"Economic and Ecologic Assessment of Groundwater Nitrogen Pollution from North Florida Dairy Farm Systems: an Interdisciplinary Approach"

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Abstract

The presence of nitrogen (N) in water is an environmental hazard because it affects human health and ecosystem welfare. The Suwannee River Basin in Florida has received much attention in recent years due to increased N levels in water bodies. Dairy waste is thought to be an important factor contributing to this water N pollution. Dairy farmers are now required to comply with stricter environmental regulations either under permit or under voluntary incentive-based programs. Dairy farmers are also aware that environmental issues in the near future will be the greatest challenges they will have to face. Evidence indicates that farms may reduce their total N loads by changing some management strategies. Using published and stakeholders' information, a dynamic, empirical, interactive, and user-friendly model was created to simulate north Florida dairy farms and use it to test management strategies that may reduce nitrogen pollution and still maintain farm profitability. Testing different crop rotations, crude protein contents, time spent on concrete by milking cows, and time of liquid manure in the storage pond, it was found that intensive crop rotations have the greatest impact on reducing N loss and at the same time improve profitability. It was also found that reducing crude protein may reduce N release and increase profitability. Reduction in time spent on concrete reduces the amount of manure N handled by the system and consequently may reduce the amount of N lost to the environment. Increasing the time liquid manure spends in the storage pond may reduce the risk of N lost to groundwater but increases the amount of N lost to the air, which is not used by the crops and consequently decreasing profitability. A combination of decreasing crude protein content in the rations and efficient crop rotations may considerably increase profitability and decrease N loss to the minimum.

1. Introduction

Dairy farming is an important part of Florida's agricultural industry. Milk and cattle sales from dairies contributed $429 million directly into the Floridian economy in the year 2001. Florida is the leading dairy state in the Southeast; it ranks 13th nationally in cash receipts for milk, 15th in milk production and 15th in number of cows (*Bos taurus*). According to the USDA (http://www.nass.usda.gov/fl), there were about 152,000 cows on about 220 dairy farms at the end of 2002, and more than 30% of these dairy operations and cows are located in the Suwannee River Basin. These dairies face increased government regulation due to social pressure because they attract the attention of neighbors and activists concerned with odors, flies and mostly with potential leaching of nutrients that might influence water quality (Giesy et al., 2002).

The presence of nitrogen (N) in surface water bodies and ground water aquifers is recognized as a significant water quality problem in many parts of the world (Fraisse et al., 1996). Over the last 15 years, nitrate levels in the middle Suwannee River basin have been increasing and these elevated nitrate levels

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can cause health problems in humans as well as negative impacts on water resources. In addition to making water unsafe for humans (Andrew, 1994) and many other animals, high nitrate concentrations lower water quality in rivers and springs causing eutrophication that results in algal blooms and depletion of oxygen that affects survival and diversity of aquatic organisms (Katz et al., 1999).

The Suwannee River basin has received much attention in recent years due to increased N levels in the groundwater-fed rivers of the basin that could seriously affect the welfare of the ecosystem (Albert, 2002). According to Katz (2000), N levels have increased from 0.1 to 5 mg l^{-1} in many springs in the Suwannee basin over the past 40 years. Pittman et al. (1997) found that nitrate concentrations in the Suwannee River itself have increased at the rate of 0.02 mg l^{-1} year^{-1} over the past 20 years and that over a 33 mile river stretch between Dowling Park and Branford, the nitrate loads increased from 2,300 to 6,000 kg day^{-1} while 89% of this appeared to come from the lower two-thirds, where agriculture is the dominant land use. One of the most publicized concerns is N losses in the form of nitrate into the groundwater through the deep sandy soils of the Suwannee River basin (Van Horn et al., 1998).

Dairy farmers are now required to develop manure disposal systems in order to comply with Florida Department of Environmental Protection water quality standards (Twatchtmann, 1990). This fact has led to considerable research efforts that emphasize N recycling and address such issues as maximum carrying capacity and nutrient uptake by crops (Fraisse et al, 1996). Dairymen in the Suwannee River basin have expressed their willingness to participate in initiatives that promote reduced environmental impacts, and in fact, many of them are already involved in using Best Management Practices (BMPs) promoted by the Suwannee River Partnership (Smith, 2002, Pers. Comm.). Staples et al. (1997) after interviewing 48 dairy farms in north Florida found that the perception of the anticipated costs of having to comply with probable upcoming environmental regulations was rated, by far, the top challenge to successful dairying in the future.

