Environmental and Economic Impacts of Manure Management Strategies for Representative Michigan Dairy Farms

By

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To my parents, brother and sister-in law

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TABLE OF CONTENTS

LIST OF TABLES

Chapter 1: Introduction

1.1 Introduction

Environmental effects of animal waste have long been a concern to the United States livestock industry. Ever increasing livestock production scale, has resulted in three crucial environmental and odor consequences:

1. Spills from animal waste stores;
2. Nutrient runoff due to the application of manure to the croplands; and
3. Direct ambient pollution, including odors, pests and gases (Innes, 2000).

Under the Federal Water Pollution Control Act of 1972, or also commonly known as the Clean Water Act (CWA) since 1977, the Environmental Protection Agency (EPA) classifies concentrated animal feeding operations (CAFOs)[1] as point source polluters and non-CAFOs as non-point source polluters. The CWA requires that all CAFOs or dairy farms with 700 or more milking cattle maintain a performance standard consisting of National Pollutant Discharge Elimination System (NPDES) permits (Section 402). Dairy farms with less than 700 cows or non-CAFOs are not required to maintain NPDES permits though non-CAFOs are sources of water quality contamination. Due to economies of size in the adoption of newer milk producing technologies, the dairy industry in the United States is rapidly moving towards fewer dairy producers and larger herds. This restructuring of the dairy industry has resulted in an increase in the number of CAFOs.

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[1] "Clean Water Act" enacted in 1972 defined a concentrated animal feeding operation (CAFO) as a 1,000 animal-unit facility, in particular a dairy milking 700 or more cows, a swine farm with 2,500 or more sows, or a beef feedlot with 1,000 or more cattle.

Point-source pollution problems have been addressed by the U.S. federal government through efforts to prevent degradation resulting from the treatment of sewage plants, businesses and factories (Batie and Arcenas, 1998). However, non-point source pollution problems are more pressing concerns with the agricultural sector as the primary source of non-point source pollution. These problems result in water and soil quality changes as a result of the emission of pollutants, mainly nitrogen, phosphorus, and pathogens that are difficult to detect and measure.

The EPA, with the help of the CWA, launched a massive effort to restore the quality of the nation's waters. In its efforts to deal with non-point sources of pollution, the EPA initiated NPDES permits as an enforcement tool for CAFOs. Although these NPDES permits are a federal requirement, due to lack of personnel, CAFO permits are administered by the state environmental agencies (Casey et al., 1999).

The state of Michigan, striving to design programs to prevent environmental degradation from all livestock operations, in May 1998, created the Michigan Agricultural Environmental Assurance Program MAEAP. The MAEAP is a voluntary program for all livestock operations. This study, focuses solely on Michigan dairy operations. The MAEAP encourages participating Michigan dairy farmers to develop their own farm specific Comprehensive Nutrient Management Plans (CNMPs). A CNMP is a voluntary effort by the dairy farmers that assists in meeting desired pollution prevention and reduction goals at both, the federal and state level. Since the state of Michigan has not yet administered CAFO permits, it is expected that participation in the MAEAP might fulfill federal policy expectations offering voluntary and potentially less expensive alternatives for manure management.

1.2 The MEAP and CNMP

The MAEAP, which focuses on voluntary participation, came into existence to make adoption of agro-environmental oriented practices economically feasible and, possibly, functionally equivalent to the EPA and other federal regulations. The mission of the MAEAP is to develop and promote a proactive environmental assurance program that ensures that livestock producers are engaging in cost-effective pollution prevention that is also in compliance with federal and state environmental regulations.

The MAEAP, unlike traditional and more rigid federal and state regulations, builds in flexibility to existing strategies like nuisance protection with Right to Farm Act P.A. 93, 1981, the Farm*A*Syst[2] approach and other flexible environmental quality incentives programs.

In the aggregate, intensification of animal agriculture has resulted in excessive levels of nutrients being applied unto the available land. Manure and nutrient mismanagement is often the cause of high consumption of commercial fertilizers, and the possible contamination of groundwater. This relationship brings into focus the need for farmer awareness of the nutrient mass balance, nutrient cycles and the total amount of nutrients applied in the form of manure to ensure optimum crop productivity and human safety.

As a foundation requirement of participation, the MAEAP calls for the farmers to follow the Generally Accepted Agricultural Management Practices (GAAMPS)[3] for

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[2] "Farm *A* Syst is a voluntary and confidential assessment tool which helps farmers identify risks to groundwater associated with their farmstead practices. In support from the Michigan Groundwater Stewardship Program, the Farm *A* Syst provides ways to reduce groundwater contamination.

[3] "GAMMPs, are a product of the Michigan Agricultural Commission and authorized by the Michigan Right to Farm Act, P.A 93, enacted in 1981."

manure and nutrient management. The GAAMPS are suggested agricultural and management practices designed (and periodically updated) using guidance from Michigan State University, state agencies, and other personnel such as agricultural engineers and professional environmental conservationists working in the field of agricultural non-point source management. The MAEAP is comprised of essentially three phases, and, if a dairy farmer adopts the MAEAP and completes the CNMP, the farmer is certified as operating an "environmentally assured" farm. However after each stage, the voluntary nature of the assurance program gives each farmer the choice to continue or opt out of participation. The MAEAP seeks to provide every Michigan dairy farmer a confidential and flexible strategy to operate and maintain the livestock operation. The three-phased approach of the MAEAP is explained as below:

Phase 1. ***Provision of manure management specific information, education and MAEAP specific training:***

- Training about the basic needs and technical requirements of the MAEAP.
- Information about existing laws and regulations that the MAEAP embodies.
- Legal training for better agro-environmental risk management.
- Certification process for use of farming accessories on farms.

Phase 2. ***Provision of farmer-specific action plan for adoption of the MAEAP:***

- Inspection of each farm within the Farm*A*Syst framework.
- Conduct informal on-site assessment with relevant standard requirements
- Developing a CNMP and regular update(s) for better nutrient management.
- Completion of this phase gives the farmer, the MAEAP assurance certificate.

Phase 3. *Provision of site certification and opportunities for incentives*

- Upon completion of the prior two phases the participant's CNMP is approved, the farmer may qualify for tax assistance from earned farm income.
- Access to potential cheaper pollution prevention farm loan schemes[4].

The three phases of the MAEAP lay strong emphasis on the knowledge and implementation of a CNMP. The research study focuses on the use, purpose, and functioning of the CNMP and its consequent economic evaluation.

1.3 Research Problem

A long-term trend towards larger facilities making use of more capital-intensive technologies has resulted in an increase in average herd size per dairy farm. The herd size evolution has resulted in a right-skewed distribution with relatively many small farms and few large farms (Wolf et. al, 2000). The large farms take advantage of size economies to produce milk at a lower cost. These economies of size in dairy operations per animal unit may also result in lower costs of federal and state regulatory compliance for the larger sized farms.

This research examines whether the adoption of MAEAP's CNMP, results in a uniform cost burden shared by the dairy farmers across all herd sizes per animal unit is scale neutral. This study also calculates the costs of implementing a CNMP for five representative herd sizes to balance phosphorus and nitrogen flows on the dairy farms.

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[4] Michigan Department of Environmental Quality's 'Small Business P2 Prevention Loan Program's for those livestock farmers engaged in Pollution Prevention (P2) strategies.

1.4 Research Objectives and Hypotheses

The primary research objective is to assess the costs of Michigan dairy farmers and owners adopting the MAEAP's CNMP. Specifically, the research objectives, rationale, and their respective hypotheses are outlined as below:

1. **To determine if the cost of following the MAEAP by Michigan dairy farmers is scale neutral**

   This study calculates the net expenses per animal unit incurred by dairy farmers across five types of farms due to their adoption of the assurance program and thus ascertains whether the program is scale neutral. It is assumed that participation in the MAEAP will be a function of participation costs. The costs assessment for producers who adopt the program will fill information gaps on the approaches used by the farmers and policy makers to adopt and implement the MAEAP in their own respective ways.

   Hypothesis:

   Balancing nutrient flows are scale neutral on a cost-per-animal unit basis. However, existing levels of on-site technology associated with large dairies, will make the adoption of the MAEAP a relatively smaller financial burden on the larger dairies if manure storage costs are considered. Small and medium sized dairy farms may have a relatively higher cost of adoption as they use an older and less flexible production technology and are more likely constrained by limited financial resources.

2. **To identify whether innovation offsets[5] (Porter, 1995) may emerge as a consequence of the MAEAP.**

With the adoption of the flexible and farmer specific MAEAP, we can examine whether Michigan dairy manure and nutrient management practices are encouraged to change or evolve through innovation offsets to allow for cost savings. These innovation offsets may occur in the form of better on-site farm operations and help reduce the non-point source pollution problems emanating from the existing manure and nutrient management systems. This study examines varying strategies to change nutrient balance on farms.

Hypothesis:

Adoption of the MAEAP with its voluntary, flexible incentive based features will allow for innovation offsets to occur. The rationale of innovation offsets originates from the "Porter Hypothesis" (Porter, M. and C.van der linde, 1995) that addresses the relationship between environment, management and profits. Porter postulated that well-framed environmental standards might trigger innovation offsets, which help overcome compliance costs.

3. **To develop recommendations for the role of policy in achieving nutrient balance.**

There exists a need to understand the farm level and industry effects of the MAEAP in order to make further improvements. Costs estimated from

[5] According to M.Porter, innovation offsets refers to concept of proper design of environmental standards or regulations triggering innovation(s) that may partially or completely offset costs of regulatory compliance (i.e. innovation offsets).

adoption of the MAEAP, could enable these farm and industry level effects to be evaluated.

1.5 Research methods

To determine farm costs, the study uses partial and capital budgeting. First, dairy farm budgets that account for the CNMP and nutrient balance requirements are built. In the second step, cost estimates of completing the MAEAP's CNMP are conducted for the representative herd sizes based on the existing technology set in use. Since the MAEAP's CNMP intends to be a complete farm based action plan the whole farm based simulation software Dairy Forage System Model (DAFOSYM)[6] that deals with animal feeds, soil, crops and milk produced, manure production, storage and treatment is then used to construct sample CNMPs. These CNMPs allow for evaluating the cost of adopting the MAEAP with respect to manure and nutrient management.

1.7 Conclusions

This analysis examines whether adoption costs of the MAEAP, through the fulfillment of its CNMP are scale neutral. The study also suggests additional measures, including modifications in suggested agro-engineering equipment or practices for enhanced participation in the MAEAP. This study should serve as a review of the MAEAP help identify future educational research areas, and provide useful insights into environmental aspects of dairy farming in the state of Michigan.

[6] The DAFOSYM is a simulation model of the dairy forage system created by engineers and scientists of the Pasture Systems and Watershed Management Research Lab, the U.S. Dairy Forage Research Center and other cooperating institutions.

Chapter 2: Comprehensive Nutrient Management Plan

A Comprehensive Nutrient Management Plan (CNMP) is an integral part of the Michigan Agricultural Environmental Assurance Program. A CNMP is a farm-specific action plan to manage and use livestock manure nutrients using scientific, structural, and engineering guidelines. Adoption of the MAEAP requires a farmer to implement a CNMP that contains structural and agro-engineering guidelines. These guidelines consist of Generally Accepted Agricultural and Management Practices for Manure Management and Utilization (Michigan Agriculture Commission, 2000) as adopted by the Michigan Agriculture Commission. The GAAMPs recommendations include testing of on-site manure and soils to assess existing crop nutrient levels and future requirements. Even though, storage facilities are not required the GAAMPs provide recommendations for existing storage facilities and engineering guidelines for setting up new facilities based on the Midwest Plan Service's Manure Characteristics (MWPS-18).

This chapter begins with a description of the objectives and goals of a CNMP. It also provides detailed information on the CNMP, its stages, and its adoption and completion requirements.

2.1 The CNMP

The CNMP is designed to account for almost all existing and possible future on-site livestock farm activities that following only the GAAMPS may fail to assimilate. Each dairy farmer is encouraged to enlist and classify complete livestock operations based on the main site of its operations, the total animal outputs based on herd size and animal type, methods and time intervals for storage and application of manure, equipment and technology used and soil and groundwater composition results from certified experts. Knowledge of the farm location, farm topography, animal type and herd size, soil composition, crops grown and expected yields, and available land are then factored into the CNMP. The data for a dairy farm allows for each farmer to estimate total annual nutrient production of nitrogen (N), phosphate (P_2O_5) and potassium oxide (K_2O) using the prescribed GAAMPS or comparing the actual farm results with the GAAMPs values.

The GAAMPs guidelines that relate to manure and nutrient management consist of detailed information on nutrient removal (lb/unit of yield) by Michigan crops of nitrogen (N), phosphate (P_20_5), and potassium (K_20), manure and nutrient constituents produced by different livestock species and nitrogen losses during handling, storage and application. The computed results of the total nutrient production, soil quality and water quality tests identify the exact nature of the soil on croplands and the rate of nutrient excretion onto the soil, and thus determine the optimum nutrient uptake per year and the appropriate method and rate of manure application on the croplands.

The CNMP provides an estimate of the changes to existing methods of manure production, collection and storage needed to improve the mass balance of the three selected nutrients.

2.2 Goal and objectives

The goal of developing and implementing a CNMP is to help farmers achieve an annual farm nutrient balance. A farm nutrient balance requires total manure nutrients available to equal total nutrients used. The three relevant manure nutrients are nitrogen (N), potassium (K) and phosphorus (P). A CNMP is designed to enable the farmer to:

1. Determine whether the farm nutrient balance is in excess or deficit of nutrients, which in turn determines the application (if in deficit) of optimum amount of commercial fertilizer. There exists an on-site surplus (deficiency) of nutrients if the initial nutrient level exceeds (is lower than) the probable crop uptake needs.
2. Ensure proper and environmentally sound storage, handling, and application of the manure.

2.3 CNMP Requirements

The essential requirements as part of developing a CNMP and then implementing it require certain stages to be completed. These stages include information collection, tests and technical guidance and verification and certification upon completion.

2.3.1 Information Collection

The initial stage of a CNMP involves information collection and record keeping. This information includes farm maps, layout, soil type and initial soil nutrient composition, cropland, topography, and available cropland. A CNMP also documents an emergency action plan in the case of a storm or flashflood. The CNMP requires that the farmer record the following: the total animal units, type of bedding used, quantity of manure produced, manure nutrient composition, types and methods of manure handling, storage practices, and application rates. The CNMP also requires detailed tracking of the types of crops grown, feed nutrient composition, cropping plans, and the proportion of available land for growing crops and manure application. Using the collected information, a final record keeping is required for accurate estimation of the manure application rate based on manure and soil tests results, which take place in the next stage.

Once the information collection phase is complete, existing temporary and permanent manure storage facilities are inspected and assessed for compliance with the GAAMPs specifications as given in the NRCS's Field Office Technical Guide (NRCS-FOTG).

2.3.2 Tests included in a working CNMP

After recording all the basic information, manure and soil nutrient tests are conducted. These tests consist of measuring the soil concentration levels of the critical nutrients, nitrogen, phosphorus and potassium. Based on the type of crops and cropping system used, the tests are then compared with GAAMPs and United States Department of Agriculture and National Resource Conservation Service's (USDA-NRCS) specifications for nutrient uptake. The three recommended CNMP test types are outlined below.

A. Soil Tests

GAAMPs calls for soil testing consisting of a basic soil test to determine existing levels of nitrogen, phosphorus and potassium and a pre-side-dress nitrate test (PSNT). Depending upon the soil type, cropping plan, type of crops grown, the basic soil test determines the existing available amounts of nitrogen, phosphorus and potassium in the soil. The test results also play a key role in manure application onto cropland. The PSNT test estimates the amount of available nitrate present in the soil in the pre-growing period. The PSNT test is particularly useful for comparing pre and post rainfall effect on the net amount of nitrates. The PSNT test is conducted only if: it is the early stages of plant growth, the current crop is corn or follows soybeans, and, cover crops like clovers have been previously grown. The PSNT test also is useful for fields that were heavily fertilized the year before because it minimizes over-application of nitrogen and prevents leachate.

The GAAMPs in accordance with the Michigan Right to Farm guidelines, emphasizes using the Bray P1 or soil test result of phosphorus per acre as a criterion for the quantity of manure to be applied. If the Bray P1 soil test value per acre is:

- More than 300 lbs/acre, no manure to can be applied to be in compliance with the Right to Farm Act;
- Between 150-299 lbs/acre, manure can be applied at phosphorus removal rates, and two years worth of manure may be applied;
- Less than 150 lbs/acre, manure can be applied such that the total nitrogen level does not exceed the crop removal rates.

If the CNMP soil test results are out of the range prescribed by the NRCS recommendations, based on the scarcity or surplus of nitrogen, P and K, a CNMP calls for conducting manure and utilization tests.

B. Manure Tests

In order to determine the total nutrients available from the manure produced on the farm, the CNMP requires manure tests. Tables 2.1 and 2.2 are taken from the MWPS-18 and are used to calculate the total amount of manure produced and the total value of manure in terms of ammonium (NH_3-N), nitrogen (N), phosphorus (P_2O_5), and potash (K_2O) content based on the size and number of milking dairy cows.

Table 2.1 also provides additional information on the amount of water present as a proportion of the total solids, density, proportion of volatile solids, and total solids in manure, and the rate of loss of biochemical oxygen in wastewater (BOD). Table 2.1 also gives benchmark values of the concentration levels of total nitrogen, P_2O_5 and K_2O. The amount of water content in the manure plays a significant role in determining the amount of manure transported and the appropriate machinery and application equipment used during manure application onto cropland. Measuring volatile solids helps estimate ammonia (NH_3) losses due to vaporization. The MWPS-18 provides values and practices in accordance with the GAAMPs (approximate) for manure properties and its nutrient composition (ASAE, 1992).

Table 1. Total Manure production and nutrient constituents

Daily Manure Production and characteristics as-excreted									
Values do not include bedding. The actual characteristics can vary +/- 30 % from table values.									
Size	Total production	Water	Density	TS	VS	BOD	Nutrient content, lb/day		
Lbs	lbs per day	%	lb per cubic ft	lb per day	lb per day	lb per day	N	P_2O_5	K_2O
150	13	88	65	1.4	1.2	0.2	0.05	0.01	0.04
250	21	88	65	2.3	1.9	0.33	0.08	0.02	0.07
750	65	88	65	6.8	5.8	1	0.23	0.07	0.22
1000	106	88	62	10	8.5	1.6	0.58	0.3	0.31
1400	148	88	62	14	11.9	2.24	0.82	0.42	0.48

Source: Midwest Planning Service Handbook-18, 1995

In order to interpret and understand the working of Table 2.1 and 2.2, consider a sample farm that house 100 milking dairy cows of approximately 1,400 pounds each. Computing the total amount of manure and the three critical nutrients nitrogen, phosphate, and potash, is done in the example below making use of the tables.

