Knowledge and Data Transferability: Geographic Transferability**

SNAP-PLUS is specific to Wisconsin cropping systems and soil test recommendations for field and vegetable crops.

### **Data Sharing**

SNAP is able to transfer data with NRCS toolkit, commercial GIS software (MapWorks, EASi-Suite, SST), export as .txt, .xml, .html, .pdf, Excel and other formats. It is set up for easy data exchange between farmers and consultants within state and federal agencies. Farmers can email in their files for easy transferability. It can be paperless plan development. Soil test results tie together the qualitative WI PI and the quantitative SNAP.

### **Data Inputs**

- Farmer's name, county where farm is located, crops grown and fertilizers used.
- Specific field data and soil test data are imported electronically.
- Livestock type and quantity by class, manure source and percent collected, analysis and volumes on an annual basis.
- Cropping data (Fig. 6.15).
  - Crop to be grown.
  - Yield goal.
  - Tillage type.

- Legume and manure credit information.
- Fertilizer application information.
- A useful feature is that any time users make a change to a screen, they get immediate feedback for making management decisions.

Field Name	Field group (subfarm)	FSA Tract #	FSA Field #	County	Size (acres)	Soil Symbol	Soil Name	Upper slope	Lower slope	Distance to water	Strip Cropped starting	Contoured starting	Terraced starting	Filter / Buffer Strip starting	Distance to home base (miles)
1		T270	12	WI-Winneb	12.26	KnB	Kewaunee	4 180		4	300				
2		T270	12	WI-Winneb	10	KnB	Kewaunee	4 180		4	400				
3		T270	??	WI-Winneb	2.43	KoC2	Kewaunee	7 120		4	700				
4		T270	??	WI-Winneb	2.37	KoC2	Kewaunee	7 120		4	800				
5		T270	10	WI-Winneb	14.39	KoC2	Kewaunee	7 120		4	400				
6		T270	11	WI-Winneb	11	KoC2	Kewaunee	7 120		4	600				
7&8		T270	11	WI-Winneb	17.89	KoC2	Kewaunee	7 120		4	300				
9		T270	11	WI-Winneb	11	KoC2	Kewaunee	7 120		0	0				
10&11		T270	8	WI-Winneb	19.63	KnB	Kewaunee	4 180		4	300				
12		T270	8	WI-Winneb	8	KnB	Kewaunee	4 180		4	50				
13		T270	8	WI-Winneb	10	KnB	Kewaunee	4 180		0	0				
14		T270	9	WI-Winneb	18	KnB	Kewaunee	4 180		0	0				
15		T270	2	WI-Winneb	10.29	KoC2	Kewaunee	7 120		0	0				
16		T270	3	WI-Winneb	4.6	KnB	Kewaunee	4 180		0	0				
17		T270	4	WI-Winneb	7.19	KnB	Kewaunee	4 180		0	0				
18		T270	6	WI-Winneb	5.88	KnB	Kewaunee	4 180		0	0				
19		T270	1	WI-Winneb	11.51	KnB	Kewaunee	4 180		0	0				
20		T270	7	WI-Winneb	12	Pu	Kewaunee	4 180		4	100				
21		T270	7	WI-Winneb	14.32	Pu	Poygan	1 150		0	0				
22		T270	5	WI-Winneb	4.51	MaA	Manawa	1 150		0	0				
S1		T10314	1	WI-Winneb	20.56	KnB	Kewaunee	4 180		4	100				
S2		T10314	2	WI-Winneb	5.47	KoC2	Kewaunee	7 120		0	0				
S3		T10314	3	WI-Winneb	11.85	KnB	Kewaunee	4 180		4	100				
S4&5		T10314	4	WI-Winneb	19.77	KnB	Kewaunee	4 180		0	0				
S6		T10314	6	WI-Winneb	11.98	KnB	Kewaunee	4 180		0	0				
S7		T10314	7	WI-Winneb	11.7	MaA	Manawa	1 150		0	0				
S8		T10314	5	WI-Winneb	4.99	FsB	Fox	4 180		0	0				

Figure 6.15: Example SNAP input screen.

## Tool Outputs

- Soil loss estimates for each crop rotation and field from RUSLE2.
- P index estimate for each field by year, rotation, and whole-farm.
- P and K balancing for each field by year and rotation.
- Multi-year view facilitates long range planning for manure and P balancing.
- User can be led to appropriate management practices from a range of options to decrease cost and/or environmental risks.
- P based nutrient management plan field by field and whole-farm.
- Record-keeping: the program itself serves as record-keeper.

## Tool Limitations

- Limited to Wisconsin soil test recommendations and WI PI.
- More data entry is necessary for SNAP-PLUS than previous versions.

- The user interface in SNAP-PLUS is more complicated than for SNAP.
- It is not GIS compatible. SNAP is in tabular format, while GIS wants data in raster or grid format. There are software compatibility issues with the RUSLE2 program.

### **Field Validation**

Validation of the P Index and soil test recommendations is continuing. Currently a beta version of the SNAP-PLUS software is being tested by 15 – 20 users to gather feedback and comments.

### **Users**

SNAP users are farmers, consultants, NRCS, teachers, students, UWEX, and state and federal agencies.

- 65% of nutrient management plans in Wisconsin use SNAP (not SNAP-PLUS yet).
- ~1000 copies distributed as far away as Japan and Australia.
- ~500 users in Wisconsin.