The Netherlands has implemented the Mineral Accounting System (MINAS) which focuses on nutrient (nitrogen and phosphorus) flows on individual farms, and taxes farms whose nutrient surplus exceeds a defined limit. MINAS embodies a new approach to environmental problems caused by agriculture. According to Ondersteijn et al. (2002) focusing on individual farmers has two major advantages. First, individuals are considered polluters and are individually held accountable for their pollution, according to the 'polluter pays' principle. Second, individuals have control over their pollution problem and will be able to deal with it on an individual level instead of being forced to comply with general measures that may be ineffective for their specific situation.

Nitrate overflow in dairy systems is affected by management practices and by environmental conditions. Changing management practices might have a great impact on overflow amounts. Agronomic measures of nutrient balance and tracking of inputs and outputs for various farm management units can provide the quantitative basis for management to better allocate manure to fields, modify dairy rations, or develop alternatives to on-farm manure application (Lanyon, 1994).

2. North Florida Dairy Farm Systems

Most dairies in Florida manage animals under semi-intensive or intensive systems. North Florida dairies are business enterprises and have full access to credit opportunities, information, and new technologies (Adams, 1998). The main production components of north Florida dairy farms are the herd and the crops. The herd is composed of young and productive livestock, while the crops are rotations of different crops in defined fields. When a heifer has her first calf, that heifer enters the productive group as a fresh cow - first lactation, and her calf, is sold or kept. All male calves are sold the day after they are born. Young livestock are usually managed in a different facility outside the main production facility.

During young and adult livestock periods, a number of animals will be culled from the herd because of their production performance, age, weight gained, general health, fertility, etc. Culling rates are characteristic of management and vary greatly across dairy farms.

The adult or productive herd develops in approximately yearly cycles. A fresh cow produces milk for ten or eleven months after which she will be dried for approximately two months. After the dry period, the cow delivers again and starts her next lactation. This intense productive cycle is possible because a cow that starts her lactation after a delivery is quickly inseminated again and can be pregnant after only a two month period (Voluntary Waiting Period (VWP)).

The number of cycles depends on management decisions. Some farmers prefer to keep cows only for three lactations, while others may want to keep them for six, seven or more. After the second and third lactations, milk production performance may decrease. Keeping cows for more lactations saves the cost of replacement, but at the same time has an opportunity cost of giving up higher expected rates of production with new cows entering the herd. During the 300-day milking period cows follow a typical milk productivity curve that increases rapidly at the beginning until reaching a peak. After that peak, production steadily decreases until the dry period.

In general, milking cows are confined while dry cows and young stock are kept in less intensive production facilities. The same happens with the diet: milking cows receive the highest nutrient-concentrated diet depending of their productivity. These diets are closely related to the N balance in and out of the farm. Different categories of milking cows are managed in the “intensive” facilities, which are the free stalls, walkways, and the milking parlor.

Florida dairies are required by official agencies to manage their on-farm waste. In north Florida, the most common practice of waste disposal is through flushing, removal of solids, storage, and crop systems. Free stalls and milking parlor (and other adjacent intensive facilities) are implemented with open canals that allow constant flushing of manure to a treatment lagoon, then to a storage pond from where liquid manure is applied to cropland (sprayfields). Before reaching the treatment lagoon manure is screened for solids, which are separated and do not reach the lagoon.

Dry cows and young stock are usually not included in the waste management program because they produce much less manure (and much lower N quantities) and spend most of their time grazing. In the case of milking cows, time spent out of confined areas also will determine the amount of reduction of manure produced. Dairy farm systems have surrounding crop fields where pasture, forage and silage crops are produced as a complement for cow diets.

For this study, the dairy farm boundaries are defined spatially as the physical farm limits excluding pastures to one meter below the surface. Any resource that enters these farm boundaries is recognized as a source (input) and any resource that exits these farm boundaries is a sink (output). This study emphasizes the flows of N entering the dairy farm system, its interactions within system, and its flows leaving the dairy farm system. Pastures are excluded because they are not presently regulated and are not seen as environmental hazards.

3. Objectives

The main aim of this research is to create a north Florida dairy farm simulation model and simulate north Florida dairy farm systems to assess the economic impact of management strategies that may decrease N leaching. This study intends to: a) understand north Florida dairy systems, b) create a north Florida dairy farm model, c) simulate north Florida dairy farms under different management strategies, d) estimate economic and ecological impacts of north Florida dairy farm systems, and e) create a user-friendly computer model for the benefit of dairy producers and other stakeholders.

User-friendliness and interactivity of models are required to gain understanding and direct feedback from stakeholders. The model developed in this research is intended to be a discussion tool for system understanding and at the same time an analyses tool. It will be used to obtain additional input during the development of a more complex model.

4. Methodology

Analysis in the systems approach is marked by recognition of the whole system and the interactions within that system rather than looking only at a system component. A systems approach employs specific techniques and tools, such as rapid appraisal, pattern analysis, diagrams, and modeling, often in a multidisciplinary fashion, to identify system boundaries and recognize component interactions (Kelly, 1995).