- **Example: Initial available information**

From Table 2.1, total manure produced = 17.7 gal/day and Table 2.2 gives the total benchmark values of concentration levels of nitrogen, phosphate and potash for a mature dairy cow, as 31, 15 and 19 pounds per 1000 gallons per day of manure respectively.

Thus total manure produced annually: = Number of head X quantity/day X 365

Using this formula manure production is:

= 100 cows x 17.7 gal/day x 365 days

= 646,050 gal. /yr

Table 2.2 Liquid manure characteristics

Production	Manure produced	Concentration (pounds per 1,000 gallons of manure)			
		Total N	NH_3-N	P_2O_5	K_2O
Dairy cow	54,000	31	6	15	19
Dairy heifer	25,000	32	6	14	28
Dairy calf	6,000	27	5	14	24
Veal Calf	3,500	26	21	22	40
Dairy herd	73,000	31	6	15	22

Source: Midwest Planning Service Handbook-18, 1995.

As a result, given the total manure produced annually, Table 2.2 can now be used with algebraic manipulations to arrive at values for total nitrogen, phosphate and potash. The estimated nutrient composition of nitrogen, phosphate and potash is as below.

= 20,027 pounds of nitrogen; 9,690 pounds of phosphate; and 12,274 pounds of potash.

The values of the three nutrients are then converted into their available forms for comparison with the nutrient uptake levels provided from the Michigan state Extension University Bulletin guidelines so as to ensure provision of optimum nutrient amounts on cropland. The nutrient removal guidelines that are discussed later in Chapter four, give a detailed account of most crop types grown in Michigan and their GAAMPs nutrient removal values for N, P_20_5 and K_20 in lbs/unit of yield. Periodic record keeping of the quantities of manure produced and its nutrient concentration levels are essential for balancing manure and commercial fertilizer usage.

If nutrients are not balanced participation in the MAEAP requires a farmer to use the CNMP to assist in possible restructuring of farming methods, and/or the re-designing of storage facilities and equipment.

C. Manure Utilization and Application Rate Index Tests

Two kinds of nutrient utilization tests exist: the Revised Universal Soil Loss Equation (RUSLE) and the Manure Application Rate Index (MARI). Both tests assist in determining levels of soil erosion, rainfall-runoff, water quality, percentage changes in surface cover, and application rates. However, the MARI estimates the nutrients in their concentration levels, while the RUSLE measures only nutrient levels.

To use the MARI test, the following 11 field features must be known:

1. Soil type, structure and physical properties;
2. Soil hydrologic group which consists of a group of soils undergoing a uniform runoff potential under certain similar storm or flashflood conditions;
3. Slope topography of the farmland;
4. Soil phosphorus tests or the Bray P1 test result;
5. Percentage of the farmland on which cover crops or vegetation is grown;
6. Manure application rate of mainly nitrogen and phosphorus;

7. Distance of the farmland from water-bodies or water flows;
8. Nitrogen leaching index;
9. Extent of use of vegetative buffer strips;
10. Degree of concentrated water flow; and,
11. Manure application method.

The CNMP calls for conducting the MARI test if the farmer finds the occurrence of any of the three qualifying conditions:

1. Soil test phosphorus levels are found in excess of 300 lbs/acre;
2. Presence of a slope exceeding 6% with solid application or 3% for liquid application; or,
3. Direct discharge of concentrated water flow.

1. If any of the above factors are present the MARI test can then be conducted.

The MARI test results are classified into one of the four risk categories: "Very Low," "Low," "Medium," and "High." Manure application onto cropland is permitted if the MARI ratings are "Very Low," "Low," or "Medium." These ratings identify the degree of risks associated with manure application and thereby match the nutrient applications to the crop's nutrient intake requirements.

2.2.3 Structural, agro-engineering and technical guidance

Based on the tested and recorded CNMP test values, the MAEAP calls for an inspection of existing manure management methods and facilities. If the existing manure treatment systems and methods do not conform to the GAAMPs specifications, the farmer receives educational and technical assistance with respect to changing methods or facilities. This assistance consists of the evaluation of existing storage facilities and recommendations for storage covers, treatment systems, and lagoons.

Agro-engineering guidelines make use of the Livestock Waste Facilities Handbook and the National Resource Conservation Service's Field Office Technical Guide (NRCS-FOTG) to design manure storage and treatment facilities with built-in seepage control features if the existing ones are not in compliance with the GAAMPs.

In addition, on-site structural and engineering changes may be necessary depending upon the number of animal units, geo-physical soil characteristics, manure application and utilization rates, and the method of manure hauling. The creation of new emergency flood control measures or a review of existing measures is also included in this stage.

2.4 Potential adoption costs of the CNMP

Completion of the above CNMP in conformity with the GAAMPs recommendations for manure and nutrient management can result in the farmer incurring costs. These costs can be of three types: information collection costs, manure nutrient management costs, and capital investments.

2.4.1 Information collection cost

1. *Costs of soil tests and manure nutrient analysis tests*

The farmer incurs a cost, as a result of information collection and record keeping regarding total daily manure produced, and existing manure storage, handling and equipment use. In addition, costs of testing may also include the soil, PSNT and the

MARI tests, manure analysis, rate of utilization and application tests. There also exist cost involved as a result of hiring personnel who invest time and effort to help test and record all relevant information.

2.4.2 Changes in farm practices and management costs

Adoption of alternative nutrient management strategies to alleviate excess nutrients may result in changes in feed costs, manure management costs or cost savings and any additional measures adopted to reduce runoff and soil erosion.

1. *Herd size adjustment costs*

Based on the initial levels of nutrients in the soil and final net nutrient imports of phosphorus in particular on to land, a deficit (surplus) in net import of phosphorus (pounds per acre) could require the representative farms to increase (decrease) their herd size. A change in herd size directly influences the total amount of phosphorus available for crop uptake (after accounting for manure losses through collection, storage and application). For lower levels or deficiency of on-site phosphorus the farm management may decide to increase their herd size which could result in additional costs of expansion. On the other hand, excessive levels of phosphorus (300 pounds per acre) could require the farm owner/operator to decrease the number of livestock and thus reduce the total phosphorus loadings. A reduction in herd size in the soil may result in costs in the form of losses in sales due to decline in milk productivity per cow.

2. *Feed nutrient composition costs*

Changing the feed nutrient composition can enable a nutrient balance or total manure nutrients available to equal total used and thus minimize an excess or deficit net import of nutrients on to the farmland.

3. *Commercial fertilizer application costs or cost savings*

The soil and manure nutrient tests may yield results that indicate the available nutrients from manure are in excess or deficit as compared to the crop uptake requirements. If there exists a deficiency of available nutrients as compared to the crop needs, the MAEAP calls for the use of Tri-State Fertilizer Application guidelines to guide the farmer to determine the supply of remaining nutrients needed to ensure a nutrient balance. An initial surplus or excess availability of nutrients over the crop needs could provide for savings when no additional commercial fertilizer is applied.

4. *Leachate and soil erosion prevention costs*

Additional costs could also result from the growing of buffer strips or vegetative filter according to the NRCS guidelines. GAAMPs recommend planting buffer strips or vegetative strips or growing cover crops to prevent wastewater runoff and erosion to surface waters. These preventive measures could result in lost productivity from land converted from crops to buffer or vegetative strips.

2.4.3 Capital investments

1. *Manure storage systems costs*

Based on the total amount of on-site manure produced annually, temporary and permanent manure storage systems may be necessary. If the manure storage facilities are not capable of handling wastewater runoff from a 25 year, 24-hour rainfall event, the GAAMPs call for the re-design of existing temporary and permanent manure storage systems. Modifications to or addition of manure handling and treatment systems could potentially involve considerable expenses.

2. *Land*

Capital investments may also involve acquisition of farmland through purchase, lease, or an arrangement for manure application. The financial impact of the land used for manure application depend on the financial strength of the farm, amount of manure produced, distance between site of manure produced, and currently applied and existing methods and practices adopted for manure and nutrient management.

2.5 Summary

This chapter defined and explained a working CNMP and provided an overview of the steps necessary for the adoption of the MAEAP. The chapter also outlined the basic goal of the MAEAP to achieve a farm nutrient balance with the help of a CNMP. For a MAEAP participant to adopt and complete a CNMP and finally receive an assurance certificate, the following stages need to be completed: Information collection, and evaluation with the GAAMPs guidelines for possible changes with regard to manure management, inspection and evaluation of manure management systems (collection, storage and application), and record-keeping to ensure the nutrient balance is achieved.

The last section of the chapter provided a summary of the costs incurred by a farmer adopting the MAEAP and its CNMP. These costs consisted of basic information collection, operational and management changes and finally capital investments in manure storage systems and land. The next chapter focuses on a literature review of previous studies in manure and nutrient management and the methods of analysis for the present study.

Chapter 3: Literature Review and Methods Analysis

In the past, a number of agronomic, economic and geo-physical studies have evaluated the role, importance, and implications of manure nutrient management on nutrient balance and productivity of dairy farms. Recently, there has been a renewed emphasis towards systems based analysis to evaluate the performance of dairy farms in the light of regulatory and policy requirements on manure and nutrient management.

The present chapter begins with a literature review of studies selected in the context of manure and nutrient management. After the literature review, the next section of the chapter analyzes research methods consisting of the Dairy Forage System Model (DAFOSYM)[1] and capital budgeting. The following sections of the chapter describe the components of the simulation software DAFOSYM, and how it is used to develop sample CNMPs that meet MAEAP and GAAMPs recommendations for the five representative farms.

3.1 An overview of existing studies on manure and nutrient management

A number of research studies have evaluated on-farm manure and nutrient management relative to regulations and policies. Most of these studies have focused on one of the two directions: manure management systems or whole farm assessments.

Manure management systems studies consist of impact and performance analysis of dairy farm compliance with regulatory measures in manure collection, handling, and application methods. Whole farm or integrated nutrient balance assessments determine the impact of changes stemming from environmental compliance including changes in:

[1] The DAFOSYM model is a whole farm simulation model of dairy production taking many years of weather into account to determine long-term performance, environmental impact and farm economics.

herd size and cropping patterns, on-farm soil variability, and the adoption of alternative manure management systems on the whole farm nutrient balance and thus nutrient flows on, off, and within the farm. The following sections provide a literature overview of some studies in each of the two respective directions.

3.1.1 Manure management systems (collection, handling and application)

Good *et al.*, evaluated the economic impact of manure management systems that comply with pollution control measures on Michigan dairy farms. A linear programming and partial budgeting technique was used to model the adoption of potential measures including mandatory control of surface runoff at the barnyard, prohibition of winter spreading of dairy wastes and mandatory subsurface disposal of dairy wastes. Good *et al.*, analyzed changes in cost of production, investment, and level of net farm income across stanchion housing systems, open lot, and cold covered systems. Good *et al.*, concluded that compliance with the likely regulations resulted in increased investments and higher milk production due to the use of a better technology set. Specifically, Good, *et al.*, found compliance with all three pollution control measures had the most severe negative economic impact on Michigan dairy farms with stanchion housing.

Ashraf and Christensen also evaluated the economic impact of complying with potential pollution control measures on dairy farms. In the northeastern U.S., Ashraf and Christensen evaluated storage methods including the use of stacking versus liquid storage in free stall and stanchion barns. Assuming an unlimited supply of labor, established crop yields, predictable weather patterns, constant price levels of inputs, and constant output levels, Ashraf and Christensen found that adoption of either storage manure system resulted in a reduction in farm income. In addition, plowing under manure imposed higher disposal costs on free stall housing than stanchion housing barns.

Garsow provided an extensive economic evaluation of the benefits and costs of potential environmental regulations on the Michigan dairy industry. Garsow considered the most prevalent 1987 dairy farm systems of Michigan for 60, 120 and 250 cows under three potential regulatory regimes: prohibition of spreading manure on frozen ground, mandatory control of runoff, and mandatory injection of livestock manure. The impact of the three potential pollution control regulations on each herd size was evaluated and using a full budget analysis, future expenses were predicted. Crop nutrient management simulations were used to calculate nutrient savings and crop nutrient removals. Garsow found that imposition of environmental regulations required additional investments in manure systems. In addition, the daily manure hauling resulted in a negative financial return with no significant reduction of on and off farm non-point source pollution.

Good *et al.*, Ashraf and Christensen, and Garsow tested for size neutrality due to compliance with environmental regulations. All found that the economic impact of compliance with pollution control measures was relatively larger for the smaller size farms and relatively lower for large farms.

3.1.2 Integrated or whole farm based on-farm nutrient balance and management

There has been a renewed focus on understanding the role and economic impact of expansion in dairy herd size, composition of feed nutrients, cropping systems, and sequence of crops grown on the on-farm nutrient balance.

Lanyon and Beegle analyzed the use of nutrient management planning, implementation and finally evaluation of resulting nutrient balances. The study noted that monitoring on-farm nutrients required tracking not only animal units and amount of manure produced but also the kinds of crops grown, crop yields, soil properties and other related variables. According to Lanyon and Beegle, with dairy cattle there is often a net positive increase in nutrients flowing in which results in a higher possibility of on-farm nutrient loading. Nutrient balance was assessed using a farm case study 138-acre dairy farm from Pennsylvania. Using daily haul of manure with surface application, the study concluded that purchased feed contributed substantially to the nutrient loading on the case study farm. The study also stressed the need for record keeping, increased understanding of the crop-livestock nutrient flow, and a greater role for the extension and on-site nutrient specialists. The study however lacked an economic assessment (cost-effectiveness or benefit-cost analysis) of the developed nutrient management plans.

Dou *et al.*, estimated efficient levels of nitrogen by analyzing the role of ration formulation, crop selection, and manure application. Primarily seeking the optimum feeding and management strategies to compare nitrogen utilization and balances of inputs and outputs, the study focused on diet formulation. The site of the case study was a New York dairy farm that had 101 lactating cows and 89 heifers. Nitrogen and not phosphorus, was considered to be the major non-point source pollutant. Information about the herd size, type and body weight, the quantity and nutrient composition of manure, soil composition, soil nitrogen residual, total cropland, and feeds were used to determine the amount of nitrogen in the feeds, feces and urine. With varying levels of nitrogen use, crop yields, and application to alfalfa, nitrogen uptake by the crops differed. The study found that enhancing crop yields resulted in increased feed production and also reduced feed purchases thus reduced surplus nitrogen available.

Reinhard *et al.*, used 613 Dutch dairy farms to calculate farm-level estimates of technical and environmental efficiency of nitrogen use. The study performed in part as a response to the National Environmental Policy Plan (NEPP), which required all Dutch dairy farms to implement and maintain nutrient balance sheets. These nutrient balance sheets recorded levels of on-site nitrogen surplus use. The study evaluated environmental and technical efficiency on dairy farms using environmentally detrimental nitrogen surplus. Technical efficiency was defined as a ratio of observed to maximum feasible output, while environmental efficiency was defined as a ratio of minimum feasible to observed use of the environmentally detrimental input.

Reinhard *et al.*, concluded that by achieving technical output efficiency, an 11 percent increase in milk output would be observed but achieving environmental efficiency would result in a 54 percent decrease in the nitrogen surplus generated. The study found that environmental and technical efficiency were inversely related. The study ignored any possibility for sudden flashflood, manure spills or weather issues affecting quantity of observed environmental output.

3.2 Methods

This study uses a total systems approach to nutrient management. Since a CNMP combines all aspects of a dairy operation to achieve a nutrient balance (zero discharge) an integrated system is required to track nutrients flowing into, within, and off the farm. The DAOFSYM is a software tool that is appropriate for this study as it tracks the sources and movements of on-site nutrients. DAFOSYM integrates all components of a dairy farm and provides a model to simulate the constructed CNMPs for five representative farms and to evaluate nutrient loads, soil accumulation of nutrients and net nutrient balance.

In addition to the management and practice changes incurred in maintaining a nutrient balance, facility and land investments may be required. These capital investments are examined using capital budgeting models.

3.2.1 The Dairy Forage System Model (DAFOSYM)

Originally developed by Parsch (1982) and Savoie (1982), DAFOSYM, was later used to evaluate forage technologies and management strategies (Rotz et al., 1989). The software simulates a dairy operation in a closed system framework assuming no interaction between the farm and external economic factors or market forces. The crop model provides for a simulation of up-to five crops: alfalfa, perennial grass, corn, small grain, and soybeans. Using herd parameters, average weather patterns, soil parameters, and machine file. DAFOSYM simulates nutrients over a time range of 1 to 26 years. Prior to simulation data relating to crop growth, harvest, storage, machinery and equipment used, feeding and animal performance over many weather years is entered. The DAFOSYM yields information averaged over 26 years about net change in total nitrogen (N), phosphate (P_2O_5) and potash (K_20). It also includes annual estimates of manure costs and nitrogen losses due to volatilization and leachate.

Studies on manure management costs using the DAFOSYM explored manure application costs, where distance from the site of manure production and final destination, method of transportation, equipment used for disposal, level of technology used in application, and labor played a critical role (Harrigan).

Borton *et al.*, used DAFOSYM to evaluate the cost of manure management to compare six manure-handling systems on two representative farms (60 and 250 cows). The authors assessed performance of and costs of semi-solid, slurry, and liquid manure systems, with respect to the changes in storage type, milk production level, and farm size. The study found that daily hauling of semi-solid manure, short-term storage, use of manure nutrients as fertilizers were economically advantageous for all farm sizes and production levels. Adoption of a long-term storage facility resulted in nutrient savings in the form of less nutrient losses into the air and soil and reduced odor loss but also a loss in net profits. According to Borton *et.al.*, the study also found transportation distance to have a major effect on manure handling costs. Increasing the distance from 0.63 miles to 3.2 miles resulted in an increase in total cost by $52 per cow. Using a nurse tank for disposal of manure reduced handling costs by $42 per cow.

This study uses DAFOSYM, to evaluate the environmental and economic impact of the CNMPs in accordance with quantitative and qualitative characteristics of the five representative farms. Based on the initial nutrient balance alternatives in cropping system, manure handling, storage and application and other options are examined to achieve a nutrient balance.

3.2.2 Capital budgeting

Capital budgeting or investment analysis can be used by a farm owner/operator to estimate the costs incurred or capital required to finance any additional changes to a farm's operations (Harsh, Connor, and Schwab). Balancing nutrients may require the representative farms to make additional investments in manure management systems or land base. A capital budgeting technique is used here to estimate the financial impact of these investments.

Estimating investment or capital costs that a farm owner or operator incurs to finance the additional changes in storage systems requires the use of a depreciation rate based on the expected life of the equipment or structure installed, tax rate, appropriate discount rate (opportunity cost of the farmer's money), and interest rate for borrowing credit and other miscellaneous variable costs such as labor, fuel and energy.