### **Is This Tool Useful in Meeting Regulatory Requirements?**

Using this software helps manage nutrients (most notably manure) on the farms. It brings soil conservation together with nutrient management and increases an awareness and participation in nutrient management planning. Using a tool such as SNAP, with a multi-year view, increases user confidence that management changes can happen and have an impact on nutrient loading. SNAP and SNAP-PLUS meet current and future regulatory requirements in the following ways:

- SNAP-PLUS meets “new” NRCS Wisconsin 590 nutrient management standard.
- CAFO rules are also met with SNAP-PLUS.
- Provides conservation plan (RUSLE2).
- Provides nutrient management plan (P based).
- Provides record-keeping program (SNAP).
- Provides manure management plan (SNAP).
- Will be a part of a Comprehensive Nutrient Management Plan.

### **Future Plans for Tool**

- Complete software development.
- Beta test software and incorporate feedback.
- GIS integration with commercial software.
- Develop an advanced version for consultants and agencies.
- Add economic outputs. There is currently no economic information in the software.
- Add a P leaching model.
- Add N and P whole-farm balancing software. This could be an area for future collaboration.

## Case Study Assessment – Doug Marshall

### Madison Area Technical College, Reedsburg, Wisconsin

Doug Marshall teaches nutrient management planning for farmers at the Madison Area Technical College in Reedsburg, Wisconsin. His curriculum consists of a 6-hour nutrient management training program for farmers. Producers spend this time in a classroom with lectures and computer training (SNAP and soon SNAP-PLUS) with the goal of learning to develop their own nutrient management plans.

#### Tool Strengths

Doug has always found SNAP to be easy to use, learn, and he considers it an excellent teaching tool.

- Easy input (soil test results imported from lab is a real benefit).
- Legume credits easy for farmers.
- Manure application easy to plan.
- Available on the Internet.
- Documentation available on the Internet.

#### Tool Limitations

Doug did point out a few problems with SNAP 2000 that he hopes could be addressed in SNAP-PLUS:

- SNAP 2000 reorders field identification numbers and this can get farmers upset.
- Data backup is not available within the program.
- Some farmers lack enough computer skills so that downloading from Internet is a problem.
- The manure log should calculate in tons/ gallons instead of loads. The classes spend a lot of time trying to get people to look at tons and gallons and then the software asks them to look at loads - this can be confusing.
- Field data screen - entering data for the wrong crop year was a frequent problem. But SNAP-PLUS seems to have taken care of this with allowing users to load 5 crop years on one screen.
- SNAP 2000 lacked clear guidelines for ranking fields for manure application. Farmers tend to look for guidance on that. Some of the added features in the newer version should improve this.

#### Future Opportunities

##### ***Next Generation of SNAP, SNAP-PLUS***

Using RUSLE2 in SNAP-PLUS will help answer some questions that previous versions did not. The ability to put the soil conservation plan and the nutrient management plan together will be very helpful. Inclusion of the WI PI will help farmers prioritize fields for manure application. Multiple year planning is extremely helpful. Doug mentioned that previous versions of SNAP were successful mainly because of their simplicity and ease of use. He would like SNAP-PLUS to be simple and user friendly as well.

##### ***Obstacles to Creating Farmer Generated Nutrient Management Plans***

- Rough topography can limit a producer from implementing a nutrient management plan exactly as he has hoped.

- Lack of coordination with custom applicators can frustrate implementation.
- Lack of “short term” storage for manure in order to use it properly as a resource.
- Lack of management time.
- Computer skills vary quite a bit, but lower level computer skills can be a problem.

***Benefits to Farmer Generated Plans***

- Awareness.
- Action.
- Ownership.

## VII. COMPARING NUTRIENT MANAGEMENT SOFTWARE TOOLS

	DAFOSYM	PALMS	Yardstick	N-CyCLE	CNCPS	Cropware	SNAP +	WI PI	NY PI
<b>Environmental outputs</b>									
Phosphorus loss/balance	■	■	■	■	■	■	■	■	■
Nitrogen loss/balance	■	■	■	■	■	■	■		
Other nutrient balances	■		■	■		■	■		
Sediment loss		■					■	■	
Manure timing/application				■		■	■		
<b>Economic inputs/outputs</b>									
Income	■			■	■				
Manure/fertilizer costs	■					■			
Feed costs	■			■	■				
<b>Production inputs/outputs</b>									
Crop production	■	■		■					
Crop nutrient requirements				■		■			
Animal products	■			■	■				
Feed requirements	■			■	■		■		
Labor requirements	■			■					
Management decisions		■			■	■	■	■	■
<b>Regulatory output</b>			■			■	■		■
<b>Record keeping output</b>						■	■		
<b>GIS capabilities</b>		■							
<b>Data transferability</b>		*	***			■	■	■	
<b>Tool documentation available</b>	■	■	■	*	■	■	*	■	■
<b>Field validation</b>	■	*	■		■	■	*	*	■
<b>Targeted audience</b>									
Farmer			■		■	■	■	■	■
Research	■	■	■	■	■			■	■
Agricultural industry	■	■	■	■	■	■	■	■	■
Policy	■				■	■	■		■
Teaching, Extension	■		■	■	■	■	■		■

\* Underway; \*\*\* Only transferable to Excel.

## **VIII. ADDITIONAL NUTRIENT MANAGEMENT TOOLS**

Due to time and monetary constraints, only nine of the nutrient management tools used in Wisconsin and New York were presented in the Fall 2003 video seminar series and included in our detailed analysis. The following is a brief list of other nutrient management tools used in the two states and beyond. This is not an exhaustive list of all nutrient management tools as putting such a list together was beyond the scope of this project.