Rationality in the simulation models follows the logic of budgeting or accounting for the flows of N in the system, as developed by Van Horn (1997), Van Horn et al. (1994, 1998, and 2001), and by the Natural Resources Conservation Service from the USDA, NRCS (2001). The simulation model accounts for N inputs (sources), within-system interactions, and outputs (sinks), according to a defined dairy farm system boundary.

Changes in alternative management strategies such as: 1) crude protein included in the diet, 2) time herd spends in confined areas, 3) time of liquid manure in waste storage pond, 4) crops planted, and 5) area planted will be tested in five-year time frames to compare economic and ecological outputs. Information was collected from published sources, personal observations, and stakeholders' communication, of which are documented in the modeling section.

Dynamic Modeling of North Florida Dairy Farm Systems

A dynamic, event-controlled, empirical model was created to represent north Florida dairy farm systems and in it the flows of economic and environmental variables are accounted for.

The Dynamic North Florida Diary Model (DNFDM, Figure 1) was intended to be user friendly as an interactive spreadsheet in Excel® software that could be shown to dairy farmers and other stakeholders in a way easy for them to understand. Creation of the DNFDM was suggested by a stakeholder as a way to gain dairy farmers' interest. The DNFDM also intends to be a powerful analyses tool for representing real situations. It runs in monthly steps, using monthly budgets, as opposed to the yearly approach of Van Horn et al. (2001) and NRCS (2001). At this point the model is considered to be preliminary to be used for user feed back while a more complex and complete model is being developed.

The DNFDM has the following modules: feedstock, cattle, milk production, waste management system, and crop system. All these components interact among themselves and have two common variables throughout: N and money. It runs on a monthly basis for a desired number of years.

The model considers 11 classes of milking cows, from one-month to eleven months of lactation; two classes of dry cows, one and two month dry cows; and 24 classes of young stock: calves and heifers. At every monthly update, cattle classes increase their age by one month. Then, cows of milking group # 1 will become cows of milking group # 2 and three month-old calves will become four month-old calves, etc.

Culling rates apply to any month and the total culling rate for a specific farm is divided among the cattle groups and applied at each update. At any point in time, different cow groups require different diets, produce different milk quantities, require specific dairy facilities, and recycle specific amounts of N.

Dry matter intake (DMI) is calculated adapting research results of Van Horn et al. (1998). It changes with the stage of cow production, from 11.4 to 25.4 kg per cow per day for dry cows to highest productive cows, respectively (Table 1). The amount of crude protein in the diet varies from 15 to 17.5% and is a user choice option. The amount of crude protein determines the quantity of N entering the system and the flow of this nutrient in the system. Crude protein could be reduced without affecting milk production, if the herd is well managed, Børsting et al. (2003), Jonker et al., (2002), Wu et al. (2001), Van Horn et al. (1998), Tomlinson et al. (1996). Therefore, higher crude protein concentrations may produce similar milk quantity, but increased environmental risk and increased costs. To assure that the highest producer cows in a group have sufficient protein, the whole group would be fed a supplement diet for the highest producers and excess of proteins will usually be provided to lower producer cows in the group. Higher crude protein rations are believed beneficial for production purposes and that is why dairymen like to use them.