3.3 Summary

Chapter three primarily focused on a review of previous literature in the field of manure and nutrient management and the methods of analysis for the estimation of the cost of adoption of MAEAP based CNMPs for the five representative farms. Existing research studies in manure and nutrient management were reviewed and in all cases the financial impact of related pollution control measures was found to be greater on the smaller herd sized dairy farms. DAOFSYM and capital budgeting are used to estimate economic impacts.

Chapter 4: Representative dairy farms

Estimation of costs of participation in the MAEAP primarily consists of ensuring nutrient balancing expenses incurred by representative farms. Harsh, Connor and Schwab, define a representative farm as being typical of internal characteristics and external conditions of some specified group or population of farms. Characteristics include size and type of farm, quality of resources, level of management and technology used. The external conditions of a representative farm refer to market conditions, climate, credit system and other conditions faced by a specified population of farms.

This chapter begins with a summary of the sources of data. It is followed by a description of the intended use of the data, and an overview of typically observed manure management systems on representative dairy farms. Farm characteristics are selected on the basis of relevance to farm manure and nutrient management including acreage, crops grown, milking and housing facilities, the equipment in use, and manure management systems. The chapter concludes with a detailed description of each of the five farms.

4.1 Data Sources

The sources of data available to build the representative farms include survey data from 458 Michigan farms (Wolf, et al.) and data from 35 intensive grazing Michigan farms (Dartt).

The 1999 survey data was used to review the entire structure and competitive performance of the Michigan dairy farm industry and assess strengths and weaknesses. The survey analyzed the financial performance, human resource availability and employer-employee and managerial issues facing the farmers. The survey also evaluated the preferences and personal attitudes of the farmers and or owners in relation to land use and environmental constraints affecting future growth plans (Wolf, et al.).

Dartt collected the 1998 grazing data set to examine management intensive grazing as a low-input alternative management strategy by evaluating differences in economic profitability, asset and operating efficiency, and labor efficiency between conventionally managed dairies and grazing farms. Dartt defined a conventionally managed farm as one that obtains at least 95 percent of the whole herd forage from mechanically harvested forages, and a grazing farm as one that obtains at least 25 percent of the annual whole herd forage requirement through forage. Comparative analysis of 35 grazing dairies and 16 conventionally managed dairies was conducted in 1994 to provide an analysis of the farm's financial and production status, and to determine if an average sized grazing dairy operation is "sustainable to operate."

4.2 Essential characteristics of a dairy manure management system

The representative dairy farms are distinguished on the basis of characteristics that influence nutrient balance, runoff potential, and in particular, soil accumulation of phosphorus and nitrogen. These characteristics include manure produced by cows (milking cows and heifers), details on the feed produced, additional feeds and supplements purchased, crops produced, and soil characteristics.

In addition, a description of facilities, type of machinery and equipment used, land tenure, financial status, and human resource issues are evaluated. Most commonly seen characteristics on any dairy farm typically include:

1. Milking, feeding and housing facilities

The most commonly used milking facilities on Michigan dairy farms are milking parlors. Some smaller farms also use pipeline or bucket systems.

2. Manure collection, storage and application facilities

Information on collection methods includes the total volume of manure produced annually as well as the type and physical dimensions of storage facilities used (temporary and permanent). Information on manure application includes the amount and frequency of manure spread (winter and non-winter) on the cropland on a field-by-field basis.

3. Soil characteristics

Soil characteristics include the nature and type of soil, soil nutrient composition, and topology. On-farm variation in soil type or soil sensitivity to nutrient flows can play a key role in influencing costs of pollution prevention efforts from pollutants like nitrogen, phosphorus and potassium. However, in this study it is assumed that all the representative farms have one uniform soil type.

4. Crop production and utilization

The amount of land for crop production, the crops grown, the amount of tilled land, and the subsequent use of manure as fertilizer affect farm nutrient balance. Effective and environmentally sound use of cropland for manure application requires soil fertility tests.

5. Land availability, utilization and management

Information on land includes an account of the total available farmland for manure application and, consequently, crop production.

7. Ration and feed purchases

Ration information consists of the feed ingredients and feed purchases. Types of feed and supplements alter the proportion of nitrogen, phosphorus and potassium in the manure and thus the nutrient balance.

4.3 An overview of the five representative dairy farms

From the initial data, five representative herd sizes were chosen and the characteristics of each were determined using averages of firms in that size. The 50 cow herd averaged characteristics of 45 to 55 cows, the 150 cow farm averaged survey data of 140 to 160 cows, an average of 250 to 450 cows was used to construct the 400 cow farm, and 700 cows to 1,200 cows was the sample averaged across for the 1,000 cow representative farm. The 100 cow grazing farm was a result of averaging across 60 to 120 cow grazing dairy farms. Table 4.1 provides a summary of the total land acreage, crops grown and average milk produced per cow.

Table 4.1. Some relevant characteristics of the dairy farms

Characteristics	*Herd size*				
	50 cows	*150 cows*	*400 cows*	*1,000 cows*	*100 cow grazing*
Total acreage	284	598	1,018	2,500	250
• Corn grain	44	150	256	612	0
• Corn silage	47	113	234	767	115
Total Corn	91	263	490	1,380	115
• Alfalfa hay	74	146	0	0	0
• Alfalfa haylage	72	157	216	590	25
Total Alfalfa	146	303	216	590	25
Grass	0	0	64	0	110
Soybeans	0	102	87	213	0
Small grain	29	32	92	55	0
Pasture	18	0	12	0	110
Total milk produced (pounds per year)	15,000	17,000	19,600	22,000	14,000
Number of replacement heifers	44	129	272	898	85

An average of 85 percent of the total acreage is tilled farmland for the 50 and 150 herd size farms and over 88 percent of the farmland of the 400 cow farm. Average annual milk productivity per cow increases with herd size. This is consistent with past studies findings (Wolf et al.). With increases in herd size, the total acres of farmland increases.

Table 4.2 On-site production practices and manure management systems

Characteristics		*Herd size*				
		50 cows	*150 cows*	*400 cows*	*1,000 cows*	*100 cow grazing*
Milking facility		Stanchion	Parlor	Parlor	Pipeline	Flat-barn
Housing facility		Stanchion	Tie-stall	Free-stall	Free-stall	Stanchion
Type of bedding		Straw	Straw	Sand	Sand	Straw
Daily hauling of manure		Yes	Yes	No	No	No
Period of manure storage	Short term	No	Yes	Yes	Yes	No
	Long term	No	No	Yes	Yes	No
Type of long-term manure storage		None	None	Clay pit	Concrete	None
Type of manure handled		Solid	Liquid	Liquid	Liquid	Solid
Average manure hauling distance (miles)		0.25	0.5	1.00	1.5	0.5
Application method		Surface	Surface	Injection	Injection	Surface

Table 4.2 provides a summary of the milking and housing facilities across the five herd sizes, frequency of manure hauling, manure storage and type of manure handled and application method. Manure storage is defined as short-term if the maximum period of manure storage is six months or less and long-term if six months or more. The smaller herd sized, 50 and 150 cow conventional dairy farms and the 100 cow rotational grazing farm use straw bedding. The 400 and 1000 cow farms use sand bedding. The 50 cow and 100 cow rotational grazing dairy farms use solid application of manure. Only the 150 cow dairy farm surface applies slurry manure. Existence of a higher technology level on the 400 and 1,000 herd sized dairy farms allows for use of liquid slurry manure with injection.

4.4 Description of representative farms

1. 50 cow dairy farm

The 50 cow representative dairy farm includes 50 milking cows and their own replacement stock of 21 heifers under one year and 23 heifers over a year in age. The average annual milk produced per cow is 15,000 pounds.

The farm has a total acreage of 332 acres with tillable cropland of 284 acres. The farm owns all of its farmland. A small proportion of the farmland is used for pasture. The entire acreage is used for crop production and the crops harvested for feed consist of corn grain and silage, haylage and oats. DAFOSYM estimates the initial volume of manure produced was 192 tons of DM or 2,984 tons of wet manure. Dry manure contains 4.4 tons of nitrogen or 2.3 percent of dry matter (DM) manure, 2.7 tons of phosphate or 1.4 percent of dry matter manure and 8.9 tons of potassium 4.6 percent of dry matter (DM) manure.

The main site of manure production is the housing facility. The farm uses a stanchion barn with a pipeline system and has no facilities. Harvested straw is used for bedding and manure collection is done with the help of a manure scraper and slurry manure is assumed to have 8-10 percent of DM manure. Total wet manure is applied onto owned cropland in the form of solid surface application with farmland tilled only during the non-winter months. Application of manure through daily hauling is carried out even through winter and the distance between hauling and application is approximately 0.25 miles.

2. 150 cow dairy farm

The 150 cow dairy farm has 52 heifers over a year old and 77 heifers less than one year and produces 17,000 pounds of milk per cow. The farm has a total acreage of 600 acres with tilled farmland amounting to 598 acres. The farm owns most of the farmland and rents a reasonable proportion of the total acreage. Crops grown for harvesting are alfalfa, corn, soybeans, mixed grass, and alfalfa legumes.

The main site of manure production is the milking and housing facility. Total manure produced on the farm is 676 tons of dry matter manure or 10,171 tons of wet manure. Initial quantities of nitrogen, phosphate and potassium in the DM manure is estimated to be 15.5 tons of nitrogen, 9.4 tons of phosphate, and 31 tons of potassium. The farm uses a milking parlor and a tie-stall barn for housing the cows with straw bedding and possesses short-term storage facilities for manure collection and storage. Solid manure storage capacity is limited. Manure collection is done with the help of a manure scraper and slurry manure is 8-10 percent of dry matter manure. The farm hauls its manure every few days and the average distance between the place of collection and application of manure is around half a mile.

3. 400 cow dairy farm

The 400 cow dairy farm has additional young stock on the farm consisting of 163 heifers under a year and 109 heifers above one year of age. Average milk produced annually per cow is 19,600 pounds.

Total farm acreage is approximately 1,018 acres, of which 900 acres is tilled farmland. The farm owns more than three fourths of its total acreage and rents the remainder. Crop harvests for feed include corn, corn silage, and grain. The farm makes use of a milking parlor, a free-stall barn with sand bedding, and possesses a relatively new housing facility.

Dry manure produced on the farm is 1,500 tons or 23,051 tons of wet manure. The proportion of nitrogen, phosphate and potassium in the dry manure is estimated to be 31.5 tons, 21 tons and 51 tons respectively. Slurry manure is collected using a flushing system. Manure is hauled only two times a year. The farm has a six-month temporary storage capacity with an earthen basin for long-term storage and the distance separating place of manure collection and application is one mile. Application of manure is by means of a liquid injection system.

4. 1,000 cow dairy farm

The 1,000 cow dairy farm raises its own heifers with 400 yearling heifers and 370 heifers above one year in age. The dairy farm makes use of a pipeline for milking cows and a free stall barn for housing. The average milk produced per cow annually is 22,000 pounds.

Total acreage of the farmland used for crop production is 2,500 acres and crops grown are alfalfa, corn, soybeans, and oats. Manure management is a prime consideration of the 1,000 cow dairy farm with investments in long-term manure storage facilities. Total manure produced on the farm is 4,253 tons of dry manure or 64,492 tons of wet manure with 85 tons of nitrogen, 55 tons of phosphate and 123 tons of potassium. Slurry manure is collected using a flush system. Concrete tank is used for storing long-term manure and the average distance between collection and application is one and half miles. Manure is applied by way of injection of liquid manure.

5. 100 cow rotational grazing farm

The 100 cow rotational grazing farm is a management intensive grazing farm with 300 acres. The total average milk produced on the farm is 14,000 pounds per year.

Total cropland is 250 acres and used for growing forages, corn grain and hay. The farm makes use of a flat barn for its milking facility. The farm does not haul manure daily in the grazing season. Total manure produced on the farm is 329 tons of dry manure or 5,119 tons of wet manure. Nitrogen content in the dry manure is 7.3 tons, while phosphate and potassium are estimated to be 4.2 tons and 12.8 tons respectively. The farm does not possess manure collection or storage facilities. Solid manure is managed with the help of surface application and the distance separating manure collection. Distance of hauling for application is one half a mile.

4.5 Conclusion

The chapter provided an overview of the five representative dairy farms that are used for estimating the cost of balancing farm nutrients. Using a detailed description of the working of the simulation model DAFOSYM from chapter three, sample CNMPs are developed and reviewed in the following chapters.

Chapter 5: Initial nutrient balances

The previous chapter described the five representative farms consisting of four conventionally managed dairy farms with 50, 150, 400 and 1,000 cows and a 100 cow intensive grazing farm. Using qualitative and quantitative information gathered from the data sources, the DAFOSYM is used to examine nutrient balancing strategies.

Chapter five begins with a summary of the formulae used by the simulation model DAFOSYM to assess the nutrient balance and economic analysis. The nutrient balance is affected by total manure produced, manure nutrient composition, and finally the net whole farm nutrient balance. The next section makes use of these formulae to provide summarized tables of the initial whole farm nutrient balance for the five representative farms.

5.1 Nutrient balance

This section provides a general overview of the formulae used in the DAFOSYM. The DAOFSYM uses a systems based approach to simulate a dairy farm and yields net nutrient balance estimates.

5.1.1 Nutrient Balance

Net nutrient balance for nitrogen, phosphorus and potassium is defined below.

Net-nutrient balance (pounds/acre) = $X_U - X_A = 0$,

where X = total nutrient contents of N, P and K, X_U = total nutrients used by crops (pounds/acre), and X_A = total available nutrients of N, P and K (pounds/acre).

DAFOSYM calculates the amount of manure nutrients used for crop production to match pre-established yield goals. Total available nutrients can also be expressed as,

$X_A = X_{(I-E)} + X_{N\text{-fixation}} + X_{fertilizer\ use} - (X_{Mineralization} + X_{N\text{-volatility}} + X_{leachate\ losses})$,

where $X_{(I-E)}$ = Nutrient imports (X_I) – Nutrient Exports (X_E), Nutrients imports (X_I) = f {Total feed intake (Dry matter)}= f {feeds grown and feeds purchased},

Nutrient exports (X_E) = f {Milk, Growth, Feeds sold, Manure}.

Nutrient Imports (X_I)

Nutrient import of nitrogen, phosphorus and potassium onto the farm takes place through the intake of feed, which consists of harvested crops (forages and grains) and purchased feeds. Nitrogen concentration level can be determined using the amount of crude protein, which is the main source of nitrogen.

According to Rotz and Coiner, the DAFOSYM makes use of nutrient concentration levels in accordance with the National Research Council (1989) recommendations for N, P and K. Total nitrogen, phosphorus and potassium contents in the dry matter feed intake are:

I_N = C.P. / 6.25 = 44% * (DM) / 6.25,

I_K = 1.13 % * (DM feed intake), and,

I_P = 1.14 % * (DM feed intake).

Nutrient Exports (X_E)

$X_E = \text{Losses}_{milk} + \text{Loses}_{growth} + \text{Losses}_{feeds\text{-}sold} + \text{Losses}_{Manure}$

Nutrient exports X_E, consists of nutrients flowing out of the farm through milk, body growth (heat, energy and maintenance), feeds sold, and manure. Exports of nutrients in milk are 0.53 percent nitrogen, 0.1 percent phosphorus and 0.15 percent potassium of dry matter feed intake. Similarly, quantities of nutrients in body growth are

2.75 percent nitrogen, 0.79 percent phosphorus and 0.2 percent potassium of dry matter feed intake.

DAFOSYM estimates the total nutrients in manure from the total dry manure produced on the farms as

$X_{manure} = X_{DM\text{-}intake} - X_E$

This can also be expressed as,

$X_{manure} = (X_{crops\ grown} + X_{feeds\ purchased}) - (X_{milk} + X_{growth} + X_{feeds\text{-}sold})$.

Total available nutrients for crops utilization (lb/acre) is then estimated as,

$X_A = X_{manure} + N_{fixation} + X_{fertilizer\ use} - (X_{Mineralization} + X_{N\text{-}volatility} + X_{leachate\ losses})$.

The initial nutrient balance assumes no initial commercial fertilizer use.

5.2 Economic analysis

This section highlights the key economic variables as used in the DAFOSYM for estimation of the cost of adoption of the MAEAP by the Michigan dairy farmers for the five representative farms. These five select economic indicators are: total revenues, total production costs, net farm return, feed costs and manure management costs. In addition, this section also provides a detailed definition of the individual components of these five economic indicators.

1. **Total revenues (R)**

DAFOSYM estimates total farm revenue to consist of revenues earned from the sale of milk, feed, calves, cull cows and heifers.

Total revenues (R) = $Sales_{Milk} + Sales_{Excess\text{-}feeds} + Sales_{Animals}$

where,

a. $Sales_{Milk}$ = f (Total milk production, milk price), and,

b. $Sales_{Animals} = Sales_{Culled\ cows} + Sales_{bred\ heifers} + Sales_{calves}$

The milk price is constant and numbers of calves sold are those in excess above the number needed for replacements.

2. Total production costs (P_c)

Total production costs consist of all the cost inducing components on the farm as part of the year's operation. The total cost of production primarily consists of costs incurred on land, animals, seeds and chemicals purchased, feeds purchased and any custom operations.

a. $Cost_A$ = Total cost {Purchased feeds + Manure management + Bedding + Livestock expenses + Purchased animals (including Replacements = number required minus number of older heifers on the farm), labor}

3. Net farm return (NFR)

According to the DAFOSYM, net farm income is calculated as the net pre-tax profits of the farm defined as.

NFR = Total {Revenues (R) – Production costs (P_C)}.

Net farm return is the difference between total revenues and production costs.

4. Feed costs

Feed requirements are determined using a feeding algorithm that determines the amount of feeds that are purchased after considering total feeds produced on the farm. Annual total feeds costs consist of the cost of producing crops (machinery, fuel, land) and quantity of purchased feeds times the feed price.

Total feeds costs = Cost of {Feeds produced, Machine and energy use, labor, (total feeds purchased) * User specified price.

5. Manure management costs

DAFOSYM estimates manure management costs using an algorithm that tracks total manure produced, collected, stored and finally applied to the cropland.

Manure handling costs = f (Total manure produced, type of storage, distance of collection from application, amount of labor and machinery used).

5.2 Initial nutrient balance assessment

Using the above formulae, the following tables of nutrient flowing onto, within and off the farm are estimated. Information required for each farm includes crops grown and amount of manure applied onto cropland. The whole net nutrient balance is then evaluated.