### **New York Tools**

#### **The Soil Moisture Model (SMR)**

The purpose of the SMR is to simulate the hydrological behavior of small rural watersheds with shallow soils and moderate slopes, and in particular to identify the surface runoff generating variable areas. The Soil Moisture Routing (SMR) Model is a continuous, physically based, spatially distributed model, fully integrated into the GRASS (Geographic Resources Analysis Support System) Geographic Information System (GIS). SMR is intended as a management tool for planners or groups interested in watershed management. Therefore, it is designed to use readily available data, which can usually be obtained in electronic form: topography (Digital Elevation Map or DEM), land use (Land Use and vegetative cover Map or LUM) and soil hydrodynamic characteristics, as a combination of a Soil Type Map (STM), its corresponding Soil Characteristics Table and some statistical relationships between textural information and hydrodynamic properties. Contact: P. Gérard-Marchant and T.S. Steenhuis, Soil & Water Lab, Department of Biological & Environmental Engineering, 222 Riley-Robb Hall, pg56@cornell.edu / tss1@cornell.edu.

#### **Nutrient Management Planning System, Crop Rotation Module**

The Crop Rotation Module is an Excel based program which balances forage production, herd feed requirements and farm feed storage. The program is designed to be used by producers to evaluate cropping, storage, and feeding alternatives. Two levels of complexity are available. Forage quality, forage feeding levels and individual field rotations are all considered in the analysis. Contact: T.F. Kilcer, 518-272-4210, Rensselaer County Cornell Cooperative Extension, 61 State St., Troy, NY, 12180-3412; tfk1@cornell.edu.

## Wisconsin Tools

### CELLO

Communities, Ecosystems, and Large Livestock Operations, a nutrient model. For any geographic area, Cello estimates nutrient flows based on county data similar to those reported by the Wisconsin Agricultural Statistical Services. It makes several assumptions about separate aggregate statistics to characterize feeding and cropping strategies. Contact: W.L. Bland, University of Wisconsin Soil Science Department (608) 262-0221; [wlbland@facstaff.wisc.edu](mailto:wlbland@facstaff.wisc.edu).

### UW-FARM Planner

UW-FARM Planner is a nutrient management planning software package, designed to identify acceptable strategies for managing on-farm and purchased nutrients in both a profitable and environmentally responsible manner. UW-FARM Planner relies on soil test results and recommendations consistent with UWEX A2809 to maximize optimum use of nutrients and restricts nutrient/manure applications in environmentally sensitive areas consistent with best management and NRCS-590 guidelines. Contact: S.M. Combs (608) 262-4364; [smcombs@facstaff.wisc.edu](mailto:smcombs@facstaff.wisc.edu); <http://uwlab.soils.wisc.edu/>.

### CROP

The Crop Rotation Options Program is a software package designed to help farmers in the upper Midwest evaluate current farming practices and test new, alternative scenarios. The program is built on the principles that guide Best Management Practices (BMP's) for crop production, the USDA's Revised Universal Soil Loss Equation (RUSLE) for soil loss estimates, and the National Research Council's (NRC) Dairy Feed Recommendations. The program is designed for use by farm advisors and government agency representatives to help their clients improve farm productivity and profitability while meeting environmental standards. Agricultural educators will also use CROP to better prepare students by working through realistic whole-farm, problem-solving exercises. Contact: J.L. Posner, 262-0876, [jlposner@facstaff.wisc.edu](mailto:jlposner@facstaff.wisc.edu).

## Tools Developed In Other States

### MMP

Manure Management Planner (MMP) is a Windows-based computer program developed at Purdue University that is used to create manure management plans for crop and animal feeding operations. The user enters information about the operation's fields, crops, storage, animals, and application equipment. MMP helps the user allocate manure (where, when and how much) on a monthly basis for the length of the plan (1-10 years). This allocation process helps determine if the current operation has sufficient crop acreage, seasonal land availability, manure storage capacity, and application equipment to manage the manure in an environmentally responsible manner. MMP is also useful for identifying changes that may be needed for a non-sustainable operation to become sustainable, and determine what changes may be needed if the operation expands. MMP currently supports 21 states (AL, GA, IN, IL, IA, KS, MA, MI, MN, MO, MS, NE, ND, NM, OH, OK, PA, SD, TN, UT and WI) by generating fertilizer recommendations and estimating manure N availability based on each state's Land Grant University and/or NRCS guidelines. For agronomic questions, contact: B. Joern, Agronomy Department, Lilly Hall of Life Sciences, 915 W. State Street, Purdue University, West Lafayette, IN 47907-2054, (765) 494-9767, [bjoern@purdue.edu](mailto:bjoern@purdue.edu). For software questions, contact: P.J. Hess, Agronomy Department, Lilly Hall of Life Sciences, 915 W. State Street, Purdue University, West Lafayette, IN 47907-2054, (765) 494-8050, [pjhess@purdue.edu](mailto:pjhess@purdue.edu), <http://www.agry.purdue.edu/mmp/>.

### MSUNM

Michigan State University (MSU) Department of Agricultural Engineering and the Crop and Soil Sciences Department designed the MSU Nutrient Management (MSUNM) computer program (Windows version). This computer program assists crop and livestock producers with fertilizer and manure nutrient management and pesticide application recordkeeping. MSUNM contains the MSU Fertilizer Recommendations computer program which provides users the convenience of generating their own MSU fertilizer recommendations utilizing soil testing laboratories. MSUNM allows the tracking of nutrient additions from fertilizer and manure applications, resulting in the reduction of critical non-point pollution. For livestock producers, MSUNM can calculate manure application rates for fields and subfields that are in compliance with the "Right To Farm Generally Accepted Agricultural and Management Practices" (GAMMPs). See: <http://www.canr.msu.edu/msunm>.