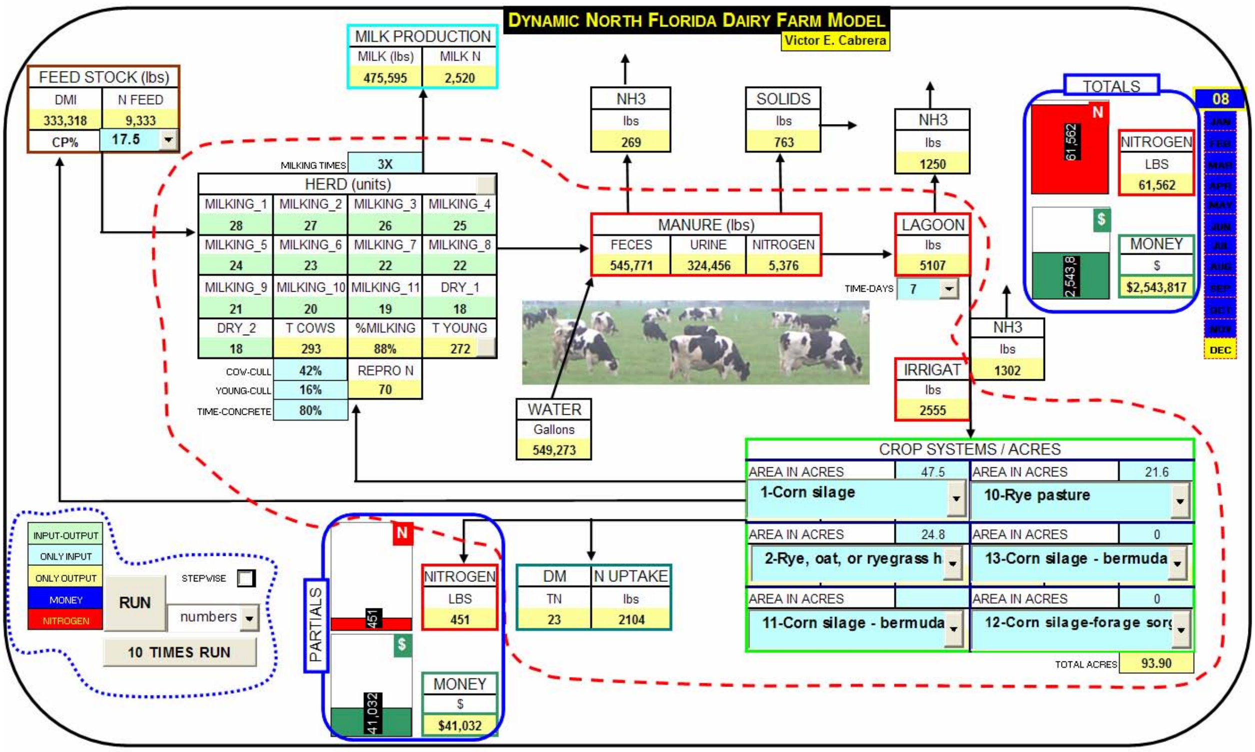


Figure 1 Dynamic North Florida Dairy Farm Model (DNFDM). Units are in local usage for interaction with the users

Milking cows require different amounts and different qualities of feed and at the same time they produce different amounts of manure (feces and urine) containing different amounts of non-digested N according to the production of milk (Table 1). Milk production per group was estimated based on the Florida average cow performance of 8,240.1 kg per year per cow, obtained from the Dairy Herd Improvement (DHI) data source (http://www.drms.org).

Manure time spent on concrete is the proportion of time milking cows stay inside intensive facilities from which manure is collected (free barn stalls, walkways, and milking parlor). Consequently time spent on concrete determines the quantity of manure (and N) for recycling. Dry cow and young stock manure is not part of the recycling program (i.e. their manure is deposited directly on pasture or it is managed in another way) because quantities are much lower than the production group. Cattle flow on the farm is greatly influenced by culling rates. Culling rates are farm-specific parameters for adult and young stock that determine the proportion of cattle that leaves the herd (for any reason) in time frames. Culling rates of 42% for the productive herd and 16% for the young stock, in a year, are acceptable for Florida dairies according to data from the DHI.

On north Florida dairy farms, the most common system used to handle manure is a liquid manure system that encompasses a flushing system, a solid screening system, a treatment lagoon, and a storage pond. The flushing system uses large amounts of water to wash the manure from point of concentration to the treatment lagoon. Before reaching the lagoon a system separates solids from the remaining liquid. Liquid manure passes through the treatment lagoon, where some sedimentation is expected, and reaches the larger waste storage pond, where it is kept for a variable time. Liquid manure from the storage pond is used as fertilizer in the farm crop fields, usually applied to fields through sprinklers in central pivot irrigation units. Solids separated from the liquid manure take only a little more than 15% of the total N and it is usually composted for use on-farm or sold.

Table 1 Milk production, dry matter intake and manure excreted by cattle groups

			kg day^{-1}cow^{-1}			
group	Description		milk	DMI*	feces	urine
1	milking	open	22.7	17.9	34.9	22.0
2	milking	open	45.4	25.4	57.3	30.0
3	milking	open	40.9	23.9	52.9	28.4
4	milking	open	31.8	20.9	43.9	25.2
5	milking	pregnant	29.5	20.1	41.7	24.4
6	milking	pregnant	27.2	19.4	39.4	23.6
7	milking	pregnant	25.0	18.6	37.2	22.8
8	milking	pregnant	22.7	17.9	34.9	22.0
9	milking	pregnant	20.4	17.1	32.7	21.2
10	milking	pregnant	18.2	16.4	30.5	20.4
11	milking	pregnant	15.9	15.6	28.2	19.7
12	dry	pregnant		11.4		
13	dry	pregnant		11.4		
		TOTAL MILK	8,240.1 kg per COW/YEAR			

Source: Adapted from Van Horn et al., 1998. *DMI is Dry Matter Intake

Using the Van Horn et al. (2001) nutrient flow approach, the amount of N that *reaches the waste system* is the difference between the amounts of N input in the feed less the digested proportion of it plus the weight gained by cows plus the amount of N used for reproduction (new calves):

$$N(waste) = N(feeding) - [N(milk) + N(weight) + N(reproduction)]$$

Part of the N is lost to the air as gaseous forms during flushing, storage, and spraying. While losses during flushing and spraying are difficult to control, the loss of N during storage can vary greatly according to management. In the DNFDM, storage time determines the quantity of N available for applying to crops. Storage time is a user choice. The greater the time in storage, the lower the N quantity available for recycling.