5.2.1 50 Cow farm

Table 5.2.1 Nutrient flows (pounds) for 50 cow farm

Total DM feed intake	918,000		
Nutrient constituents (pounds)	**Nitrogen**	**Phosphorus**	**Potassium**
	64,627.2	23,859	12,558
Nutrient Exports			
Milk	3,975	750	1,125
Growth	1,777	188.4	25
Other outflows	50,383	11,379	-7,582
Manure nutrients	8,492	11,541	18,991
Collection, handling and application	0	733	0
Net Nutrient Imports			
Net-nutrient imports (X_I) to land (pounds / acre)	133	3.7	4.6
Commercial fertilizer	0	0	0
Nitrogen volatilization + Leaching	-33	0	0
Total availability (lb/ac)	171.2	6.8	40
Total nutrients used / required (lbs/ac)	134.6	11.7	85.6
Net surplus (+) / deficits (-)	+ 36.7	- 5.0	- 45.4

The dairy farm possesses 44 replacement heifers. A medium loam soil is used for crops to grown are alfalfa, grass and corn. 9,18,000 pounds of dry feed matter is fed to the herd. The initial nutrient constituents in the feed intake consist of 66,4627 pounds of nitrogen, 23,859 pounds of phosphorus and 12,558 pounds of potassium. Total nutrient exports through losses from milk and body growth is estimated to be 5,752 pounds, 939 pounds and 1,150 pounds for nitrogen, phosphorus, and potassium respectively. Net manure nutrients from the dry matter manure are 8,492 pounds of nitrogen, 11,541 pounds of phosphorus, and 18,991 pounds of potassium. After collection, handling and application losses of manure, the net nutrient imports onto the land are 171.2 pounds per acre for nitrogen, 6.8 pounds per acre for phosphorus, and 40 pounds per acre for potassium. The whole farm nutrient balance shows an excess of available nitrogen on the land of 36.7 pounds/acre and a deficiency in phosphorus and potassium availability of 5.4

and 45.4 pounds/acre respectively. Any nutrient deficits will be supplemented with the use of commercial fertilizer.

5.2.2 150 cow farm

Table 5.2.2 Nutrient flows for the 150 cow farm

Total DM feed intake	2,986,000		
Nutrient constituents (pounds)	**Nitrogen**	**Phosphorus**	**Potassium**
	210,214	77,606	40,848
	Nutrient Exports		
Milk	13,515	2,550	3,825
Growth	5,781	613	82
Manure nutrients (pounds)	25,688	37,315	71,385
	Net Nutrient Imports		
Net-nutrient imports to land (pounds / acre)	157.7	6.3	10.2
Commercial fertilizer	0	0	0
Volatilization and Leaching	-65	0	0
Total availability (lb/ac)	244	11.5	82
Total nutrients used (lb/ac)	189.2	16.1	106.6
Net surplus (+) / deficits (-)	+ 55.3	- 4.6	- 25.1

Table 5.2.2 provides a nutrient assessment for the 150 cow dairy farm with a total acreage of 600 acres of farmland, 129 replacement heifers and a medium clay soil. The crops grown are alfalfa, corn and oats. DAFOSYM estimates the total dry matter feed intake fed to the cows to be 2986,000 pounds or 1,493 tons with nutrient constituents of 210,214 pounds of nitrogen, 77,606 pounds of phosphorus and 40,848 pounds of potassium. Total net losses or exports of nutrients through milk and growth are 19,296 pounds, 3,163 pounds and 3,906 pounds of nitrogen, phosphorus, and potassium respectively. Resulting net nutrients from manure are 5,688 pounds of nitrogen, 37,315 pounds of phosphorus and 71,385 pounds of potassium. Total net nutrient imports onto land are 157.7 pounds/acre for nitrogen, 4.9 lb/acre for phosphorus and 8.4 lb/acre for

potassium. The net whole farm nutrients balance for the 150 cow farm shows a surplus of nitrogen of 55.3 pounds/acre and a deficit of 4.6 and 25.1 pounds/acre of phosphorus and potassium respectively. Any nutrient deficits will be supplemented with the use of commercial fertilizer.

5.2.3 400 cow farm

Table 5.2.3 Nutrient flow for 400 cow farm

Total DM feed intake	7,488,000		
Nutrient constituents (pounds)	**Nitrogen**	**Phosphorus**	**Potassium**
	527,155	194,613	102,436
	Nutrient Exports		
Milk	41,603	7,850	11,775
Growth	14,496.6	1,537.4	205
Manure nutrients (pounds)	62,958	96,535	122,318
	Net Nutrient Imports		
Nutrient imports (pounds / acre)	201	16	37
Commercial fertilizer (+)	0	0	0
N-volatilization and Leaching	-70.8	0	0
Total availability (lb/ac)	231.7	17.8	84.6
Total nutrients used (lb/ac)	162	12.6	66.8
Net surplus (+) / deficits (-)	+ 69.7	+ 5.1	+ 17.8

Table 5.2.3 gives an in-depth analysis of the nutrient flows and final net nutrient balance for a dairy farm with 400 milking cows and 272 heifers on the farm. The farm has a total acreage of 1,018 acres of farmland and grows corn, corn silage and grain for feed. The initial dry matter fed to the cows is estimated by the DAFOSYM to be 7,488,000 pounds with nutrient constituents estimated to be 527,155 pounds of nitrogen, 194,613 pounds of phosphorus and 122,318 pounds of potassium. Nutrient losses of nitrogen, phosphorus and potassium from milk and body growth are 408,097 pounds of nitrogen, 88,691 pounds of phosphorus and – 31,861 pounds of potassium. The farm

balance for the 400 cow dairy operation shows a surplus stock of nitrogen of 69.7 pounds per acre, 5.1 pounds/acre for phosphorus and 17.8 pounds/acre for potassium.

5.2.4 1,000 cow farm

Table 5.2.4 Nutrient flow for 1,000 cow dairy farm

Total DM feed intake	201,88,000		
Nutrient constituents (pounds)	**Nitrogen**	**Phosphorus**	**Potassium**
	1,421,798.4	262,548	282,744
	Nutrient Exports		
Milk	116,600	22,000	33,000
Growth	39,083.9	4,145	552.3
Manure nutrients (pounds)	170,120	110,578	246,674
	Net Nutrient Imports		
Nutrient imports (pounds / acre)	294.3	25.6	43.9
Commercial fertilizer	0.0	0.0	0.0
Nitrogen volatilization and leaching (-)	- 49.2	0.0	0.0
Total availability (lb/ac)	377.5	29.3	126
Total nutrients used (lb/ac)	255.2	23.3	111
Net surplus (+) / deficits (-)	+ 122.3	+ 6.0	+ 15.0

Table 5.2.4 is a DAFOSYM generated output of the initial state nutrient flows on the 2,500 acre 1000 cow dairy farm, which is in an informal agreement with the neighboring crop grower to manage the manure produced from the dairy operation. The farm has a total of 898 replacement heifers. The total intake of dry matter feeds by the milking cows is estimated to be 201,88,000 pounds. The nutrient constituents of nitrogen, phosphorus and potassium in the total dry matter feeds are 1,421,235 pounds, 524,686 pounds and 27,6172 pounds respectively. After the deduction of total nutrient losses or nutrient exports through milk and growth, nutrients from dry manure is found to be 170,120 pounds, 110,578 pounds and 24,674 pounds for nitrogen, phosphorus and potassium respectively. Assessment of nutrient flows shows a surplus of all three

nutrients. These surpluses are estimated to be 122.3 pounds per acre of nitrogen, 6.0 pounds/acre of phosphorus and 15 pounds/acre of potassium.

5.2.5 100 cow intensive farm

Table 5.2.5 Nutrient flow for the 100 cow intensive farm

Total DM feed intake	1,738,000	1,738,000	1,738,000
Nutrient constituents	**Nitrogen**	**Phosphorus**	**Potassium**
	122,355	45,170.6	23775.8
	Nutrient Exports		
Milk	7,420	1,400	2,100
Growth	3,37	357	47.5
Manure nutrients (pounds)	14,476	19,674	2,147.5
	Net Nutrient Imports		
Nutrient imports (pounds / acre)	143	12	32
Commercial fertilizer (+)	0	0	14
Nitrogen volatilization and Leaching (-)	- 58.6	0	0
Total availability (lb/ac)	195.7	17.3	100
Total nutrients used (lb/ac)	148.1	15.0	91
Net surplus (+) / deficits (-)	+ 47.7	+ 2.3	+ 9.1

The 100 cow rotational grazing farm makes use of medium loam soil to grow alfalfa and corn. Table 5.2.5 provides nutrient flows based on the formulae used by the DAFOSYM. Total dry matter feed intake consists of 122,355 pounds of nitrogen, 45,170.6 pounds of phosphorus and 23,776 pounds of phosphorus respectively. Nutrient exports of nitrogen, phosphorus, and potassium from the land is found to be 10,784.8 pounds of nitrogen, 1,756.8 pounds of phosphorus and 2,147.5 pounds of potassium. Net nutrient imports to land are 143 pounds/acre for nitrogen, 12 pounds of phosphorus and 32 pounds of potassium. The farm net nutrient balance for the 100 cow rotational farm shows an excess of supply of nitrogen, phosphorus and a marginal surplus supply of potassium. DAOFSYM estimates net surpluses of 47.7 pounds/acre for nitrogen, 2.3 pounds/acre for phosphorus and 9.1 pounds/acre for potassium.

5.3 Conclusion

The chapter provided an overview of the system based simulation tool DAFOSYM, and provided an assessment of nutrient inflows, outflows and net nutrient balance for each of the five representative farms. Nutrient flow analysis showed the 50 and 150 cow farms to have an excess supply of on-site nitrogen and deficits of phosphorus and potassium. DAFOSYM results indicate that the 400 and 1000 cow conventionally managed dairy farms and the 100 cow rotational grazing farms have surpluses of all three nutrients, nitrogen, phosphorus and potassium.

The next chapter makes use of the DAFOSYM to determine nutrient flows and final nutrient balances to estimate the costs of achieving a nutrient balance by each of the five representative farms.

Chapter 6: Nutrient balancing management strategies and economic implications

Chapter six identifies management changes and associated changes in costs and revenue from nutrient balances due to participation in the MAEAP. The chapter initially reviews literature on nutrient management and strategies. Using the experience of past studies, this study concentrates on effects of managerial changes in crops grown, ration reformulation, and land available for manure application, manure management, heifer management, and combined strategies to alleviate excess phosphorus and nitrogen. Capital investments including land and manure storage facilities are analyzed in the following chapter.

The adoption of the CNMP involves several types of costs. This chapter explicitly considers three types of costs: cost incurred on soil and manure nutrient analysis tests, changes in operational practices, and any capital investments to meet GAAMPs recommendations. A fourth cost, payments to a consultant to write the plan is not considered in the final chapter. Anecdotal evidence suggests that plan writers can charge a total of thousands of dollars. Sections 6.1 through 6.6 focus on the soil and manure nutrient tests and costs, a literature review of select studies, adoption of nutrient management strategies, effect on nutrient balances, a summary of the nutrient balances, and finally, an economic analysis of the adopted strategies.

6.1 Soil and manure nutrient analysis tests

An initial soil test is required to determine existing soil nutrient levels. The GAAMPs require collection of soil samples at a minimum rate of one sample for 15 acres of farmland where manure is applied. The tests determine soil pH levels, as well as phosphorus, nitrogen, and potassium levels (GAAMPs-Michigan Agriculture Commission). The cost of conducting soil and manure nutrient tests at the Michigan State University Department of Crop and Soil Sciences is $8 per soil sample. Manure nutrient tests determine the nutrient content as a percentage of dry matter (solids), ammonium N (NH_4-N,) and total nitrogen, phosphorus, and potassium. Testing of manure nutrients determines the appropriate rate of manure application. A typical cost for a manure nutrient test, $27.50 from A&L Great Lakes Laboratories Inc., is used in this analysis.

Table 6.1 Costs of soil fertility and manure nutrient tests

Herd size	Total land operated[1] (acres)	Number of soil samples	Total soil tests cost ($)	Manure analysis ($)	Total cost ($)
50 cow farm	312	21	168	27.50	195.50
150 cow farm	600	40	320	27.50	347.50
400 cow farm	1,018	68	544	27.50	571.50
1000 cow farm[1]	2,500	166	1,333	27.50	1,360.80
100 cow grazing farm	400	27	216	27.50	243.50

[1]Includes both owned and rented land.

Table 6.1 indicates total cost of soil and manure nutrient tests incurred by the representative farms due to the adoption of a CNMP. As expected, costs of soil testing increase with total farmland used for manure application.

6.2 Nutrient balancing strategy literature review

Research studies often possess a normative or positive approach. In addition, studies are often also conducted using experimental or simulation methods. A broad classification of the studies based on their approach and method used, helps to evaluate the relevance of the study under consideration. A study is normative in its approach if the findings yield knowledge or solutions from research questions that describe the ideal desired state or what ought to be. In contrast, a positive approach consists of findings that take into consideration actual farm or site-specific conditions and evaluates the net financial, environmental or productivity results (for example, a policy or technology adoption or meeting a pollution standard).

Table 6.2 summarizes a literature review of relevant studies with feasible nutrient management strategies.

Table 6.2 Overview of nutrient management strategies from selected literature

Author	Nutrient(s) considered	Strategies	Results
Chalupa and Ferguson (1996)	Nitrogen	1. Ration reformulation a) Reduce crude protein (C.P.) b) Increase dietary non-fiber carbohydrates (NFC) c) Increase ammonia uptake and bacterial growth rate	(1a) Manure N excreted reduced 16% (1b) NFC reduced 42% manure N by 18.8% (1c) Manure N declines and higher dietary N in milk
Dou et al. (1996)	Nitrogen	1. Ration reformulation 2. Manure application a) Change from same day manure incorporation to no incorporation b) Increased manure application on alfalfa	(1) Feed N intake reduced 7% and excess N reduced 16% (2a) Manure N utilization increased 130% (2b) Manure N utilization increased 32%
Fulhage (1997)	Nitrogen	1. Increase land available for manure application 2. Increase corn silage acreage	Not applicable
Alocilja (1998)	Phosphorus	1. Ration reformulation a) Increase corn silage content b) Altering milk yield levels	(1a) Increased milk yield, and P utilization rate increased 43% (1b) P excretion rate decreased 20% and utilization rate increased 20%
Klausner et al (1998)	Nitrogen	1.Ration reformulation a) Higher proportion of farm produced feeds b) Use treated soybean meal	(1a) C.P. reduced 2% and N excretion reduced 34% (1b) 13% increase in milk yield
Koelsch and Lesoing (1999)	Nitrogen and Phosphorus	1. Reduced use of commercial fertilizer 2. Alternative feeding systems 3. Sale of manure nutrients	(1) Nutrient balance improved (2) Decline in excess nitrogen of 47% and 155% in phosphorus
St.Pierre and Thraen (1999)	Nitrogen and Phosphorus	1. Herd grouped based on: a) Actual Fecal matter and varying Net energy lactation and CP levels b) Clustering of herd size	(1) N excretion reduced 16% and improved N utilization
Neeteson (2000)	Nitrogen	1a. Ration reformulation 1b. Limited grazing time	(1a) 63% decline in N excess, 92.5% decline in P excess (1b) Milk N increased 4%, total N losses due to leaching decreased 70%.

Chalupa and Ferguson conducted simulations using the Cornell Net Carbohydrate Protein System model to assess the impact of three ration reformulation strategies on manure management. The study changed non-fiber carbohydrate levels and the level of metabolizable protein. Changes in ration utilized corn gluten and blood meal to lower crude protein levels and increase milk nitrogen intake. Increasing the NFC content from 36 percent to 43 percent reduced nitrogen excretion by 18.8 percent. However, these results are based on simulations rather than actual farm data.

Dou *et al.*, considered integrating changes in dietary composition with alternative cropping mix to balance nitrogen. Dietary manipulations using a simulation to meet herd nutritional requirements with the CNCPS compared to NRC recommendations consisted of reduced feed nitrogen intake by 7 percent resulting in a 16 percent decline in excess manure nitrogen. Changing from an existing strategy of manure application with same day incorporation to no manure incorporation increased manure nitrogen losses through volatilization and resulted in a 130 percent increase of manure nitrogen utilization. In addition, increasing the rate of manure application to alfalfa land increased manure nitrogen utilization by 32 percent.

For an expanding dairy farm with excess on-farm nutrients, Fulhage suggested increasing land available for manure application and recommended corn silage is grown due to its high nitrogen removal rate.

Alocilja made use of a ration combination of high corn-to-alfalfa silage ratio, reductions in dietary nitrogen and phosphorus, and high plant biomass content to assess its effect on phosphorus. These changes resulted in an increased milk yield and a 43% increase in phosphorus utilization rate. Reformulation of ration increased milk production per cow from 20,075 pounds to 28,105 pounds per year for one milking cow. As a result, the study found a 20% decline in phosphorus excretion rate and 20% increase in utilization rate. Increased milk production of 40% in this extreme case would not be typical for a well-managed dairy farm.

Klausner *et al.*, conducted a partial budgeting economic analysis of modifying rations to manage nutrients on a New York case study dairy farm. An assessment of mass nutrient balances found excess rates of 72, 59, and 71% for nitrogen, phosphorus and potassium respectively and 60 to 80% of the imported nutrients from purchased feeds. Evaluation and refinement of animal diets resulted in a 2% reduction in crude protein content of the rations while supporting a 13% increase in milk production and a 34% decrease in total nitrogen excreted. Partial budgets projected that ration reformulation increased net farm income by $40,200. The Klausner study results depend crucially on the initial conditions of the case farms. No rationale for a "well-managed" farm realizing a 13% increase in milk production due ration reformulation is provided.

Koelsch and Lesoing evaluated nutrient balance on 33 Nebraska livestock farms and observed a 50% excess in nitrogen and phosphorus loading. Adopting a strategy of reduced use of commercial fertilizer resulted in a significant reduction in excess nitrogen. Use of alternative feeding programs consisting of not purchasing by-products of processed ethanol and corn resulted in a 47% and 155% improvement in nitrogen and phosphorus balance respectively. Koelsch and Lesoing concluded that efficient use of manure nutrients with an agronomic rate of manure application and reducing the use of commercial fertilizer help alleviate excess nutrients on the farm. The study also explored the scope for marketing manure to eliminate nutrient imbalance on farms.

St.Pierre and Thraen used a simulation study to evaluate changes in ruminant nutrition and adopting an animal grouping strategy was the focus of a nutrient balance assessment. The study assumed the animals are usually in different stages of lactation and thus a response model to determine optimum allocation of net energy for lactation (NE_L) and CP levels was derived for varied levels of lactation. Strategies adopted consisted of varying actual fecal matter production, net energy lactation and crude protêin levels, and clustering herd size. The results found a 16% reduction in nitrogen excretion and improved nitrogen utilization rate.