### NMP

Nutrient Management Planner from Minnesota is a computer program in Microsoft Access designed to assist in developing field specific crop nutrient management plans for crop and livestock farms. The software will develop basic crop nutrient management plan for a crop and livestock farm, a nutrient plan that meets requirements of USDA-NRCS Programs, and a manure-nutrient management plan that meet requirements of Minnesota State 7020 Feedlot Rules. Features of the program include the Manure and Crop Nutrient Calculator which provides an analysis of the crop acres that would be needed for utilizing the nutrients from manure applications (required for feedlot permit), and generates a Manure Source Report that gives the annual manure and nutrient production from the farm's manure storage systems. The Field-specific Planner of

Manure and Fertilizer Applications provides annual field-specific crop nutrient application planning based on crop history and past management, and University of Minnesota Extension Service recommended nutrient application rates. Contact: K. Blanchet, University of Minnesota Extension Service, Farmington Regional Center, 4100 220th Street West, Farmington, MN 55024-9539, (651) 480-7739, [blanc013@umn.edu](mailto:blanc013@umn.edu), <http://manure.coafes.umn.edu/assets/NutrientManagementPlanner.pdf>.

## **IX. CONCLUSIONS**

There is a wide variety of nutrient management tools available for use by the academic communities, agricultural educators, farmers, and policy makers in New York State and Wisconsin. Each tool plays a significant role in furthering the understanding and practical application of nutrient management issues. Our project goal therefore was twofold: to share and disseminate research tools among potential users and to examine what makes a tool useful in its intended application.

### **What do Researchers Expect from a Nutrient Management Tool?**

- Accurate modeling.
- Predictive capabilities.
- Adequate field validation.

### **What do Farmers, Consultants and Regulators Want to See in a Nutrient Management Tool?**

- Fulfill regulatory needs.
- Include Land Grant University guidelines.
- Address water and air quality concerns.
- Provide economic analyses.
- Provide management and planning recommendations.
- Include or link to record keeping systems.

The Cornell/Wisconsin/USDFRC team met throughout the course of the project. Through the analyses of existing tools and discussions with stakeholders, we identified several areas of improvement for our current tools. Some tools do cover some of these perceived gaps, others do not. Areas that could be improved include:

- GIS capabilities.
- Economic benefits predictions.
- Nutrient balance import and export values (simple).
- Record keeping.
- Ability to account for fields that do need P versus those that do not need P.
- Ammonia emissions, odor control.
- Diet information integration with CNMP tools.
- Farmers will want to know when their soil test P soil test levels surpass an environmental threshold.
- Farmers are NOT taking into account enhanced N based on specific application techniques.

An issue mentioned frequently during the course of our seminar series was the need for record-keeping systems to make nutrient management decision-making easier for educators and farmers. The Soil Nutrient Application Program (SNAP) from Wisconsin is the only one that was developed with a record-keeping component. Several other tools have limited recordkeeping capabilities (e.g. Cropware).

## X. EDUCATIONAL TOOLS

As a part of our exchange related to nutrient management, Cornell University and the University of Wisconsin shared course outlines and other educational resources that are used for undergraduate and graduate instruction relate to nutrient management. This includes a course entitled “Whole-farm nutrient management (AS/CSS 412)” taught at Cornell University, and “Environmental Management of Livestock Operation (Dairy Science 375)” taught at Wisconsin. Each will be outlined briefly.

### Cornell University: Whole-Farm Nutrient Management (ANSC/CSS 412)

This course provides students with an understanding of the concepts underlying whole-farm nutrient management planning to improve profitability while protecting water and air quality. Students develop components of a CNMP for a case study farm using the Cornell University Nutrient Management Planning System (*cuNMPS*) and other tools. During the first half of the semester in Module 1 (2 credit option), students learn the concepts and processes of developing the crop and manure nutrient management plan component of a CNMP. Students opting to continue through the end of the semester in Module 2 (enrolled in the 4 credit option) will build upon the first half of the semester by learning the knowledge and skills necessary to integrate crop production and herd feeding management for reducing nutrient imports on farms.

Module 1: Crop and Manure Nutrient Management Planning	Module 2: Herd Nutrient Management Planning
<ul style="list-style-type: none"> <li>▪ <b>Required</b> -- 2 credits</li> <li>▪ Start of classes to spring break</li> <li>▪ Students will:               <ul style="list-style-type: none"> <li>○ Explore the latest environmental policy in agriculture (CAFO, CNMP, etc.).</li> <li>○ Learn N, P, and K management.</li> <li>○ Develop a nutrient management plan with <u>Cropware</u> for an operating dairy farm to meet state and federal regulations.</li> <li>○ Consider improvements and impacts throughout the whole-farm system.</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>▪ <b>Optional</b> -- 2 credits</li> <li>▪ Spring break to end of classes</li> <li>▪ Pre-requisites: AN SC 411 and Module 1</li> <li>▪ Students will:               <ul style="list-style-type: none"> <li>○ Learn and apply the concepts of precision feeding with <u>CNCPS</u>.</li> <li>○ Practice feed inventory management.</li> <li>○ Integrate the herd and crop nutrient management plans to improve nutrient use efficiency and profitability across the entire farm.</li> </ul> </li> </ul>
Module 1:	Module 2:
Greg Albrecht, Extension Associate Nutrient Management Spear Program Dept. of Crop and Soil Sciences 813 Bradfield Hall gla1@cornell.edu 607 255-1723 Dr. Quirine Ketterings, Assistant Professor Nutrient Management Spear Program Dept. of Crop and Soil Sciences 817 Bradfield Hall qmk2@cornell.edu 607255-3061	Dr. Michael Van Amburgh, Associate Professor Dept. of Animal Science 272 Morrison Hall mev1@cornell.edu 607 254-4910