Parameterizations of the amounts of N that do not reach the sprayfields were adapted from Van Horn et al. (1998 and 2001) on a monthly basis. These are the result of extensive long term research in Florida which found that 5% of N is lost during flushing, 14.02% is extracted with the solids, 24.48% of the rest is lost during storage in the pond, and 50.94% of the rest is lost during the spraying.

Van Horn et al. (1998) indicate that most of the N that reaches the sprayfields is urea, ammonia, and other easily degradable N forms, and long term research applying this liquid manure developed by Newton et al. (1995) presented estimations of N uptake by crops in dairy farms. Van Horn et al. (2001) adapted these values for nutrient balances by adding 30% of N that is lost in the soil by volatilization, and discounting 20% of N that is fixed by bacteria in the case of legume crops (alfalfa and peanuts). These values can be found in Table 5: in Van Horn et al. (2001).

Dairy farms have many crop options for their land. Many times options are narrowed by trying for the most efficient use of nutrients from manure. There are many crops cultivated in north Florida dairy farm systems. Some are corn, rye, oat, ryegrass, peanut, alfalfa, bermudagrass, and sorghum. These are usually planted from seed or sod planted in rotations according to season. Some of them can be planted for different dairy purposes as for example the case of the bermudagrass that can be used as hay or as pasture. Crops are assumed to be well managed and with all their required nutritive demands to accomplish maximum dry matter accumulation; if the amounts of manure N are not enough for crop growth, farmers apply additionally chemical fertilizers. Biomass produced by crops is entirely used by the farm cattle, closing in this way the nutritive cycle.

The DNFDM allows choosing up to 6 different field sizes with the 13 most common crop rotations for north Florida. Following rationality of many dairy farmers, total N available to apply is evenly distributed to all sprayfields. Different crops under different environmental conditions in different seasons with different areas applied with liquid manure (sprayfields) will uptake different amounts of N. In some circumstances the quantity of applied N will be lower than the quantity required by the crop, a situation in which extra fertilization of N would be justified. But other times the quantity of N applied is greater than the uptake capacity of the present crops. In this case, extra N in the soil will be lost out of the farm boundaries (leaching below one meter soil depth) and may constitute an environmental hazard for groundwater resources. The DNFDF estimates in monthly steps the amounts of N outgoing from the farm.

Income to the dairy farm comes basically from selling milk and male calves. Male calves are sold at $30 per head one day after they are born and milk price is a stochastic function based on historical milk prices collected for the last five years from the USDA Website (http://www.nass.usda.gov/fl). The milk price contains an independent stochastic function that generates monthly milk prices based on the ranges of variation observed in the last five years as seen in Table 2. Farm expenses are only based on feed protein purchased after using all dry matter produced on farm evaluated at the market price of $290 per Mg (http://coopworth.org.nz/coopbul8.html). The cost of a pound of feed varies according to the chosen protein amount as a function of the following form: $1.2 \times [\%crudeprotein] - 0.07$, which is an equation adapted from Van Horn et al. (1998) with information on prices obtained from the Louisiana State University Agricultural Center (http://www.lsuagcenter.com/dairy/pdfs/1997report/feed%20cost.pdf).

Assessment of quantities of N lost as well as economic performance are calculated on a monthly basis, so comparisons of environmental and economic outcomes can be achieved in monthly time frames or be accumulated for long term analyses. The DNFDM is a user-friendly, interactive model that allows input and output data directly from the model. Color codes indicate properties of cells with respect to inputting or outputting data in cells. Light green cells indicate cells that are input and output cells: users can introduce data in those cells by overwriting them; results will be displayed in the same cells. Light blue cells (including scrolling boxes) indicate cells that allow the user to change parameters of the model before running; these cells will not change values during simulation. Yellow cells are output cells that display the internal model calculation results.