Neeteson analyzed the Dutch regulatory policy on animal nutrient use and evaluated the effect of adopting nutrient management strategies on dairy farms that met regulatory goals. Regulatory requirement on Dutch dairy farms calls for the farmers to adopt an on-farm nutrient budgeting procedure, Minerals Accounting System (MINAS, 1998). This regulatory procedure tracks nutrient flows into, within and off the farm. Neeteson found the information derived from nutrient budgeting be useful in assessing the impact of adopting nutrient management strategies to nutrient balances. By comparing a case study farm with other commercially managed dairy farms, Neeteson considered a combination strategy of reduction in use of purchased concentrates, increased on-farm feed production and limited grazing time. Such a unified strategy resulted in excess nitrogen levels to fall by 63% and 92.5% decline in phosphorus. The study also observed that lowering the use of concentrates helped increased milk production by 4% and total nitrogen losses through leaching decreased by 70%.

The literature review of nutrient management strategies reveals several common strategies. Koelsch and Lesoing suggested reduction or elimination of commercial fertilizer, which resulted in an improvement in nutrient balance.

Neeteson, Chalupa and Ferguson, and Alocilja adopted ration re-formulation for reducing excess nitrogen in manure. However, only Klausner *et al.*, and Alocilja conducted nutrient management studies using actual case study farms while the others were simulation studies partly or completely.

Studies by Hart *et al.*, and Fulhage possessed normative approaches in their conclusions while the analysis of other studies were positively oriented. As a result, this study aims to adopt similar but feasible strategies from studies that were positive in their analysis and conclusions so as to achieve a higher reliability of nutrient management findings of the five representative Michigan dairy farms. This study considers nutrient management strategies including changes in crop mix, ration reformulation, removal of replacement heifers, a combination of ration reformulation and crop mix, increasing land availability for manure application and finally an integrated use of all above changes.

We assume that the representative farms are not making any management errors as we examine ration changes while maintaining a fixed production milk level rather than considering a change in production level. Based on a review of the literature, five strategies for alleviation of excess nitrogen and phosphorus without any use of commercial fertilizer more are considered in this study:

1. Changes in crop mixture or rotation,
2. Removing the replacement heifer enterprise from the farm premises,

3. Ration change,

4. Combining crop mixture and removal of replacement heifers, and,

5. Integrating adoptions of crop mix, removal of replacement heifers and ration change strategies.

A sixth strategy involves increasing land available for manure application. Increasing land available for manure nutrient application is another option for the farm operator to better manage excessive manure produced. In the case of a surplus of nutrient loadings in proportion to the land available, the farmer may acquire more land through purchase, leases, or a mutual agreement with a landowner. The cost of a management strategy of investing into additional cropland to ensure a farm nutrient balance is evaluated in the next chapter. Each strategy is examined for each farm size in the following sections. The "optimal" strategy is discussed using economic variables to conclude for each representative farm. This possibility is considered in the following chapter.

The details for the first five strategies are discussed below through sections 6.3 to 6.7 each of which consists of:

1. An initial prior and post strategy adoption overview of representative farms,
2. Review of net nutrient balances, and,
3. Economic analysis for the five representative farms.

6.3 Changes in crop mix and nutrient management

The proportion of alfalfa and corn (high or low moisture grain), primary feed crops for Michigan dairy farms, influence the net nutrient balance. Other crops, primarily small grains, also can be grown to alleviate excess nutrients. Nutrient removal rates of several Michigan field crops guide crop selection for optimal nutrient utilization.

Table 6.3 Removal rates for Michigan field Crops

Crop grown	N	P	K
	lbs/ton		
Alfalfa hay	45.0	23.0	54.0
Alfalfa haylage	14.0	3.2	14.4
Barley[1]	50.0	43.6	75.0
Birds foot trefoil Hay	48.0	27.6	50.4
Brome grass hay	33.0	29.9	78.0
Clover Grass	41.0	29.9	46.8
Corn Grain	50.4	45.1	18.1
High moisture corn grain	26.0	27.6	7.8
Corn silage	9.4	8.3	9.4
Oats[1]	51.7	42.4	82.6
Orchard Grass Hay	50.0	39.1	74.4
Red Clover Hay	40.0	23.0	48.0
Rye[1]	70.2	61.3	46.1
Sorghum-sudan grass Hay	52.0	45.1	91.2
Soybeans Grain	126.0	75.0	42.8
Wheat[1]	53.0	50.8	28.0

[1] Includes nutrients removed by the grain and straw.
[2] Source: "Fertilizer Recommendations for Field Crops in Michigan" Michigan State University Extension Bulletin E-629.

Farm operational strategies that consist of changing the crop mix require substitution of crops with low removal rates of nitrogen or phosphorus to those crops with high utilization rates. Corn, corn silage, small grains orchard grass, and sorghum sudan grass have relatively high phosphorus removal rates and thus reduce soil accumulation of phosphorus.

Since alfalfa fixes nitrogen directly from the air, growing alfalfa crops for forage may result in increasing soil nitrogen levels. Nutrient balancing may therefore involve decreasing total alfalfa acreage to reduce soil nitrogen levels. Corn silage in particular is a substitute for alfalfa in dairy cow diets, and this strategy is also considered in the present study. Crop changes consist of altering the initial distribution of acreage between alfalfa and corn to a ratio of one to three as previous studies with DAFOSYM found this ratio most beneficial to reducing excessive on farm nutrients however not economically profitable to farmers (Borton, 1996).

6.3.1a 50 cow farm crop mix strategy effect

An initial assessment of nutrient balances of the 50 cow farm reveals a phosphorus deficiency but surpluses of available nitrogen. As a result, the primary motivation of a crop change management strategy adoption is to increase utilization of excessive levels of nitrogen without a surplus of phosphorus.

Table 6.3.1a Crop mix change and nutrient balance

Characteristics		Initial state	Post changes
Total available farmland (acres)		312.0	312.0
Crops grown and number of acres	Alfalfa	146.0	78.0
	Corn	91.0	159.0
	Small grain (Oats)	29.0	29.0
	Pasture	18.0	18.0
Feeds sold (tons)	Alfalfa haylage	167.0	40.0
	Alfalfa hay	108.6	51.7
	Corn silage	74.3	28.6
	High moisture corn grain	0.0	0.0
Feeds purchased	Corn grain	50.8	6.8
Net nutrient balance (pounds per acre)			
Nitrogen		+ 36.7	+ 19.9
Phosphorus		- 5.0	- 2.4
Potassium		- 45.4	- 16.0

Due to an increase in production of corn relative to alfalfa there is a significant increase in the total dry matter produced for feed intake. Reducing total acreage for growing alfalfa also results in a significant reduction in sales, of 76 percent in alfalfa hay and 52 percent in haylage. Feeds purchased in the form of corn grain reduces distinctly and a higher corn and corn silage content in the forages; result in a higher utilization of manure nitrogen, particularly surplus nitrogen resulting in phosphorus and potassium levels to improve and available excess nitrogen excess reduced to 19.9 pounds per acre from 37 pounds per acre. DAFOSYM automatically adjusts the ration and purchases feed as needed.

6.3.1b 150 cow farm crop mix strategy effect

Table 6.3.1b Crop mix change and nutrient balance

Characteristics		**Initial state**	**Post changes**
Total land available (acres)		600	600
Crops grown (acres)	Alfalfa	303	187
	Corn	263	412
	Soybean	102	102
	Small grain (Oats)	32	32
Feeds purchased	Alfalfa hay	177.7	6.2
Feeds sold	Alfalfa haylage	115.4	1.1
	Alfalfa hay	160.9	
	Corn silage	34.7	0.0
	Corn grain	74.4	238.2
	High moisture corn	0	0
Net nutrient balance (pounds per acre)			
Nitrogen		+ 55.3	+ 37.0
Phosphorus		- 4.6	- 3.4
Potassium		- 25.1	- 4.8

Altering the initial cropping distribution from alfalfa, corn and oats, to that of a one is to three ratio between alfalfa and corn respectively, reduces excessive levels of nitrogen by little less than a half and phosphorus and potassium are found to be in deficit levels. Increasing total production of corn results in no sales of corn silage and thus ensuring higher nitrogen utilization. Such a crop mix strategy has a positive effect (reduction of excess levels) of all three nutrients under study.

6.3.1c 400 cow farm crop mix strategy effect

Adopting a crop mix strategy by the 400 cow farm has no significant influence in alleviating excessive levels of all three nutrients. Table 6.3.1c below provides a farm overview of adoption changes due to crop mix.

Table 6.3.1c Crop mix change and nutrient balance

Characteristics		Initial state	Post changes
Total land available (acres)		1,018	1,018
Crops grown (acres)	Alfalfa	216	233
	Grass	64	64
	Corn	490	470
	Oats	92	92
	Soybeans	87	87
Net nutrient balance (pounds per acre)			
Nitrogen		+ 69.7	+ 71.4
Phosphorus		+ 5.1	+ 5.0
Potassium		+ 17.8	+ 16.1

Adoption of a crop mix strategy on the 400 cow farm proves effective as the initial excess levels of nitrogen and phosphorus decline and phosphors is no longer a case of concern. Almost half of the total acreage is used for growing corn due to its high nitrogen removal rate, however, decreasing the corn acreage to ensure a one to three proportions between alfalfa and corn does not improve the nitrogen balance. In fact, only phosphorus and potassium levels marginally improve.

This indicates that a crop mix strategy is not beneficial to the 400 cow conventional farm and other strategies in isolation or in combination may be effective.

6.3.1d 1,000 cow farm crop mix strategy effect

Table 6.3.1d Crop mix change and nutrient balance

Characteristics		**Initial state**	**Post change**
Total land available (acres)		2,500	2,500
Crops grown (acres)	Alfalfa	590	657
	Corn	767	1,313
Feeds purchased	Corn grain	1,931.0	2,014.5
	Alfalfa hay	963.3	729.0
Feeds sold	Alfalfa haylage	112.8	2.7
	Corn silage	0.0	0.0
Net nutrient balance (pounds per acre)			
Nitrogen		+122.3	+ 125.1
Phosphorus		+ 6.0	+ 5.6
Potassium		+ 15.0	+15.0

Altering alfalfa to corn ratio from one to one (1:1) crop ratio to about one to three (1:3), keeping the total land available for crop production constant, reduces total nitrogen levels. There is a resulting increase in purchase of corn silage and a marginal decline in purchases of alfalfa hay for feeds purposes. Dietary intake is assumed fixed with a soybean meal and user defined feed supplement. Such a crop mix strategy does not by itself alleviate the soil nitrogen levels and decreases surplus phosphorus levels marginally, which also is a concern.

6.3.1e 100 cow grazing farm crop mix strategy effect

Table 6.3.1e shows the prior and post effects of adoption of the crop mix strategy with alfalfa and corn in the ratio of one to three on the manure nutrients.

Table 6.3.1e Crop mix change and nutrient balance

Characteristics		Initial state	Post changes
Total available farmland (acres)		250.0	250.0
Crops grown (acres)	Alfalfa	25.0	46.0
	Grass	110.0	110.0
	Corn	75.0	94.0
Feeds purchased	Alfalfa hay	45.8	124.6
	Corn grain	91.6	45.0
Feeds sold	Alfalfa haylage	5.6	12.2
	Alfalfa hay	40.4	47.6
	Corn silage	9.7	21.4
	High moisture corn	2.0	5.4
Total net feeds (tons of DM)		874.0	870.0
Net nutrient balance (pounds per acre)			
Nitrogen		+ 50.9	+ 43.3
Phosphorus		+ 3.0	+ 4.1
Potassium		+ 20.0	+ 35.0

6.3.2 Crop changes and nutrient balances

Table 6.3.2 below provides a final summary of the net nutrient balances for the five representative farms as a result of changing the crop mix with more corn silage as to ensure higher nutrient utilization. The simulation results below also give a prior and post adoption change expressed in percentage form all the three nutrients under study. Percentage changes are used to evaluate whether changing the crop mix in a ratio of one to three for alfalfa to corn helps alleviate excessive nutrients (primarily nitrogen) or has a detrimental effect.

Table 6.3.2 Summary of nutrient balances due to adoption of crop mix strategy

Characteristics		Herd size *(Number of milking cows)*				
		50	*150*	*400*	*1000*	*100 grazing farm*
Nitrogen	Initial	+ 36.7	+ 55.3	+ 69.7	+ 122.3	+ 47.7
	Post adoption	+ 19.9	+ 37.0	+ 71.4	+ 125.1	+ 54.0
	Percent change (%)	- 45.8	- 33.0	+ 2.4	+ 2.2	+ 13.2
Phosphorus	Initial	- 5.0	- 4.6	+ 5.1	+ 6.0	+ 2.3
	Post adoption	- 2.4	- 3.4	+ 5.0	+ 5.6	+ 1.9
	Percent change (%)	+ 52.0	- 26.0	- 2.0	- 6.6	- 18.0
Potassium	Initial	- 45.4	- 25.1	+ 17.8	+ 15.0	+ 9.1
	Post adoption	- 16.0	- 4.8	+ 16.1	+ 9.8	+ 2.1
	Percent change (%)	+ 64.7	+ 81.0	- 9.5	- 34.6	- 24.0

DAFOSYM generated simulation results indicate that prior to the adoption of a crop change strategy to reduce excessive on-farm manure nutrients, the smaller, (50 and 150 herd size) dairy farms possessed excessive levels of nitrogen and deficits of phosphorus and potassium. However, the remaining three farms including the 100 cow rotational grazing farm, showed an initial surplus in all three nutrients. Adoption of a crop mix and simulation of the new changes resulted in significant reductions in levels of nitrogen only for the 50 and 150 cow farms as a result of better utilization of nitrogen with increased growth of corn silage. However, the remaining three farms had insignificant improvement in excessive levels of nitrogen but relatively fair reductions in surpluses of phosphorus and potassium.

6.3.3 Economic analysis of adoption of crop mix strategy

Table 6.3.3 Economic analysis

Characteristics		**Herd size**				
		50 cows	*150 cows*	*400 cows*	*1,000 cows*	*100 grazing farm*
Total farm sales	Initial	149,321	410,101	1,186,284	3,748,476	211,723
	Post adoption	128,688	399,473	1,187,565	3,108,650	213,809
	Percent change (%)	- 13.8	- 2.6	+ 0.01	- 0.17	+ 0.9
Feed costs	Initial	101,455	181,600	521,812	1,178,357	124,452
	Post adoption	99,943	200,358	519,476	115,6251	120,739
	Percent change (%)	- 1.4	+ 10.3	- 0.4	- 1.5	- 3.0
Manure costs	Initial	9,918	18,621	61,148	248,019	16,396
	Post adoption	9,801	18,811	61,146	240,046	16,289
	Percent change (%)	- 1.1	+ 1.1	- 0.3	- 3.2	- 0.6
Other costs	Initial	55,400	189,725	345,316	1,135,220	159,214
	Post adoption	55,400	189,725	565,766	1,135,220	159,034
	Percent change (%)	0	0	+ 63.8	0	+ 0.01
Net return	Initial	22,058	158,277	482,302	1,427,055	39,817
	Post adoption	3,054	128,701	485,920	1,457,436	45,723
	Percent change (%)	- 86	- 18.6	+ 0.7	+ 2.1	+ 14.8

Table 6.3.3 displays an overview of the prior and post adoption effect of a crop mix strategy across all five representative dairy farms. The table indicates that the smaller conventional dairy farms with 50 and 150 milking cows experience a decline in total farm sales resulting in a fall in net farm return by 86 percent for the 50 cow farm and 18.6 percent for the 150 cow farm. However, due to a larger herd size, the 400 and 1000 cow herd dairy farms experience marginal gains in net return due to higher farm sales as a result of fairy amount of revenue earned from sales of forages and corn silage.

The 100 cow rotational grazing farm proves to be most profitable on a pre-tax basis, with net farm return increasing by over 15 percent.

To conclude, adoption of a management strategy to better utilize on farm nutrients with a crop mix strategy with alfalfa to corn grown in a ratio of one is to three is advantageous to only the 400 and 1000 cow farms and the 100 cow grazing farm.

6.4 Removal of Custom raising or purchase of replacement heifers

The number of replacement heifers raised on the farm has a direct impact on the quantity of manure produced and resulting nutrients, additional feeds and supplements purchased, and net farm income. In instances of excess manure produced on the farm, a dairy farmer might consider removing the replacement heifer enterprise from the farm by using a custom heifer raiser. As a result total quantity of manure is reduced lowering soil nutrient loadings. In addition, reducing the number of replacement heifers raised (or not raising them at all) reduces the total dry matter fed and may increase feeds sold. This potential advantage of custom heifer-raising is not usually explicitly considered when making heifer-raising decisions. We assume the heifer raising cost is $1.50 per heifer per day—a typical charge (Wolf and Harsh). A farm operator may also consider selling heifer calves and purchasing springing heifers. The resulting change in net farm return depends on the cost of raising heifers on farm versus custom raising or purchasing heifers.

6.4.1a 50 cow farm heifer enterprise removal

Table 6.4.1a Removal of replacement heifers and nutrient balance

Characteristics		Initial state	Post changes
Total farmland available (acres)		312	312
Number of total replacement heifers on farm		44	0
Crops grown (acres)	Alfalfa	146	146
	Corn	91	91
	Small Grain (Oats)	29	29
	Pasture	18	18
Net nutrient balance (pounds per acre)			
Nitrogen		+ 36.7	+ 27.4
Phosphorus		- 5.0	- 7.0
Potassium		- 45.4	- 49.5

A farm managerial decision to remove the replacement heifers and using a custom heifer raiser reduces the total quantity of manure-produced. Nitrogen levels reduce to 27.4 pounds per acre from 36.7 pounds per acre while there is also a decline in phosphorus and potassium deficiency levels. No change in dietary supplements was made and DAFOSYM defined initial soybean meal was fed.

6.4.1b 150 cow farm heifer enterprise removal

Table 6.4.1b Removal of replacement heifers and nutrient balance

Characteristics		Initial state	Post changes
Total land available (acres)		600	600
Number of total replacement heifers		129	0
Crops grown (acres)	Alfalfa	303	303
	Corn	263	263
	Soybean	102	102
	Small Grain (Oats)	32	32
Net nutrient balance (pounds per acre)			
Nitrogen		+ 55.3	+ 40.2
Phosphorus		- 4.6	- 7.0
Potassium		- 25.1	- 49.5

Removal of replacement heifers from the farm reduces the total manure produced. Dry manure nitrogen reduces by a fair amount and phosphorus and potassium levels remain in a deficit thus implying the need for commercial fertilizer use based on nitrogen based agronomic application.