## **University of Wisconsin: Environmental Management of Livestock Operation (Dairy Science 375)**

Agriculture and especially livestock industries (cattle and dairy) are under increasing scrutiny from the general public to minimize environmental risks. Emotions and lack of understanding are often the sources of mistrust between the general public and agricultural communities. Students and producers would benefit from an improved understanding of environmental concerns. N-CyCLES, the web site, provides a series of modules that focuses on nutrients cycles at different scale:

- Current global and national environmental issues.
- Soil and landscape issues.
- Manure and crops.
- Livestock & nutrition.
- Whole-farm phosphorus management.
- Whole-farm nitrogen management.

These modules present (qualitative) information from a variety of sources and perspectives from producers, extension agents and scientists. The class uses N-CyCLES, to describe the dynamics of nutrients within and across the dairy system components that producers manage. The course follows the general outline below:

Module 1	Global issues, policies, regulations
Module 2	On-farm nutrient management plan
Module 3 & 4	Soils and crop fertilization
Module 5	Nutrition, livestock - crop interactions, engineering
Module 6	Computer lab: whole-farm nutrient balance spreadsheets

The course is archived at <http://www.dairynutrient.wisc.edu/ncycle.htm>. Contact: Michel Wattiaux, Assistant Professor Dairy Science, 460 Animal Science Building, 1675 Observatory Drive, Madison WI 53706, (608) 263-3493, [wattiaux@facstaff.wisc.edu](mailto:wattiaux@facstaff.wisc.edu).

## **Other Educational Tools**

### **NM Farmer Education Curriculum**

Farmer outreach curriculum that includes a plan for farm visits, educational workshops and farm follow-up. The goals of the program include educating farmers on sound nutrient management, writing a nutrient management plan, and following up with evaluation of nutrient management plan implementation. Application includes a CD-Rom and 3-ring binder with extensive information. The powerpoint presentation includes over 140 slides broken into 2 modules, Nitrogen and Phosphorus. Contact: S. Sturgul, 608-262-7486, [ssturgul@facstaff.wisc.edu](mailto:ssturgul@facstaff.wisc.edu).

**Dairy Whole-Farm Nutrient Management: The Diet Connection**

Feed management information is crucial for today's farm audience. Excess nutrients in feed contribute to excess nutrients in the environment resulting in elevated soil test levels and increased potential for nutrient losses to groundwater, surface water, and the atmosphere. The curriculum, in CD-Rom format, contains a PowerPoint presentation, speaker notes, and supplemental publications on dairy diet and nutrient management planning. The presentation can be used 'as-is' or be modified for local audiences and situations. This curriculum leads the audience (farmers, students in agriculture, and agribusiness professionals) through the animal feed management aspects of whole-farm nutrient management and covers P, N, and K in detail. It can be used alone, or as a companion to the "Nutrient Management Farmer Education Program" curriculum. Contact: L.N. Adams, 608-265-2379, [lnadams@facstaff.wisc.edu](mailto:lnadams@facstaff.wisc.edu).

**Dairy Forage Research Center Winter Seminar**

Enhanced Integrated Nutrient Management on Dairy Farms - This six part series examined research, extension, and policy approaches to understanding and improving nutrient use on dairy farms (educational CD-Rom in production). Contact: J.M. Powell, 608-264-5044, [jmpowel2@wisc.edu](mailto:jmpowel2@wisc.edu), <http://dfrc.wisc.edu/powell/>.

**Phosphorus Research Roundtable**

Several University of Wisconsin groups presented a series of roundtable discussions to bring together researchers, educators, and policy makers to explore issues of phosphorus and the environment. The Phosphorus Research Roundtables offer an excellent opportunity to share information and learn about current issues associated with P and water quality. [http://www.soils.wisc.edu/extension/p\\_roundtables/title.htm](http://www.soils.wisc.edu/extension/p_roundtables/title.htm).

## XI APPENDICES

### National Center Matrix

The Cornell-Wisconsin team met in July 2003 to begin identifying gaps in nutrient management tool capabilities and nutrient management knowledge. As a group exercise, we categorized our perceptions and current understanding of nutrient management tools based on level of knowledge and level of adoption or practice. Tables 11.1 and 11.2 are the result of that group exercise.

Explanation of symbols:

Does the scientific community have knowledge in this area? X=some, 0=none.

What is the level of knowledge? 1=high, 2= some, 3=little knowledge.

What is the level of adoption or practice? Low, Med, High.

**Table 11.1:** Nutrient management tool capabilities and nutrient management knowledge concerning phosphorus (from July 2003 Project Meeting).

Animals (diet manipulation, facility design & management)			
Phosphorus impacts	Knowledge Exists	Level of Knowledge	Level of Adoption
Animal utilization	X	1	M-L
Excretion	X	1	M-L
Impact on milk production, health and reproduction	X	2	L
Incorporation into CNMP	X	3	M
<i>Notes:</i> Good level of knowledge on impact of diet P on dairy cattle. Gap in knowledge with P and CNMP, manure P extraction techniques and solubility issues. Diet P implications have not been put in Wisconsin P index.			
Manure Handling (collection, storage, treatment, recovery)			
Losses	X	2	L
Recovery	X	2	L
Utilization Value	X	3	L
Land Application and Management			
Crop uptake and utilization	X	1	H
Soil accumulation	X	1	L
CNMP	X	1	L
<i>Notes:</i> Knowledge gap concerning interaction between crop P uptake and runoff and P depletion in soils.			