Table 2 US$ price per 45.4 kg of liquid milk in Florida, (1998-2002)

MONTH	MIN	MAX	AVG	RANGE OF VARIATION
JAN	12.00	17.99	15.86	5.99
FEB	11.80	15.95	14.75	4.15
MAR	11.90	16.65	14.84	4.75
APR	11.90	17.44	14.35	5.54
MAY	12.10	18.21	14.59	6.11
JUN	12.30	18.99	14.88	6.69
JUL	12.60	19.34	15.12	6.74
AUG	12.50	19.40	15.35	6.90
SEP	13.00	19.56	15.51	6.56
OCT	12.60	19.93	15.30	7.33
NOV	12.30	19.76	14.82	7.46
DEC	13.10	15.98	14.51	2.88

The DNFDM can run in different modes. It can run showing "number" results which appear in cells. The "number" simulation is intended to show the friendliness of the model to stakeholders, especially to dairy farmers to gain their interest; additionally four boxes indicate graphically the monthly and accumulated values of N loss (red) and money (green). The DNFDM can also be run in a "graph" mode which shows the big picture of the main variables (profit, N leached (temporal and total), and cattle flow) during the time frame of simulation. "Graph" outputs are intended for analysis purposes, after several simulations. In either mode, "number" or "graph," there is the option to run a "stepwise" simulation, which stops the running every month to provide time to analyze the evolution of the variables. Simulations of main variables are also stored in an independent spreadsheet as an organized table for analysis purposes. Additionally, a "run 10 times" button is conveniently located to allow the user to run the model 10 times with chosen parameters and save results in an independent table. Experiments analyzed in this study were accomplished using this useful function.

5. Limitations of the DNFDM

Some current limitations of the model need to be recognized in order to improve it for further versions. These are:

- Cows get pregnant at the same time; monthly groups are assumed to be exactly the same age
- Costs and incomes only include variable costs related to the parameters in the study. For example initial cost of waste management facilities were ignored
- Production of milk is not seasonally corrected, it is only cow stage dependent
- N is evenly applied to all sprayfields. If fallow present, N goes first to covered land.
- The same crop rotations are present for the whole simulation time
- Milk production concentration in winter, which may be a management strategy in some north Florida dairy farms, was not included
- The value of manure solids are not yet incorporated in the model.

6. General Results of Simulations

A simulation was set up for the cattle module to reach a “steady state” after a number of years of simulation. Analyses were done after the herd reached this steady state, in which there were about 300 adult cows (88% of them as milking cows) and about 270 young stock. This simulated dairy farm had 37.48 Ha of sprayfields with three crops: 19 Ha of corn silage, 8.64 Ha of rye pasture, and 9.84 Ha of oat haylage. Also, this farm was assumed to use a 17.5% crude protein diet for milking cows, have their milking cows 80% of the time confined on concrete, and applying the liquid manure after seven days of storage.

An N balance for this arrangement for December indicates 9,564 kg of N entering the system in the feed, is used to produce milk containing 2,120 kg of N. Additionally, 1109 kg of this is used in reproduction and weight gain of animals and the difference, 6,334 kg, are excreted in feces and urine. 316 kg of N are lost during flushing and 887 are recovered in solids. Therefore, 5,130 kg of N reach the storage pond from which 1,256 kg of N are volatilized. From the remaining, 3,875 kg of N, 1,972 are lost to the air during spraying and effectively 1,902 kg of N reach the 37.84 Ha of land. Thirty percent of this is lost as volatilization (571 kg) and the difference, 1,330 kg of N, are available for crops, that equals approximately 35 kg of N Ha^{-1} month $^{-1}$. In December, crops uptake 1078 kg of N and the difference, 282 kg of N, will be prone to leach.

Simulation also for this arrangement was run for a five-year period, where profit varies every month because of the stochastic price variability. Figure 2a shows that August is the most profitable month because more feed is produced on farm in that month. The opposite is also true; November and April are least profitable months because of the purchase of maximum quantities of feed because there is no on-farm production.

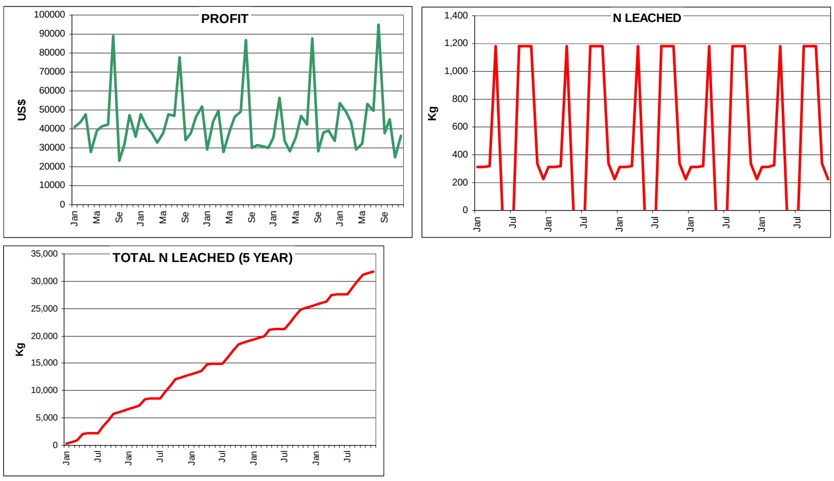


Figure 2 a) Monthly changes of profitability, b) N leached by month, and c) Cumulated N leached in five-year period

N leached into the subsoil is highly related to crop N uptake, and to profit. It changes completely according to the area planted and crop rotations. Using the above crop and areas, the N leached changes seasonally as seen in Figure 2b. Figure 2b shows that with these 37.48 Ha planted, there will be considerable N lost in most months, however no leaching will be expected during May, June and July. Figure 2c shows the cumulative N leached during a five-year period.