6.4.1c 400 cow farm heifer enterprise removal

Table 6.4.1c Removal of replacement heifers and nutrient balance

Characteristics		**Initial state**	**Post changes**
Total land available (acres)		1,018	1,018
Number of total replacement heifers		272	0
Crops grown (acres)	Alfalfa	216	216
	Grass	50	50
	Corn	490	490
	Small grain (Oats)	92	92
Net nutrient balance (pounds per acre)			
Nitrogen		+ 69.7	+ 50.0
Phosphorus		+ 5.1	+ 2.2
Potassium		+ 17.8	- 8.1

Similar to the other two farms described above, a decision to purchase custom raised heifers reduces total manure produced and resulting excess manure nitrogen level. With zero replacement heifers on the farm, phosphorus levels reach a near zero thus meeting GAAMPs requirements for least possible phosphorus accumulation in the soil.

6.4.1d 1,000 cow farm heifer enterprise removal

Table 6.4.1d Removal of replacement heifers and nutrient balance

Characteristics		**Initial state**	**Post changes**
Total land available (acres)		2,500	2,500
Number of total replacement heifers		898	0
Crops grown (acres)	Alfalfa	590	590
	Corn	767	767
Net nutrient balance (pounds per acre)			
Nitrogen		+ 122.3	+ 84.6
Phosphorus		+ 6.0	+ 5.2
Potassium		+ 15.0	- 30.3

Reducing total herd size by removing the 898 replacement heifers from the farm reduces all the three nutrient levels. Nitrogen reduces by 31 percent, and phosphorus levels decline marginally. Excessive levels of potassium are best reduced to deficit levels by the removal of replacement heifers. However, there is still an excess of nitrogen and phosphorus that makes it not feasible to consider this strategy as the only one to enable manure management to meet GAAMPs recommendations and the dairy operator or crop producer may have to explore other management alternatives or options for on-farm nutrient management.

6.4.1e 100 cow grazing farm heifer enterprise removal

Table 6.4.1e Removal of replacement heifers and nutrient balance

Characteristics		Initial state	Post changes
Initial total farmland available for manure application (acres)		250	250
Number of total replacement heifers		85	0
Crops grown (acres)	Alfalfa	25	25
	Grass	110	110
	Corn	115	115
Net nutrient balance (pounds per acre)			
Nitrogen		+ 47.6	+ 20.1
Phosphorus		+ 2.3	- 2.2
Potassium		+ 9.0	- 24.6

Decline in the herd size due to the removal of stock of 85 young heifers results in a decline in total nitrogen levels by more than half to 20 pounds per acre and phosphorus and potassium change from levels of surplus to deficit. This is a satisfactory improvement in nutrient balances however, the grazing farm still does not meet the GAAMPs recommendations for complete utilization of available nitrogen and thus the operator may require further changes to adopt so as to seek a nutrient balance.

6.4.2 Removal of custom-heifers and nutrient balances

Table 6.4.2 Summary of nutrient balances due to removal of heifer enterprise

Characteristics		Herd size				
		50 cows	*150 cows*	*400 cows*	*1,000 cows*	*100 grazing farm*
Nitrogen	Initial	+ 36.7	+ 55.3	+ 69.7	+ 122.3	+ 47.6
	Post adoption	+ 27.4	+ 40.2	+ 49.9	+ 84.6	+ 20.1
	Percent change (%)	+ 25.3	+ 27.3	- 28.4	- 30.8	- 42.2
Phosphorus	Initial	- 5.0	- 4.6	+ 5.1	+ 6.0	+ 2.3
	Post adoption	- 6.5	- 7.0	+ 2.2	+ 0.19	- 2.2
	Percent change (%)	- 30.0	+ 52.0	- 56.8	- 96.8	- 197.0
Potassium	Initial	- 45.4	- 25.1	+ 17.8	+ 15.0	+ 9.0
	Post adoption	- 61.0	- 49.5	- 8.1	- 37.4	- 24.6
	Percent change (%)	- 34.3	+ 97.2	- 145.0	- 349.0	- 373.0

Table 6.4.2 provides a summary picture of the nutrient balances across all the five dairy farms due to the adoption of the removal of replacement heifer strategy. It is observed that the strategy does prove effective in reducing excessive levels of nitrogen on all farms by an average of 25 percent at the minimum. Phosphorus and potassium levels fall to higher levels of deficits for the 50 and 150 conventional dairy farms and the 100 cow grazing farm however, the decline is lesser for the larger, 400 and 1,000 cow dairy farms. Simulated results generated from the DAFOSYM prove that the dairy operator or owner may have to consider other nutrient management strategies in combination to better manage excessive nutrients as per GAAMPs recommendations.

6.4.3 Economic impact of removal of heifers from enterprise strategy

Table 6.4.3 Economic analysis

Characteristics		Herd size				
		50 cows	*150 cows*	*400 cows*	*1,000 cows*	*100 grazing farm*
Total farm sales	Initial	149,321	410,101	1,186,284	3,748,476	211,723
	Post adoption	157,172	437,915	1,197,930	3,229,378	223,926
	Percent change (%)	+ 5.2	+ 6.3	+ 0.9	- 13.8	+ 5.7
Feed costs	Initial	101,455	181,600	521,812	1,178,357	124,452
	Post adoption	97,812	176,204	475,136	1,050,946	115,161
	Percent change (%)	- 3.5	- 3.0	- 9.0	- 10.8	- 7.4
Manure costs	Initial	9,918	18,621	61,148	248,019	16,396
	Post adoption	7,677	13,830	50,472	179,221	10,965
	Percent change (%)	- 22.5	- 26.0	- 17.5	- 27.7	- 33.1
Other costs	Initial	55,400	189,725	345,316	1,135,220	159,214
	Post adoption	76,400	252,125	696,116	1,135,220	201,214
	Percent change (%)	+ 27.4	+ 32.8	+ 101.5	0	+ 26.3
Net return	Initial	22,058	158,277	482,302	1,427,055	39,817
	Post adoption	15,864	133,565	429,561	1,272,959	24103.5
	Percent change (%)	- 28.0	- 15.6	- 11.0	- 10.7	- 39.4

In this study we assume the heifer raising cost is $1.50 per heifer per day—a typical charge (Wolf and Harsh). A farm operator may also consider selling heifer calves and purchasing springing heifers. The resulting change in net farm income depends on the cost of raising heifers on farm versus custom raising or purchasing heifers. Additional cost of $ 1.50 per heifer per day due to purchasing heifers is included in the calculation of other costs. Table 6.5.2 above shows that net farm returns fall as a result of removal of replacement heifers from the enterprise. The cost of adopting this strategy is not size neutral or the smaller farms, 50 and 150 cow farms have a larger loss in net return as compared to the 400 and 1000 cow conventional dairy farms. The 100 cow rotational grazing farm has the largest decline in net return. The heifer raising cost as stated earlier, has a significant impact on the total net returns and a rise in other miscellaneous costs induces total costs to rise across all the five representative dairy farms.

6.5 Ration changes

Another strategy to reduce soil nutrient levels is ration reformulation. Ration reformulation includes any changes made to the dietary intakes of phosphorus in particular, by cows to limit excess nutrients in manure.

According to Valk *et al.*, phosphorus inputs onto intensive dairy farms are mainly in the form of purchased feeds (59 percent) and less in the form of inorganic fertilizer (26 percent). Most producers overfeed their cows a diet with excessive amounts of phosphorus (Kalscheur). Previous recommendations included high phosphorus rates to help with reproduction. Recent research suggests that lower phosphate rates in dry matter intake are acceptable. For example, the 1989 National Research Council's (NRC) *National Nutrient Requirements for Dairy Cattle* recommends phosphorus content be 0.45 percent to 0.55 percent of dry matter intake while the 2001 NRC reduces this recommendation to 0.35 percent to 0.38 percent thus resulting in inefficient use of inorganic expensive phosphate (Kalscheur). In the DAFOSYM, we reduce the phosphorus feeding level from the existing 100 percent as recommended by the NRC 1989, and adjusted to 80 percent to meet the new NRC 2001 recommendations. Sections 6.5.1 to 6.5.6 below provide individual farm based summary of reducing phosphorus-feeding levels.

6.5.1a 50 cow farm ration changes

Table 6.5.1a Ration change and nutrient balance

Characteristics		**Initial state**	**Post changes**
Total farmland available (acres)		312	312
Number of total replacement heifers on farm		44	0
Crops grown (acres)	Alfalfa	146	146
	Corn	91	91
	Small Grain (Oats)	29	29
	Pasture	18	18
Phosphorus feeding level		100 %	80 %
Net nutrient balance (pounds per acre)			
Nitrogen		+ 36.7	+ 36.7
Phosphorus		- 5.0	- 6.2
Potassium		- 45.4	- 45.6

Table 6.5.1a clearly indicates the effect of adopting a ration change strategy consisting of reduction in NRC recommended phosphorus-feeding level from the initial 1989 levels of 100 percent to those of 80 percent as recently proposed in the NRC 2001 guidelines. Phosphorus levels drop further into deficits from the initial five pounds per acre to 6.2 with no change for nitrogen and potassium as expected. There is no strong need for the 50 cow farm to adopt this strategy in isolation as the initial nutrient states of the farm indicate a concern of excessive levels of nitrogen and phosphorus deficiency can be best managed with adequate fertilizer application. It may be necessary for the farm to consider other managerial alternatives so as to reduce nutrient loadings to zero.

6.5.1b 150 cow farm ration change strategy effect

Table 6.5.1b Ration change and nutrient balance

Characteristics		**Initial state**	**Post changes**
Total farmland available (acres)		600	600
Number of total replacement heifers on farm		129	129
Crops grown (acres)	Alfafa	303	303
	Corn	412	412
	Soybean	102	102
	Small grain (Oats)	32	32
Phosphorus feeding level		100 %	80 %
Net nutrient balance (pounds per acre)			
Nitrogen		+ 55.3	+ 55.3
Phosphorus		- 4.6	- 6.3
Potassium		- 25.1	- 25.0

Reduction of the phosphorus feeding level from an initial user defined 100 percent in the DAFOSYM to 80 percent to match the NRC 2001 guidelines results in a further decline in the phosphorus levels on the 150 cow farm. This effect is similar to the one in the 50 cow farm and with no changes in levels of nitrogen and potassium.

6.5.1c 400 cow farm ration change strategy effect

Table 6.5.1c Ration change and nutrient balance

Characteristics		**Initial state**	**Post changes**
Total farmland available (acres)		1,018	1,018
Number of total replacement heifers on farm		272	272
Crops grown (acres)	Alfafa	216	216
	Grass	64	64
	Corn	490	490
	Soybean	92	92
	Small grain (Oats)	87	87
Phosphorus feeding level		100 %	80 %
Net nutrient balance (pounds per acre)			
Nitrogen		+ 69.7	+ 69.7
Phosphorus		+ 5.1	+ 1.4
Potassium		+ 17.8	+ 17.8

Table 6.5.1c indicates that the adoption of a ration change with 80 percent user defined feeding level results in a sharp decline in surplus levels of phosphorus. Adoption of only a ration change strategy may help meet the GAAMPs and MAEAP requirements for zero nutrient loadings of phosphorus given existing manure management facilities and practices, however, surplus levels of 55 pounds per acre of nitrogen remains a concern which may require additional nutrient management strategies to be adopted.

6.5.1d 1,000 cows farm ration changes strategy effect

Table 6.5.1d Ration change and nutrient balance

Characteristics		Initial state	Post change
Total land available (acres)		2,500	2,500
Number of replacement heifers		898	898
Crops grown (acres)	Alfalfa	590	590
	Corn	1,380	1,380
Phosphorus feeding level		100 %	80 %
Net nutrient balance (pounds per acre)			
Nitrogen		+122.3	+ 122.3
Phosphorus		+ 6.0	+ 1.2
Potassium		+ 15.0	+15.0

Reducing the total phosphorus feeding level from the initial 100 % to 80 % has a positive improvement in reduction of excessive levels of phosphorus with no net change in the nutrient balance of nitrogen and potassium. Phosphorus levels almost reach zero, which is optimally desired by the GAAMPs recommendations. The results obtained are similar to that of the 400 cow farm and if adopted in isolation, is not sufficient to address the concern of high levels of nitrogen.

6.5.1e 100 cow grazing farm ration changes strategy effect

Table 6.5.1e Ration change and nutrient balance

Characteristics		Initial state	Post changes
Total available farmland (acres)		250.0	250.0
Crops grown (acres)	Alfalfa	25.0	25.0
	Grass	110.0	110.0
	Corn	75.0	75.0
Phosphorus feeding level		100 %	80 %
Net nutrient balance (pounds per acre)			
Nitrogen		+ 47.6	+ 47.6
Phosphorus		+ 2.3	- 0.4
Potassium		+ 9.0	+ 9.0

Table 6.5.1e indicates that reduction in phosphorus levels from the initial 1989 recommendations of the NRC on a 100 cow rotational grazing farm declines minor excessive levels of phosphorus to a deficit of 0.4 pounds per acre or a near balance. This is a result ideally desired for meeting the GAAMPs recommendations however, like in earlier cases of the representative farms, the grazing farm also has surplus nitrogen levels to deal with and reduce to minimal levels.

6.5.2 Overview of adoption of a ration change strategy and nutrient balances

Table 6.6.2 below provides a general summary of the nutrient balances across all five representative dairy farms under this study as a result of adoption of the ration change strategy.

Table 6.5.2 Impact of a ration change strategy on nutrient balances

Characteristics		Herd size				
		50 cows	*150 cows*	*400 cows*	*1,000 cows*	*100 grazing farm*
Nitrogen	Initial	+ 36.7	+ 55.3	+ 69.7	+ 122.3	+ 47.6
	Post adoption	+ 36.7	+ 55.3	+ 69.7	+ 122.3	+ 47.6
	Percent change (%)	0.0	0.0	0.0	0.0	0.0
Phosphorus	Initial	- 5.0	- 4.6	+ 5.1	+ 6.0	+ 2.3
	Post adoption	- 6.2	- 6.3	+ 1.4	+ 1.2	- 0.4
	Percent change (%)	+ 24	+ 57.5	- 72.5	- 80.0	- 101.0
Potassium	Initial	- 45.4	- 25.1	+ 17.8	+ 15.0	+ 9.0
	Post adoption	- 45.6	- 25.0	+ 17.8	+ 15.0	+ 9.0
	Percent change (%)	+ 0.4	0.0	0.0	0.0	0.0

It can be inferred that a reduction in phosphorus feeding level from the user defined initial 100 % to 80 % in the DAFOSYM results in significant reductions in surpluses of phosphorus for the 400, 1000 and 100 cow grazing farms and relatively lesser reductions in surplus for the 50 and 150 cow farms.

6.5.3 Economic analysis of all five representative dairy farms

Similar to the earlier two strategies, a prior and post adoption economic effect of the representative farms is analyzed with the help of five relevant indicators: total farm sales, feed costs, manure costs, other costs and net farm return. Table 6.6.3 on the next page highlights the prior and post changes for all above five indicators in absolute U.S. dollars with a net percentage change.

Table 6.5.3 Economic impact of a ration change adoption

Characteristics		Herd size				
		50 cows	*150 cows*	*400 cows*	*1,000 cows*	*100 grazing farm*
Total farm Sales	Initial	149,321	410,101	1,186,284	3,748,476	211,723
	Post adoption	43,500	410,101	1,186,288	3,108,349	211,725
	Percent change (%)	- 70.8	0.0	+ 0.0003	- 17.0	0.0
Feed costs	Initial	101,455	181,600	521,812	1,178,357	124,452
	Post adoption	101,110	180,741	518,713	1,172,184	124,023
	Percent change (%)	- 0.3	- 0.4	- 0.6	- 0.5	- 0.3
Manure costs	Initial	9,918	18,621	61,148	248,019	16,396
	Post adoption	9,918	18,621	61,139	240,265	16,112
	Percent change (%)	0.0	0.0	- 0.01	- 3.1	- 1.7
Other costs	Initial	55,400	189,725	345,316	1,135,220	159,214
	Post adoption	55,400	167,231	565,316	1,135,220	159,214
	Percent change (%)	0.0	- 11.8	+ 63.7	0.0	0.0
Net return	Initial	22,058	158,277	482,302	1,427,055	39,817
	Post adoption	22,403	159,136	485,413	1,440,983	40,532
	Percent change (%)	+ 1.5	+ 0.5	+ 0.6	+ 0.9	+ 1.7

Table 6.5.3 provides summarized results from the DAFOSYM due to the adoption of a ration change strategy shows cost of adoption is more or less size neutral. Average increase in net farm return across all five representative farms is 1.04 percent. It is obvious that if there was any farm with initially, zero or significantly low levels of excess nitrogen, adopting such a strategy with NRC 2001 guidelines for feeding phosphorus may not just turn out economically profitable but also beneficial to nutrient management on the farm.

6.6 Crop mix and removal of replacement heifer

A management strategy of integrating alternative cropping mix with removal of replacement heifers was the fourth strategy considered for seeking nutrient balance due to its increased effectiveness in reducing excess nutrients as compared to a dual strategy of crop changes and ration change with NRC 2001 recommended phosphorus levels. In the following sub sections we evaluated the effect of the adoption of such a dual strategy across all five representative farms.

6.6.1a 50 cow farm crop mix and removal of heifer strategy effect

Table 6.6.1a Crop mix and removal of heifers and nutrient balance

Characteristics		**Initial state**	**Post changes**
Total available farmland (acres)		312.0	312.0
Number of replacement heifers		44.0	0.0
Crops grown and number of acres	Alfalfa	146.0	78.0
	Corn	91.0	159.0
	Small grain (Oats)	29.0	29.0
	Pasture	18.0	18.0
Feeds sold (tons)	Alfalfa haylage	167.0	80.5
	Alfalfa hay	108.6	57.2
	Corn silage	74.3	99.1
	High moisture corn grain	0.0	0.0
	Corn grain	0.0	32.8
Feeds purchased	Corn grain	50.8	0.0
Total net feeds (tons of DM)		459	312
Net nutrient balance (pounds per acre)			
Nitrogen		+ 36.7	+ 11.4
Phosphorus		- 5.0	- 3.8
Potassium		- 45.4	- 28.5

Adopting a corn to alfalfa one to three strategies with a ration change consisting of a decline in phosphorus content in feeds from 100 % to 80 % resulted in nitrogen levels to drop significantly, to more than half, and phosphorus and potassium levels improve towards zero. There seemed to be a higher efficiency in utilization of feeds with a reduction in total dry matter fed to the cows.