**Table 11.2:** Nutrient management tool capabilities and nutrient management knowledge concerning nitrogen (from July 2003 Project Meeting).

Animals (diet manipulation, facility design & management)			
Nitrogen impacts	Knowledge exists	Level of knowledge	Level of adoption
Animal utilization	X	2	M-L
Excretion	X	2	L
Impact on milk production, health and reproduction	X	2	L
Incorporation into CNMP	X	2	L
Notes: We lack knowledge/understanding of interactions of microbial protein, recycled N, and amino acid utilization. CNMP implications: do we know that diet manipulation has an impact on availability of manure to crops? What is impact on urine N excretion and volatilization?			
Manure handling (collection, storage, treatment, recovery)			
Losses	X	2	L
Recovery	X	2	L
Utilization Value	X	2	L
Note: How much do we know about compost and anaerobic digestion?			
Land application and management			
Crop uptake and utilization	X	2	M
Soil accumulation	X	2	L
CNMP	X	2	M
Notes: We know generally the direction of change but cannot quantify these changes very well. How do manure applications affect soil organic matter? We do not know much about carbon in this system.			

## Additional Resources

*Animal Agriculture and the Environment: Nutrients, Pathogens, and Community Relations (NRAES-96)*. This is the proceedings from the Animal Agriculture and the Environment conference, held December 11-13, 1996 in Rochester, New York. Included are 33 papers divided into six categories: environmental concerns, protecting the environment, protecting the environment-land application, protecting the environment-animal management, considerations in public policy, and cost to the farmer.  
<http://www.nraes.org/publications/nraes96.html>.

Cornell field crops and soils handbook. 1987. New York State College of Agriculture and Life Sciences, Cornell University. Ithaca, NY 14853. 168 pages.

*Cornell Guide for Integrated Field Crop Management*. Cornell Cooperative Extension. 2004. Cornell University, Ithaca NY. 15853.  
<http://www.css.cornell.edu/extension/CornellGuide.html>

*Dairy farm sustainability final report*. Fox, D.G., C.N. Rasmussen, R.E. Pitt, J.J. Hanchar. 1996. Cornell University Animal Science Mimeograph Series 188; ABEN Staff Report No. 96-1; ARME Research Bulletin 96-07; and SCAS Research Series 96-4.

*Developing a Plan for Assigning Manure Spreading Priorities-UWEX A3626*  
<http://extremist.uwex.edu/ces/pubs/pdf/A3626.PDF>

*Developing and Applying Next Generation Tools for Farm and Watershed Nutrient Management to Protect Water Quality*. Cornell CALS Integrated Nutrient Management Program Work Team. Proceedings of December 2001 Workshop. AnSci Mimeo 220. CSS Extension Series E02-1. Cornell University Ithaca, NY. 89 pp.  
[http://www.inmpwt.cce.cornell.edu/documents/Workshop%20proceedings%202012\\_19\\_01.pdf](http://www.inmpwt.cce.cornell.edu/documents/Workshop%20proceedings%202012_19_01.pdf).

*Guidelines for Applying Manure to Cropland and Pasture in Wisconsin*. Explains the basics of crediting and over application's impact on ground and surface waters. Available from the Nutrient and Pest Management Program, UW-Madison 608-265-2660. <http://ipcm.wisc.edu/pubs/default.htm>.

*Liquid Manure Application Systems: Design, Management, and Environmental Assessment (NRAES79)*. This is the proceedings from the Liquid Manure Application Systems conference that was held in December 1994. It includes twenty-six papers and is divided into five categories: livestock manure systems for the 21st century, design of liquid manure systems, planning environmentally compatible systems, custom application, and managing for economic and environmental sustainability.  
<http://www.nraes.org/publications/nraes79.html>.

*Looking at Dairy Manure Application Rates*. A visual guide to what various manure application rates look like. Available from the Nutrient and Pest Management Program, UW- Madison 608-265-2660.

*LPES Curriculum*. This project delivers a national curriculum and supporting educational tools to U.S. livestock and poultry industry advisors, who in turn, will help producers

acquire certification and/or achieve environmentally sustainable production systems. Producers will also benefit directly from the information and assessment tools that the curriculum provides. <http://www.lpes.org/>.

*Managing Nutrients and Pathogens from Animal Agriculture (NRAES-130)*. This is the proceedings from "Managing Nutrients and Pathogens from Animal Agriculture: A Conference for Nutrient Management Consultants, Extension Educators, and Producer Advisors," held March 28-30, 2000, in Camp Hill, Pennsylvania. <http://www.nraes.org/publications/nraes130.html>.

*Manage to Your Advantage*. A two page guide to the basic calculations involved in taking credits, and applying manure in the fields that need it. Available from the Nutrient and Pest Management Program, UW - Madison, 608-265-2660. <http://ipcm.wisc.edu/pubs/default.htm>.

*Midwest Plan Service Publications* - MidWest Plan Service develops agricultural publications covering topics including: agricultural engineering; farm business management; animal sciences such as, dairy, swine, beef, horse, and sheep; construction; grain and postharvest; soil, air, and water management; manure management; and ventilation for livestock housing. <http://www.mwpsdq.org/Default.htm>.