7. Five-year Management Strategies

Ten different management strategies were experimented with using the DNFDM model. These are summarized in Table 3. The control management strategy was based on the same farm parameters shown in section 4: 17.5% crude protein for feeding milking cows, milking cows spend 80% of the time in confined areas, liquid manure is applied after seven days in the waste storage pond, and there are 37.48 Ha of sprayfields to apply manure.

Experiments one to four tested the output changes with respect to changes in crude protein content in the diet of milking cows. Experiments five and six tested different lengths of storage of liquid manure in the storage pond. Experiments seven and eight tested the possible decrease of time spent in confined areas by milking cows. Experiment nine changed the crop of the largest field of 47.5 acres to a rotation (crop rotation # 2) of corn silage, forage sorghum, and rye silage. The last experiment, number ten, was similar to number nine for crop rotations, but crude protein in the diet was reduced to 15%. For each experiment, five years of simulation time was run, from January 2004 to December 2008, and two main variables were monitored: profit and N leaching. Every experiment was run ten times to observe the distribution of results for the profit that has stochastic price functions. Results are summarized in Figure 3. The baseline, or control treatment has the following outputs: 90% chance of getting at least $2.02 million of profit, 50% chance of getting at least $2.12 million of profit and 100% of chance of getting less than $2.18 million. There is an estimated N loss of 28,148 kg of N during this five-year period.

Table 3 Control and "experiments" with DNFDM for a 5-year period

Experiment	Crude Protein (%)	Time on Concrete (%)	Days in Lagoon	Crop Rotation
CONTROL	17.50	80%	7	1
1	17.00	80%	7	1
2	16.50	80%	7	1
3	16.00	80%	7	1
4	15.00	80%	7	1
5	17.50	80%	14	1
6	17.50	80%	28	1
7	17.50	60%	7	1
8	17.50	50%	7	1
9	17.50	80%	7	2
10	15.00	80%	7	2

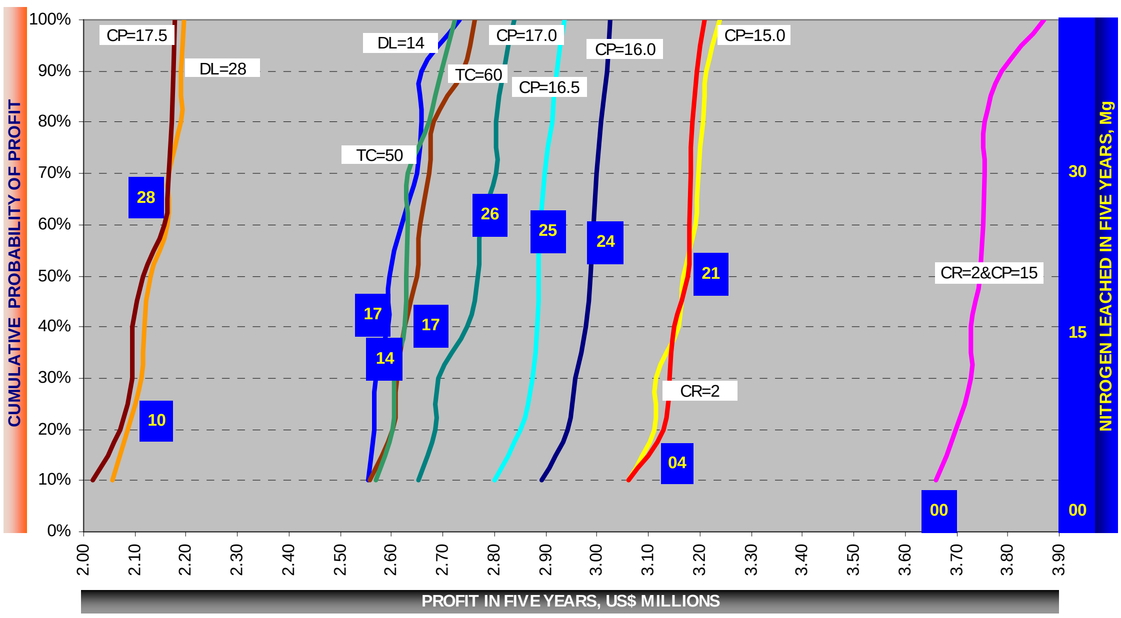
Van Horn et al. (1998) indicate that some diet control over N excretion is possible. Decreasing crude protein may decrease the amount of N in the manure still maintaining optimum animal performance and milk production. These authors tested two different diet formulations proposed by the National Research Council (NRC, 2001): high and low. The high diet requires more crude protein to *assure* requirements are met and the low diet minimizes dietary N. These levels, high and low, were estimated to be 17.5 and 15.0 % of crude protein on diet by local dairy farmers. These ranges along with numbers provided by Van Horn et al. were used as functions in the DNFDM.