6.6.1b 150 cow farm crop mix and removal of heifer strategy effect

Table 6.6.1b Crop mix and removal of heifers and nutrient balance

Characteristics		**Initial state**	**Post changes**
Total available farmland (acres)		600	600
Number of replacement heifers		129	0
Crops grown (acres)	Alfalfa	303	187
	Corn	263	412
	Soybean	102	102
	Small grain (Oats)	32	32
Feeds purchased	Alfalfa hay	177.7	0.0
Feeds sold	Alfalfa hay	115.4	158.6
	Alfalfa haylage	177.7	142.1
	Corn silage	34.7	82.2
	Corn grain	74.4	247.5
	High moisture corn	0.0	0.0
Total net feeds (tons of DM)		1,493	1,081
Net nutrient balance (pounds per acre)			
Nitrogen		+ 55.3	+ 21.8
Phosphorus		- 4.6	- 5.7
Potassium		- 25.1	- 32.3

A dual strategy of crop mix and removal of heifers by the 150 cow farm proved effective as nitrogen levels reduce from an initial surplus of 55.3 pounds per acre to 21.8. Phosphorus and potassium levels declined further in deficit levels thus making the combined strategy adoption relatively effective. Additional land or other manure management alternatives may help tackle and alleviate the remaining excess levels of nitrogen on the farm and help ensure a nutrient balance.

6.6.1c 400 cow farm crop mix and removal of heifer strategy effect

Table 6.6.1c Crop mix and removal of heifers and nutrient balance

Characteristics		Initial state	Post changes
Total available farmland (acres)		1,018	1,018
Number of replacement heifers		272	0
Crops grown (acres)	Alfalfa	216	233
	Grass	64	64
	Corn	490	470
	Oats	92	92
	Soybeans	87	87
Total net feeds (tons of DM)		3,744	2,894
Net nutrient balance (pounds per acre)			
Nitrogen		+ 69.7	+ 51.5
Phosphorus		+ 5.1	+ 2.1
Potassium		+ 17.8	- 10.2

Removal of 272 heifers in combination with a crop mix as reviewed previously had a moderately positive impact on reducing excessive levels of nitrogen and phosphorus. On site phosphorus levels reached a near nutrient balance with zero excess loading, and potassium declined into deficits. Keeping total available farmland constant and distribution of crops other than alfalfa and corn constant, such a strategy may not be effective by itself so as to meet GAAMPs recommendations for managing manure nutrients.

6.6.1d 1000 cow farm crop mix and removal of heifer strategy effect

Table 6.6.1d Combination of a crop mix and removal of replacement heifers

Characteristics		Initial state	Post change
Total land available (acres)		2500	2,500
Number of replacement heifers		898	0
Crops grown (acres)	Alfalfa	590	657
	Corn	1,380	1,313
Feeds purchased	Corn grain	1,931	1,862
	Alfalfa hay	963.3	0.0
Feeds sold	Alfalfa haylage	112.8	991.5
	Alfalfa hay	0.0	0.0
	Corn silage	0.0	800.2
Total net feeds (tons of DM)		10,094	7,582
Net nutrient balance (pounds per acre)			
Nitrogen		+122.3	+ 87.5
Phosphorus		+ 6.0	- 2.4
Potassium		+ 15.0	- 43.6

From Table 6.6.1d it is clear that adoption of the dual strategy by the largest size farm in this study, the 1000 cow farm had a result similar to that of the 400-cow farm. With significant reductions in excessive levels of nitrogen, and phosphorus and potassium attaining a balance, the farm may be better off, if the remaining excess levels of nitrogen are managed additional land or other management practices.

6.6.1e 100 grazing farm crop mix and removal of heifer strategy effect

Table 6.6.1e Crop mix and removal of heifers and nutrient balance

Characteristics		**Initial state**	**Post changes**
Total available farmland (acres)		250.0	250.0
Number of replacement heifers		85	0
Crops grown (acres)	Alfalfa	25.0	46.0
	Grass	110.0	110.0
	Corn	75.0	94.0
Feeds purchased	Alfalfa hay	45.8	124.6
	Corn grain	91.6	45.0
Feeds sold	Alfalfa haylage	5.6	51.1
	Alfalfa hay	40.4	82.8
	Corn silage	9.7	157.2
	High moisture corn	2.0	0.0
Total net feeds (tons of DM)		874.0	636.0
Net nutrient balance (pounds per acre)			
Nitrogen		+ 47.6	+ 34.2
Phosphorus		+ 2.3	- 2.6
Potassium		+ 9.0	- 30.8

The 100 cow rotational grazing farm experienced a marginal improvement in its nitrogen levels while the phosphorus and potassium levels reached deficit levels which are not a concern. It may be possible for the 100 cow rotational grazing operator to manage nitrogen surplus but may have to ensure other nutrients to not unmanageable levels of surplus. Possible prevention of runoff from manure storage with better manure storage systems may also help towards reducing the excessive levels.

6.6.2 Adoption of a crop mix and heifer removal strategy and nutrient balances

Table 6.6.2 Impact of crop mix and heifer removal on nutrient balances

Characteristics		Herd size				
		50 cows	*150 cows*	*400 cows*	*1,000 cows*	*100 grazing farm*
Nitrogen	Initial	+ 36.7	+ 55.3	+ 69.7	+ 122.3	+ 47.6
	Post adoption	+ 11.4	+ 21.8	+ 51.5	+ 87.5	+ 34.2
	Percent change (%)	+ 70.0	- 60.5	- 26.1	- 28.5	- 28.1
Phosphorus	Initial	- 5.0	- 4.6	+ 5.1	+ 6.0	+ 2.3
	Post adoption	- 3.8	- 5.7	+ 2.1	- 2.4	- 2.6
	Percent change (%)	+ 24.0	+ 24.0	- 58.8	- 140.0	- 256
Potassium	Initial	- 45.4	- 25.1	+ 17.8	+ 15.0	+ 9.0
	Post adoption	- 28.5	- 32.3	- 10.2	- 43.6	- 30.8
	Percent change (%)	+ 37.2	+ 28.6	- 157.0	- 390.0	- 442.0

Table 6.6.2 outlines a broad summary state of prior and post adoption levels of manure nutrients, primarily, nitrogen, phosphorus and potassium for a crop mix and removal of replacement heifer strategy. The table reveals that the strategy was most effective for the 50, 150 and 1000 cow farms in alleviating surplus levels of nitrogen and was also extremely successful in bringing surplus phosphorus into balance across all herd sizes.

6.6.3 Economic review of adopting crop mix and heifer removal strategy

Table 6.6.3 on the next page provides a broad overview of the economic impact of adoption of a crop mix and removal of heifer's management strategy.

Table 6.6.3 Economic analysis

Characteristics		Herd size				
		50 cows	*150 cows*	*400 cows*	*1,000 cows*	*100 grazing farm*
Total farm sales	Initial	149,321	410,101	1,186,284	3,748,476	211,723
	Post adoption	135,865	425,770	1,202,474	3,249,127	226,045
	Percent change (%)	- 9.0	+ 3.8	+ 1.3	- 13.3	+ 6.7
Feed costs	Initial	101,455	181,600	521,812	1,178,357	124,452
	Post adoption	96,575	191,118	476,420	1,053,266	112,173
	Percent change (%)	- 4.8	+ 5.2	- 8.6	- 10.6	- 9.8
Manure costs	Initial	9,918	18,621	61,148	248,019	16,396
	Post adoption	7,639	13,879	50,464	179,580	11,336
	Percent change (%)	- 23.0	- 25.4	- 17.4	- 27.5	- 30.8
Other costs	Initial	55,400	189,725	345,316	1,135,220	159,214
	Post adoption	76,400	252,125	696,566	1,555,189	201,214
	Percent change (%)	+ 27.4	+ 32.8	+ 101.7	+ 37.0	+ 26.3
Net return	Initial	22,058	158,277	482,302	1,427,055	39,817
	Post adoption	- 4,169	106,458	432,850	1,290,011	28,840
	Percent change (%)	- 118.9	- 32	- 10.2	- 9.6	- 27.5

The table indicates that an adoption cost of such a management alternative to help alleviate excessive levels of nutrtients is not size neutral. The 50 and 150 cow farms experience significant reductions in their net farm return due to high costs of purchasing replacement heifers from external sources, in addition to other rising miscellaneous costs. The 1,000 cow farm experienced the least reduction in net farm return.

6.7 Combination of crop mix, removal of replacement heifers and ration change

The final of the five selected strategies consist of evaluating the effect of an integrated adoption of changes in crop mix, ration reformulation, and removing the replacement heifer enterprise from the farm enterprise.

6.7.1a 50 cow farm effect of crop mix, removal of heifers and ration change

Table 6.7.1a Adoption of integrated strategy and nutrient balance

Characteristics		**Initial state**	**Post changes**
Total available farmland (acres)		312.0	312.0
Number of replacement heifers		44	0
Crops grown and number of acres	Alfalfa	146.0	78.0
	Corn	91.0	159.0
	Small grain (Oats)	29.0	29.0
	Pasture	18.0	18.0
Feeds sold (tons)	Alfalfa haylage	167.0	80.5
	Alfalfa hay	108.6	57.2
	Corn silage	74.3	99.1
	High moisture corn grain	0.0	0.0
	Corn grain	0.0	32.8
Feeds purchased	Corn grain	50.8	0.0
Total net feeds (tons of DM)		459	312
Phosphorus feeding level		100 %	80 %
Net nutrient balance (pounds per acre)			
Nitrogen		+ 36.7	+ 11.3
Phosphorus		- 5.0	- 3.9
Potassium		- 45.4	-28.5

Table 6.7.1a reveals the adoption of an integrated approach of combining crop mix, moving the replacement heifer enterprise to a custom grower and ration reformulation on a 50 cow dairy farm resulted in nitrogen within a close range of balance. Deficits of phosphorus and potassium may be met with additional commercial fertilizer at an appropriate agronomic rate. A reduction in total land available for growing alfalfa results in lower amount of alfalfa hay and haylage sold as feeds. Thus

the farm may only need to invest in addition six-month manure storage systems and not consider additional land investments.

6.7.1b 150 cow farm crop mix, removal of heifers and ration change effect

Table 6.7.1b Adoption of integrated strategy and nutrient balance

Characteristics		Initial state	Post changes
Total available farmland (acres)		600	600
Number of replacement heifers		129	0
Crops grown (acres)	Alfalfa	303	187
	Corn	263	412
	Soybean	102	102
	Small grain (Oats)	32	32
Feeds purchased	Alfalfa hay	177.7	0.0
Feeds sold	Alfalfa hay	115.4	158.6
	Alfalfa haylage	177.7	142.1
	Corn silage	34.7	82.2
	Corn grain	74.4	247.5
	High moisture corn	0.0	0.0
Total net feeds (tons of DM)		1,493	1,081
Phosphorus feeding level		100 %	80%
Net nutrient balance (pounds per acre)			
Nitrogen		+ 55.3	+ 21.8
Phosphorus		- 4.6	- 6.9
Potassium		- 25.1	- 32.3

Adoption of the integrated strategy by the 150 cow farm consisting of crop mix, ration reformulation and raising of no replacement heifers on the farm reduced surplus nitrogen by more than half. Phosphorus and potassium levels did not prove to be nutrients of concern. If the dairy operator adopted this strategy, there may be some investments to be made into the purchase of/lease in land for manure application so as to meet GAAMPs recommendations. Possible fitting in of a six-month manure storage system is the only additional cost required by the farm and it is evaluated in the next chapter.

6.7.1c 400 cow farm crop mix, removal of heifers and ration change effect

Table 6.7.1c Adoption of integrated strategy and nutrient balance

Characteristics		Initial state	Post changes
Total available farmland (acres)		1,018	1,018
Number of replacement heifers		272	0
Crops grown (acres)	Alfalfa	216	233
	Grass	64	64
	Corn	490	470
	Oats	92	92
	Soybeans	87	87
Total net feeds (tons of DM)		3,744	2,894
Phosphorus feeding level		100 %	80%
Net nutrient balance (pounds per acre)			
Nitrogen		+ 69.7	+ 51.2
Phosphorus		+ 5.1	- 1.2
Potassium		+ 17.8	- 10.2

DAFOSYM simulated results from the above Table 6.8.1c show the effect of adoption of an integrated approach of crop mix, no replacement heifers and a decline in phosphorus feeding level on a 400 cow farm. There is marginal reduction in nitrogen levels, and final net nutrient results indicate the dairy operator to possibly consider acquiring additional land through direct ownership or leasing in of more land in addition to the adoption of a six-month manure storage system at the minimum. These manure management changes might involve costs that are assessed in the next chapter.

6.7.1d 1,000 cow farm crop mix, removal of heifers and ration change effect

Table 6.7.1d Adoption of integrated strategy and nutrient balance

Characteristics		Initial state	Post change
Total land available (acres)		2,500	2,500
Number of replacement heifers		898	0
Crops grown (acres)	Alfalfa	590	657
	Corn	1,380	1,313
Feeds purchased	Corn grain	1,931	1,862
	Alfalfa hay	963.3	0.0
Feeds sold	Alfalfa haylage	112.8	991.5
	Alfalfa hay	0.0	0.0
	Corn silage	0.0	800.2
Total net feeds (tons of DM)		10,094	7,582
Phosphorus feeding level		100 %	80 %
Net nutrient balance (pounds per acre)			
Nitrogen		+122.3	+ 87.5
Phosphorus		+ 6.0	- 4.5
Potassium		+ 15.0	- 43.0

An integrated approach of crop mix, ration reformulation and reducing replacement heifers to zero, showed a reasonable decline in nutrient levels of nitrogen and reduced excess phosphorus to a deficit. Increasing the proportion of corn grown as compared to alfalfa results in no forages purchased. The 1,000 cow farm may require investing in more land either though a lease arrangement or a purchase and thus ensuring compliance with GAAMPs recommendations. In addition, possession of more land may also make manure management manageable as a result of potential herd expansion plans.

6.7.1e 100 cow grazing farm crop mix, removal of heifers and ration change effect

Table 6.7.1e Adoption of integrated strategy and nutrient balance

Characteristics		Initial state	Post changes
Total available farmland (acres)		250.0	250.0
Number of replacement heifers		85	0
Crops grown (acres)	Alfalfa	25.0	46.0
	Grass	110.0	110.0
	Corn	75.0	94.0
Feeds purchased	Alfalfa hay	45.8	124.6
	Corn grain	91.6	45.0
Feeds sold	Alfalfa haylage	5.6	51.1
	Alfalfa hay	40.4	82.8
	Corn silage	9.7	157.2
	High moisture corn	2.0	0.0
Total net feeds (tons of DM)		874.0	636.0
Phosphorus feeding level		100 %	80%
Net nutrient balance (pounds per acre)			
Nitrogen		+ 47.6	+ 34.2
Phosphorus		+ 2.3	- 5.8
Potassium		+ 9.0	- 28.0

Incorporation of all changes with no replacement heifers resulted in final net nutrient balance to improve for nitrogen from existing initial levels of 47.6 pounds per acre to 34.2. Post adoption net phosphorus and potassium levels were in deficit thus growing more of corn or acquiring additional land with a six month storage system are the feasible options for future managerial consideration.

6.7.2 Review of nutrient balances

Table 6.7.2 Impact of crop mix, heifer removal and ration change on nutrient balances

Characteristics		Herd size				
		50 cows	*150 cows*	*400 cows*	*1,000 cows*	*100 cow grazing farm*
Nitrogen	Initial	+ 36.7	+ 55.3	+ 69.7	+ 122.3	+ 47.6
	Post adoption	+ 11.3	+ 21.8	+ 51.2	+ 87.5	+ 34.2
	Percent change (%)	+ 69.0	- 60.5	- 26.5	- 28.4	- 28.1
Phosphorus	Initial	- 5.0	+ 4.6	+ 5.1	+ 6.0	+ 2.3
	Post adoption	- 3.9	- 6.9	- 1.2	- 4.5	- 5.8
	Percent change (%)	+ 22.0	+ 50.0	- 123	- 175	- 352
Potassium	Initial	- 45.4	+ 25.1	+ 17.8	+ 15.0	+ 9.0
	Post adoption	- 28.5	- 32.3	- 10.2	- 43.0	- 28.0
	Percent change (%)	+ 37.2	+ 78.0	- 157	- 386.6	- 211

Adopting a combined strategy with a crop change, reduction in phosphorus feeding level to 80 percent as per the NRC guidelines and removal of replacement heifers from the enterprise resulted in significant reductions in excessive levels of nitrogen. The managerial alternative also proved effective in ensuring phosphorus balance across all representative farms. From a nutrient management perspective, such a strategy may be most beneficial particularly to the smaller herd size dairy farms and the 100 cow grazing farm.

6.7.3 Economic impact of adoption of integrated strategy

Table 6.7.3 Economic analysis

Characteristics		Herd size				
		50 cows	*150 cows*	*400 cows*	*1,000 cows*	*100 grazing farm*
Total farm sales	Initial	149,321	410,101	1,186,284	3,748,476	211,723
	Post adoption	135,866	425,771	1,202,478	3,249,140	226,047
	Percent change (%)	- 9.0	+ 3.8	+ 1.3	- 13.3	+ 7.0
Feed costs	Initial	101,455	181,600	521,812	1,178,357	124,452
	Post adoption	96,574	190,535	473,597	1,048,110	111,597
	Percent change (%)	- 4.8	+ 5.0	- 9.2	- 11.0	- 10.3
Manure costs	Initial	9,918	18,621	61,148	248,019	16,396
	Post adoption	7,638	13,878	50,464	179,580	11,336
	Percent change (%)	- 23.0	- 25.6	- 17.4	- 27.5	- 30.8
Other costs	Initial	55,400	189,725	345,316	1,135,220	159,214
	Post adoption	76,400	252,126	432,916	1,555,220	201,214
	Percent change (%)	+ 38.0	+ 32.8	+ 25.3	+ 37.0	+ 26.4
Net return	Initial	22,058	158,277	482,302	1,427,055	39,817
	Post adoption	- 4,166	107,044	435,656	1,786,853	29,417.5
	Percent change (%)	- 118.0	- 32.3	- 9.6	+ 25.1	- 26.1

The above table yields results that are similar to the one observed in the fourth management strategy. Cost of adopting an integrated strategy as discussed previously, was found not to be size neutral and has the most serve negative impact to the smaller or the 50, 150 and 100 cow grazing representative farms. Other costs including the cost of purchasing replacement heifers from an external source or supplier may have added to the total costs and as a result offset the decline in feed costs for few of the farms. The integrated strategy proved to be most economically profitable to the 1,000 cow farm with net farm return gains of 25 percent.

6.8 Conclusions

This chapter presents an evaluation of adoption of five management strategies on the representative farms. The main goal of the analysis was to seek a nutrient balance and in the process track total feeds produced, sold, feeds and manure costs and finally the net nutrient balance due to the adoption of five management strategies selected based on existing literature and ongoing studies. The 50 and 150 cow farm shows a nutrient balance with no existing storage systems, meeting minimum GAAMPs guidelines. Thus, the 50 and 150 cow conventionally managed farms need to invest in additional land however, unlike the 400 and 1000 cow farms they must invest in setting up a six month storage facility to prevent manure runoff and leakage. The 400 and 1,000 cow-milking farms need additional land due to surplus levels of nitrogen and phosphorus even after the adoption of the five management strategies.