*The New York Nitrate Leaching Index*. Czymmek, K.J., Q.M. Ketterings, H. van Es, and S.D. DeGloria. Department of Crop and Soil Sciences Cornell University. CSS Extension Series E03-2. Cornell University, Ithaca NY. 34 pp. <http://nmsp.css.cornell.edu/publications/nleachingindex.pdf>

*The New York Phosphorus Runoff Index. User's manual and documentation*. Czymmek, K.J., Q.M. Ketterings, L.D. Geohring, and G.L. Albrecht. 2003. Department of Crop and Soil Sciences. CSS Extension Publication E03-13. Cornell University, Ithaca NY. 72 pp. [http://nmsp.css.cornell.edu/publications/Pindex/PI\\_User\\_Manual.pdf](http://nmsp.css.cornell.edu/publications/Pindex/PI_User_Manual.pdf)

*Nitrogen Guidelines for Field Crops in New York (Second Release)*. Ketterings, Q.M., S.D. Klausner, and K.J. Czymmek. 2003. Department of Crop and Soil Sciences. CSS Extension Series E03-16. Cornell University, Ithaca NY. 70 pp. <http://nmsp.css.cornell.edu/publications/articles/extension/Ndoc2003.pdf>

*Nutrient Management: Crop Production and Water Quality*. Klausner, S. 1997. Natural Resource, Agriculture, and Engineering Service, Cooperative Extension, Cornell University, Ithaca, NY.

*Phosphorus Balancing Cards* are pocket sized information cards for farmer outreach.

- Phosphorus balancing- Optimizing dietary P levels.
- Phosphorus balancing- The ins and outs.
- Phosphorus balancing- Dietary P and spreadable acres.
- Phosphorus balancing- Managing protein supplements- *in development*.

Available from the Nutrient and Pest Management Program, UW-Madison 608-265-2660. <http://ipcm.wisc.edu/pubs/default.htm>.

*A Phosphorus Budget for Wisconsin Cropland.* A report submitted to The Wisconsin Department of Natural Resources and the WDATCP. Available from the Nutrient and Pest Management Program, UW-Madison 608-265-2660.  
<http://ipcm.wisc.edu/pubs/default.htm>

*Phosphorus Guidelines for Field Crops in New York (Second Release).* Ketterings, Q.M., K.J. Czymmek, S.D. Klausner. 2003. Department of Crop and Soil Sciences. CSS Extension Series E03-15. Cornell University, Ithaca NY. 35 pp.  
<http://nmsp.css.cornell.edu/publications/articles/extension/Pdoc2003.pdf>

*Potassium Guidelines for Field Crops in New York (Second Release).* Ketterings, Q.M., S.D. Klausner and K.J. Czymmek. 2003. Department of Crop and Soil Sciences. CSS Extension Series E03-14. Cornell University, Ithaca NY. 41 pp.  
<http://nmsp.css.cornell.edu/publications/articles/extension/Kdoc2003.pdf>

*Recommended Methods for Manure Analysis.* Peters, J. (Ed). 2003. A3769. Cooperative Extension Publishing, University of Wisconsin – Extension, Madison, WI. 58 pp.  
<http://soilfertility.unl.edu/Materials%20to%20include/2003%20NCR-13%20manure%20manual%20A3769.pdf>.

*Whole-farm Nutrient Management Planning Workbook.* A comprehensive farmer level guide to Whole-farm Nutrient Management Planning. Available from the Nutrient and Pest Management Program, UW-Madison 608-265-2660.

## Pre-seminar Survey

Once the Cornell-Wisconsin-USDFRC work group had narrowed the list of nutrient management tools to evaluate in our fall seminar series, we needed to develop a list of criteria that each nutrient management tool would be measured against. Rather than come up with these criteria on our own, we decided to ask what type of information would be most useful to our audience.

We developed a simple on-line survey to solicit opinions from interested parties. The survey went out to 53 people via email and included University of Wisconsin and Cornell University faculty and staff, UWEX County agents, and several agribusiness consultants. We received 21 responses and used these to guide the seminar series, and the criteria that each speaker would use when covering his or her nutrient management tool (see Presentation Outline, Page 105). Respondents were asked to choose the top four issues that would make the seminar interesting to them. Table 11.3 lists the issues that could potentially be covered in our seminar and the number of votes that each issue received from survey participants.

**Table 11.3:** Results of pre-seminar survey of audience interests.

Number of votes	Nutrient management issue to be covered
14	Identifying the gaps in knowledge about nutrient management planning.
12	Comparing which types of models have been most useful in meeting current and future regulatory criteria.
12	Understanding which types of models have been most useful in reducing nutrient load to the environment.
11	Learning what other researchers are doing in the field of nutrient management modeling-(covering the greatest number of different models possible).
9	Comparing my concepts and equations with those of other models.
6	A guide to help me choose which tools to recommend to farmers, consultants and others.
5	A comparison between New York and Wisconsin nutrient management regulations.
4	A resource to compliment a software tool that I am currently working on.
2	A guide to choose a tool to use in my own future research and modeling of nutrient management issues.
1	Understanding how I can use this software in undergraduate/graduate teaching.

## Presentation Outline

Each speaker invited to the seminar series was asked to cover the exact same topics about their nutrient management tool in order to gain an objective comparison of tools. The outline below is the document that speakers were working from to prepare their presentation.

### Descriptive Information

- Tool name.
- Purpose.
- Developer(s).
- Contact person(s).
- Stage of development (development, testing, released, version).