Total N lost during the five-year period varies considerably with different protein diets as seen in Figure 3. If crude protein is 17.5%, 28,148 kg of N is expected to be leached, but if the crude protein is only 15% it is expected to leach about 20,884 kg of N. Profit changes inversely; while with 17.5% crude protein the profit would be less than $2.2 million, with 15% crude protein there is 90% chance that the profit could be greater than $3.0 million. Inputting less crude protein saves important feeding costs and decreases the risk of N overflows.

Time that the liquid manure is stored in the waste pond affects the results in the following way: the N leaching amounts would decrease from 28,148 to 17,152K kg when the manure is stored 14 days instead of 7 days, and it could even decrease to 9,988 kg when it is stored 28 days; the profit increases to $2.5 million (90% chance) when it is 14 days instead of 7 days, and decreases again to original levels when it is stored 28 days. Less N leached will be expected with more stored time because large amounts of ammonia N are expected to be lost to the air during storage time; this decreases the risk of N groundwater pollution, but it increases the risk of air pollution and it requires larger facilities. Time of liquid manure storage in the pond is part of the nutrient management plan and it could be controlled by the regulatory agencies. It is also expected that in the future, N pollution to the air could be measured and regulated. On the other hand, by not recycling maximum amounts of N on the farm there is a negative economic impact because of the lost value of N as crop fertilizer.

Time that milking cows spend on concrete has a direct relationship with the amount of N produced as waste for the system to handle. With 60% or 50% of the time on concrete (versus 80% in the control) the amount of N leached would decrease from 28,148 kg to 16798 kg and 13,620 kg respectively. The profit will also be affected by these changes because mainly the N as fertilizer has a value and produces biomass as feeding for the milking cows. With both treatments (60% and 50%) larger profit margins than the control are expected. With the 60% level, profits greater than the 50% level are expected because greater utilization of N as fertilizer is expected.

Changing the main field (47.5 acres) crop has a relevant effect on the results. Changing the corn silage to a rotation that includes forage sorghum, corn silage in summer, and rye silage in winter implies first, that the field will be cultivated longer in time, and second, it will have greater rates of N up take at any point in time. That is why with this rotation only about 4,086 kg of N would be leached during five years (compared to the control 28,148 kg). Besides the low rate of N leached, a much greater profit is expected because of the use of the N as fertilizer: with this new rotation at least $3.062 million profit is expected (90% chance) and at most $3.21 million. Profit of this treatment is quite similar to that from crude protein at 15% as can be seen in Figure 3, although the levels of N leached are quite different.



Note of abbreviations: CP is crude protein, DL is days in storage lagoon, TC is time in concrete, and CR is crop rotation.

Figure 3 Profit and Nitrogen Lost with Different Treatments for the Whole Farm

A final treatment combined the most encouraging previous results: crude protein at 15% and a crop rotation of sorghum, corn, and rye in the largest field. The results were quite revealing. First, no N is expected to be leached out of the farm, the entire N produced is recycled on farm. Second, the profit levels are far above the previous ones: it would be at least $3.66 million (90%) and at most $3.87 million. There is less risk of N lost in the system because the low protein in the diet and the high up-take capabilities of the crops. Higher profits are expected because of maximum use of the N as fertilizer and greater biomass accumulation.

8. Conclusions

- Seasonality and monthly nutrient balances make a difference compared with the traditional one-year nutrient budgeting
- Crude protein and kind of nitrogen as a feed supplement have a great impact on outputs, but experimental data are required to support and tune up interactions with N flow
- Crops are the best way of N recycling on farm. Dairy farms have to complement livestock activity with crop activity. If crops are well managed they can provide a good feed source to livestock and they can recycle large amounts of N
- Increasing the time of liquid manure storage would not be practical in real situations because facilities are designed for a specific holding time according to the herd size. Besides trying to lose N to the air intentionally (in order to decrease soil N lost) could be a bad economic decision and another environmental hazard
- Changing the time milking cows spend on concrete facilities is highly dependent on climatic conditions. Milking cows will be grazed only when weather is cool enough not to affect milk production because of heat stress. Therefore, options on trying to change time spent in confined facilities should be combined with changes in the herd breed (breeds with heat tolerance, for example) or providing shade in grazing areas. In practical and real situations, it seems that dairy farmers try to graze as much as they possibly can.

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