### Scale and Tool Focus

- Focus (soil, crops, animals).
- Scale (field, whole-farm, watershed, regional, etc.).
- Primary area of concern (nitrogen, phosphorus, leaching, runoff, air quality, etc.).

### Tool Application

- Who are the intended users?
- What format does the tool use? (Excel format, windows based, etc.).
- Is there user documentation, who is it designed for? (highly technical, non-technical).
- Does documentation include model equations and references?

### Knowledge and Data Transferability

- What geographic area is the tool designed for?
- Which variables are site specific, and which can be modified for any area?
- Is there capability to merge and share data with other tools?
- In general terms, what are the necessary inputs?

### Tool Outputs

- Production outputs (e.g., crops, meat, milk, manure).
- Environmental outputs (forms and amount of nutrients lost, e.g., P runoff, N leaching, ammonia emissions).
- Economic (Social) outputs:
  - Cost of management practices.
  - Land use decisions.
  - Other?
- Fulfills a regulatory requirement.

### Tool Limitations

- What limits the tool from being used by a wider audience?

- What are identifiable weaknesses in terms of technical abilities of the tool (algorithms, data sharing capabilities, etc.)?
- Was this tool designed because of a lack of knowledge of some aspect of nutrient management?

### **Has This Tool Been Useful in Reducing Nutrient Loads to the Environment?**

- Describe any gaps in the abilities of this model to balance nutrients or predict nutrient outcomes.
- Describe the quality of results with respect to handling nutrients.
- What is your confidence level in the tool outputs?
- Has there been any field validation? Or do you plan any?
  - By how many people?
  - What were the results?
- Who has used this tool, and in what capacity? What is the estimated number of users?

### **Has This Tool Been Useful in Meeting Current and Future Regulatory Requirements?**

- Are any regulatory issues addressed with this tool?
- Does this tool produce a nutrient management plan?

### **Future Plans for Tool.**

- What is your next step for this tool (no immediate future plans, completely reforming tool, etc.)?

## Using Video Conferencing as an Educational Tool

### The Project

Starting in January 2002 Cornell University, the University of Wisconsin, and USDFRC have been working on a joint project to study nutrient management tools, research applications, and educational efforts for dairy farms. At each location, interdisciplinary teams are working on research, extension and educational programs to improve farm profitability while protecting the environment.

### The Video Conference

In order to present nutrient management tools to a wide range of interested audiences from multiple locations, Cornell University and the University of Wisconsin presented a series of video seminars connecting speakers and audiences from New York State and Wisconsin in the fall of 2003. We held 6 video seminars, each focusing on an identified 'type' of nutrient management tool. Out of the many tools available for us to cover in an educational seminar, we chose nine tools based on several factors — focus, scale, and level of use in either states. There are obviously many more tools used in nutrient management research and planning that we were unable to cover in this seminar due to time and money constraints.

Speakers in the seminar series alternated originating in New York or Wisconsin, while a moderator was present at the second location. For each seminar, we heard from one or two tool developers and one person who had experience using the tool in the 'real world'. The exception to this was the October 28 seminar with N-CyCLE and the Modified Dutch Yardstick where we could not include a commentator due to time constraints. The combination of hearing from developer and user of each tool created a very effective means of feedback, generated discussion, and often pointed towards ways in which the tools could be improved in the future.

We chose video conferencing as the best means of providing information to audiences in both New York State and Wisconsin. Video conferencing offers a close approximation of a face-to-face meeting without the cost of speaker travel.

### Successes

- **Attendance**

The seminar series had, in general, excellent attendance at both the Wisconsin and the Cornell locations with between 15 and 30 people attending each seminar. The audience was usually bigger in Wisconsin when the main speaker was in Wisconsin, and bigger in New York when the speaker was from New York. Those attending included faculty, staff, students, extension educators, out of state visitors working in the area of nutrient management, and nutrient management planners from the private sector (agricultural consultants).

- **Discussions**

Each seminar was scheduled to allow ample time for audience questions and discussions. It was imperative to keep speakers on time, but as long as that happened, there was ample discussion from the audience during each seminar. At both sites, discussion often continued after the video link had been shut down.

Participants were anxious to talk to one another about points that had been made during the video conference.

- **Feedback**

We have received excellent informal feedback on the seminar series. A planned evaluation is underway to collect more formal feedback.

## **Difficulties**

- **Technical Difficulties**

We experienced very few technological problems during the seminar series. When speaker presentations were difficult to read, it was generally due to the speaker having too much information on a slide, or not following other suggested guidelines for video conference presentations.

- **Audience Attention**

The biggest problem in the beginning was that the audience at the remote site (without the day's main speaker) often appeared bored during a 40 minute presentation that was not happening in the room. In other words, it is not easy to look at a presentation without having the direct interaction of the speaker. This was improved somewhat by focusing the camera on a 'wide shot' that included the speaker and the presentation in the background. Both sites always had copies of the presentations and a close up was possible if people needed to see individual slides up close.

- **Speakers and Some Audience Members Intimidated by Video Medium**

The only other problem was that discussion was probably somewhat inhibited by the medium. We overcame this by coaching our 'moderators' for each session to follow protocols like repeating questions, calling on people from both the in-house and the remote audience, and giving people extra time to respond because of the extra time it takes to transmit and question and people's potential reluctance to speak 'on camera'.

Streaming video clips of the seminar presentations and speaker PowerPoint slide shows are available at <http://www.dfrc.ars.usda.gov/powell/wholefarm.html>.