Economic analysis of the five farms shows costs of adoption of all strategies except for the ration change one, are size sensitive. The integrated strategy of a crop mix, removal of replacement heifers and ration change resulting economic profits or positive increase in net farm return for only the 1,000 cow farm due to possible herd size and technological advantage over the other farms.

Chapter 7: Capital Asset Investment and Control

The previous chapter evaluated adoption costs of key nutrient management strategies for five representative farms participating in the MAEAP. A significant finding from the previous chapter was that the farms with large herd size could not balance existing nutrients levels using current available land base.

In this chapter, post-strategy adoption nutrient levels of nitrogen in particular, for the five representative farms are used to determine the additional land required to alleviate nutrient imbalances. We assume the acquired land will be used for growing corn grain. Control of land for manure application in the form of purchase, lease, or a formal agreement that allows manure application is evaluated. Finally, the cost of installing a short-term manure storage facility to prevent manure runoff and seepage losses are examined.

7.1 Control of land for manure application

Direct purchase of additional land means that financial capital be invested in land. Potential advantages of land purchase include managerial independence and freedom, and providing a hedge against inflation (Kay and Edwards,1999). However control of land in the form of ownership also has disadvantages. Land may yield a low return to capital invested, require a large debt, and reduce cash flow.

Leasing of additional land is commonly used practice to control land. Financially, a lease may prove more cost effective than a purchase if the annual cost of leasing land is lower than ownership costs. Factors that determine lease costs consist of type of lease, time period of lease, and geographical location of land. For this study, we assume the farmer will use a cash rental agreement.

A mutual agreement, either formal or informal, with a crop producer is the third option to meet the nutrient balance requirement. A mutual agreement between the dairy operator and a crop producer may also include the dairy operator purchasing feed crops.

Distance between the site of manure production and collection and the site of application onto land may influence costs of manure management. A study evaluating this aspect using the DAFOSYM software has been reviewed earlier (from chapter three).

7.2 Land requirements

In order to determine additional land required for managing nitrogen surplus, the total acreage needed to achieve a nitrogen balance for the representative farms is estimated. Corn grain has a nitrogen removal rate of 0.9 bushel per ton. Since alleviating the nitrogen imbalance on the farms also removed any surplus phosphorus, the focus of this analysis is nitrogen.

The additional land required to bring the surplus nitrogen on the representative farms to zero (nitrogen balance) is calculated as:

$$\text{Additional land required (acres)} = \frac{\text{Excess manure nutrients (lbs/acre)}}{\text{Yield (bu/acre)*Removal rate (lbs/bu)}}$$

Additional land required for ensuring a nutrient balance of nitrogen is determined on the basis of three strategies and these are: "initial state", "best nutrient", and "best income." The "initial state" strategy is the nitrogen surplus levels prior to adoption of any management changes (from chapter five). The "best nutrient" strategy consists of the combination of strategies that resulted in least net nitrogen surplus. The "best income" strategy across all representative farms is one that resulted in nitrogen level form strategies that yields the highest net farm income.

Table 7.1 displays the strategies adopted and resulting nitrogen levels. This information is used below to calculate the additional land required by each farm.

Table 7.1 Summary of nutrient management strategies and final nitrogen levels

Herd size	Management changes adopted	Net nitrogen levels (lbs/acre)
50 cow farm	Initial state	36.7
	Crop mix	19.9
	Removal of heifers	27.4
	Ration change	36.7
	Crop mix and no heifers	11.4
	Crop mix, ration change and no heifers	11.3
150 cow farm	Initial state	55.3
	Crop mix	37
	Removal of heifers	40.2
	Ration change	55.3
	Crop mix and no heifers	21.8
	Crop mix, ration change and no heifers	21.8
400 cow farm	Initial state	69.7
	Crop mix	71.4
	Removal of heifers	50.0
	Ration change	69.7
	Crop mix and no heifers	51.5
	Crop mix, ration change and no heifers	51.2
1,000 cow farm	Initial state	122.3
	Crop mix	125.1
	Removal of heifers	84.6
	Ration change	122.3
	Crop mix and no heifers	87.5
	Crop mix, ration change and no heifers	87.5
100 cow grazing farm	Initial state	47.7
	Crop mix	54.0
	Removal of heifers	20.1
	Ration change	47.6
	Crop mix and no heifers	34.2
	Crop mix, ration change and no heifers	34.2

Based on these management changes and their respective net surplus levels of nitrogen Table 7.2 estimates the additional land required, rounded to the nearest acre, for the farms to utilize all remaining surplus nitrogen.

Table 7.2 Additional land requirements for excess manure disposal*

Herd size and strategy adopted		Additional acres of land required (acres)
50 cow farm	Initial state	76
	Best nutrient strategy	24
	Best income strategy	76
150 cow farm	Initial state	226
	Best nutrient strategy	89
	Best income strategy	226
400 cow farm	Initial state	472
	Best nutrient strategy	338
	Best income strategy	483
1,000 cow farm	Initial state	2,258
	Best nutrient strategy	331
	Best income strategy	1,616
100 cow grazing farm	Initial state	109
	Best nutrient strategy	34
	Best income strategy	85

*Removal rate is based on the assumption that all additional land is used to produce corn (removal rate = 0.9 lbs of lb/bu) and average yield used is 130 bu/acre.

Table 7.3 provides expenses based on the managerial choice of three possible strategies, initial state strategy, best nutrient strategy or best income strategy assuming a price of $1,459 per acre of land if purchased and $75 per acre if rented (Hanson and Schwab).

Table 7.3 Total land required, costs of purchased and leased land

Herd size and strategy adopted	Additional land required (acres)	If purchased[1] ($)	Monthly mortgage Payments[3] ($)	If leased[2] ($)
50 cow farm				
Initial state	76.1	111,029	815	5,707
Best nutrient strategy	23.4	34,140	250	1,755
Best income strategy	76.1	111,029	815	5,707
150 cow farm				
Initial state	226	329,734	2,419	16,950
Best nutrient strategy	89.2	130,143	955	6,690
Best income strategy	226.2	330,026	2,422	16,965
400 cow farm				
Initial state	472	688,648	5,053	35,400
Best nutrient strategy	338.4	493,726	3,623	25,380
Best income strategy	483	704,697	5,171	36,225
1000 cow farm				
Initial state	2,258	3,294,422	24,173	169,350
Best nutrient strategy	331	482,929	3,543	24,825
Best income strategy	1,616	2,357,744	1,728	121,200
100 cow grazing farm				
Initial state	109	159,031	1,167	8,175
Best nutrient strategy	34	49,606	364	2,550
Best income strategy	84.5	123,285.5	905	6,337.5

[1] Purchase is estimated at $1,459 per acre using 8% interest rate over 360 months.
[2] Annual lease rate is $ 75 per acre.
[3] Annual mortgage payment estimates are taken from Agstar Financial Services Inc.

Using a 30 year loan period and 8 percent rate of interest over 360 months, annual cost of renting is provided in Table 7.3. The mortgage payments were calculated with internet services of Agstar Financial Services Inc (http://www.agstar.com/cgi-bin/users/agstar/loan/calc_straight.pl). Since the aim of this study is to seek the minimum cost for being in balance, primarily nitrogen and phosphorus, we assume the final adopted strategy is the one that requires the least additional farmland. Thus, we expect the 50 cow farm to adopt the "best nutrient strategy" that involves additional control of 23.4 acres of land. This choice means an investment of $34,140 in principal if the farmer decides to purchase or $1,755 per year to rent. The 150 cow farm needs an additional 89.2 acres of land to ensure a farm nutrient balance and thus a total principal investment of $130,143 or $6,690 per year if rented. Seeking a minimum investment costs for control of land, indicates the 400 cow operator will opt in favor of the "best nutrient strategy" resulting in principal land purchase cost of $493,726 or annual rental payments of $6,690. Similarly, the 1,000 cow farm adopts a "best nutrient strategy" resulting in an expense of $482,929 or an annual rental payment of $24,825 for 331 acres of land so as to achieve a nutrient balance. The last farm in the study, or the 100 cow rotational grazing farm requires an additional 34 acres of land as a result of adopting the "best nutrient strategy" which requires lesser farmland as compared to the "best income strategy". As a result, all five representative farms in this study may prefer to opt for the "best nutrient strategy."

If the farms decide to control additional land through a rental for growing corn, an average yield of 130 bushels per acre and a market sale price of $2.10 per bushel would provide cash revenues of $273 per acre. With annual lease costs of $75 per acre breakeven cost is then $198 per acre. This is higher than cash costs from the Michigan State University 2001 Budget Book (Dartt and Schwab) cost but is lower than economic costs on dairy farms (Harsh, Wolf and Wittenberg). The ultimate decision to purchase or lease land depends on a number of factors. These factors are: the amount of land used for manure application, revenues earned from the sale of corn, cost savings arising out use of manure as a fertilizer, labor and other managerial expenses, and cost of mortgage or rental payments.

The attractiveness of a mutual agreement for manure application depend on the location of the dairy farm and crop producing farmland and the distance between the two farms, existing soil conditions and fertility levels, and neighbor relations.

7.2 Storage investments

It is assumed that all the five representative farms have adequate vegetative buffer strips and filters to prevent runoff and groundwater discharge of manure. In addition, it was also assumed the smaller dairy farms, the 50 cow and 150 conventionally managed dairy farms, and the 100 cow rotational grazing farm possess no permanent manure storage facilities. The 400 and 1,000 cow conventionally managed farms have a long-term manure storage system in place and these costs have been included in the total manure management costs.

Under the EPA regulations, designated CAFOs are required to have permanent manure storage facilities to prevent only manure runoff from any leakage or 24-hour flood. The MAEAP and GAAMPs do not call for mandatory manure storage facilities. However, a minimum six-month storage facility is suggested. We analyze the minimum, the 50 and 150 cow conventional dairy farms and 100-cow rotational grazing farm using a capital budget.

An earthen storage pit is simply a lagoon dug in the earth while a clay-lined pit is the same earthen pit but with an additional three inch lining of clay. A clay lining is more expensive than a earthen lagoon, however, clay lining helps reduce and possibly also prevent any seepage of manure into the soil. These investment costs into storage are determined using four data sources running software called the Capital Investment Model

(CIM), developed by Harsh and Phillips, Department of Agricultural Economics, Michigan State University. The four data sources used for the computation of net investment costs in a partial budgeting framework include:

- **Garsow (1990)**

  Prices of short-term earthen and clay lined manure storage pits using data made available from the thesis of Jim Garsow. These cost estimates are from 1990, so they have been adjusted for inflation using the Farmer's Price Productivity Index (NASS, 2000) for building and equipment price category.

- **Kammel, and Brannstrom (2001)**

  Cost estimates of manure storage from 350 dairy farms from the midwestern region (Minnesota, Michigan, Iowa and Wisconsin) over a five year period 1995-2000. Total cost of manure storage in an earthen pit was estimated using the formula:

  *Total cost of earthen manure storage = $0.02 * Total number of gallons produced.*

  The cost estimate of earthen manure storage pit for a 100 cow grazing farm is assessed from the amount of manure collected as a result of the six months of non-grazing period.

- **DAFOSYM**

  Economic costs estimate due to installation of clay lined storage pit for six month period is used from the simulation software DAFOSYM's manure module.

- **Natural Resource Conservation Service (NRCS)**

  Installation cost estimates of clay lined manure storage for the 50 cow, 150 cow and 100 cow-grazing farm are used from Michigan's NRCS sources. These estimates are currently also being used by the NRCS to assist dairy farmers in Michigan with nutrient management planning.

7.3 Capital Investment Model

The Capital Investment Model (CIM) software was developed to assess financial feasibility of farm investments. An annual cost of investing in manure storage facility is estimated with the help of two types of information: cost saving or income producing information and investment and operating cost related information.

Cost saving and income producing information includes the percent of investments to be absorbed or factored into assessing the cost of financing the investment in the first year to determine the feasibility of the farm to finance the investment, considering the available cash inflow of the farm.

Investment and operating cost related information includes information on the initial total amount or expected cost of investment, number of years the machinery or a structure is expected to last, rates of interest on credit taken, and the percentage of down payment, method, rate and number of years of depreciation, and salvage value. Operating costs consist of maintenance costs, labor, fuel and energy costs. An appropriate tax rate depending upon the bracket of farm income the farm operator is also utilized.

For this study, the CIM software is used to analyze investment in a six-month earthen manure storage facility on a breakeven return basis. The investment is evaluated over 15 years. Advanced Straight Line (ADS) form of depreciation is used. Annual depreciation costs are not factored into the operating cost because depreciation is treated as a non-cash but tax deductible expense (Harsh, Connor and Schwab). Based on commonly used investment financing practices on Michigan dairy farms, a half yearly convention for depreciation is used with a repayment period of loan of seven years at nine percent rate of interest. The average cost of fuel and other energy sources is assumed at $5 per hour and labor compensation, including other fringe benefits is fixed at $12 per hour. The values are those used in the DAFOSYM for economic impact evaluation of nutrient management strategies. Since all three representative farms fall in a total 36 percent tax liability category, 36 percent is entered in as the tax rate that includes the farm income state, federal and social security taxes. For each half of the years of investment, a typical rate of 9.7 percent rate of return on the investment financed is selected. Based on all above information, running the tool provides an annualized cost per cow as reviewed below. However, these costs do not include any manure handling and equipment costs.

7.3.1 Manure storage investment costs

Tables 7.4 to7.9 display total initial investment costs, expected cost per cow, and net annualized cost per cow using the CIM software for a clay lined and non-clay lined storage pit. Any cost estimates prior to year 2000, are indexed to factor in inflation.

7.3.2 50 cow farm manure storage investment

Tables 7.4 and 7.5 review economic costs of total investment and final net cost per cow, assuming fifty percent debt based financing for investing into the asset.

Table 7.4 Economic costs of earthen storage pit for 50 cow farm

Data source	Total investment ($)	Initial cost per cow ($)	Annualized cost per cow ($)
Garsow	23,456	469	81.5
Center for Dairy Profitability	18,650	373	69.2

It can be seen that between the two available data sources, the earthen pit is estimated at either $81.50 with 70 percent of being fixed costs or $69.2 with 69 percent as ownership costs and remaining costs for each being overhead maintenance costs.

Table 7.5 Costs of clay-lined manure storage for 50 cow farm

Data source	Total investment ($)	Initial cost per cow ($)	Annual CIM based cost per cow ($)
Garsow	34,526	690	110
DAFOSYM	39,600	792	123
NRCS	58,000	1,160	170

Choosing a clay-lined three inch pit provides the 50 cow farm operator increased reliability of better manure storage and lesser potential for groundwater seepage of manure nutrients, but the annual economic cost per cow for financing the investment for using a clay lined pit for an average of 15 years are higher than earthen lined pit. The cost per cow on an annual basis ranges from $110 and $123 to $170.

7.3.3. 150 cow farm manure storage investment

Table 7.6 Investment costs for earthen manure storage pit for 150 cow farm

Data Source	Total investment ($)	Initial cost per cow ($)	Annual CIM based cost per cow ($)
Garsow	33,794	225.30	50
Center for Dairy Profitability	28,050	187	45

If $50 per cow of annual investment for 15 years is undertaken the operator would have $29.50 worth of fixed ownership costs and remaining cost for maintenance of the asset under control. The other estimate is to spend $45 per cow annually with $24 as ownership costs and $21 as maintenance costs.

Table 7.7 Cost of financing a clay lined manure storage pit for the 150 cow farm

Data source	Total investment ($)	Initial cost per cow ($)	Annual CIM based cost per cow ($)
Garsow	48,190	329	62
DAFOSYM	48,333	322	62
MI-NRCS	97,000	970	104

Installation of a three-inch clay lined pit provides the 150 cow conventionally managed representative dairy farm with costs per cow as shown above in Table 7.7. The data sources from Garsow and DAFOSYM after computation of the CIM based net investment costs are similar at $62 with 67 percent of it being ownership costs. The cost estimates from NRCS sources are higher at $104 per cow on an annual basis however with 80 percent of these costs being fixed asset ownership costs.

7.3.4 100 cow grazing farm manure storage investment

Similar to the earlier two cases, for the 100 cow rotational grazing farm, economic costs are estimated using the CIM software for earthen storage and then a clay lined pit.

Table 7.8 Investment costs for earthen manure storage

Data source	Total investment ($)	Initial cost per cow ($)	Annual CIM based cost per cow ($)
Garsow	28,625	286.2	58
Center for Dairy Profitability	23,350	233.5	51

Table 7.8 above reveal the net CIM based annual investment cost per cow if the 100 cow grazing chooses a regular earthen manure storage pit for 180 days period. There

is a difference in costs by about $7 between the two data sources. Garsow's data based inflation indexed costs amounts to $58 per cow with 65 percent being ownership costs annually however, if cost estimates of Center for Dairy Profitability is considered, net annual investment costs is $51 per cow with 60 percent as fixed asset ownership costs.

Table 7.9 Investment costs for clay lined manure storage pit

Data source	Total investment ($)	Initial cost per cow ($)	Annual CIM based cost per cow ($)
Garsow	41,358	414.0	74.0
DAFOSYM	43,966	380.6	77.3
MI-NRCS	58,000	580.0	96.0

Table 7.9 displays the net annual investment cost in the last column as a result of adoption of GAAMPs based recommendations consisting of clay lined pit by a 100 cow rotational grazing farm. Estimates based on Garsow's numbers evaluated using CIM investment planner indicates an annualized cost of $74 over 15 years to break even and be in ownership of the storage pit. Following DAFOSYM based estimates would mean an annual investment of $77.3 per cow. Consideration of NRCS estimates require the dairy operator to incur a cost of $96 per cow which like all earlier net investment costs does not include manure hauling and maintenance costs.

These facilities possibly exceed GAAMPs requirements for participation with the MAEAP and therefore are optional investment costs.

7.3 Conclusion

This chapter accounted for the additional investments that the representative farms may undertake in controlling land and/or manure storage systems. Using three different types of management strategies, total additional land required for ensuring a farm nutrient balance was determined, and minimum possible costs of purchasing or taking on lease or through a mutual agreement was evaluated. In addition, optional cost of investments into manure storage systems was also considered. As expected, economic costs of investment were found to increase with increasing herd size and cost of building a clay-lined six-month storage was more expensive compared to a regular earthen storage facility on a per cow basis.

The concluding chapter of this study summarizes the entire study and assesses the total cost of adoption to meet minimum GAAMPs requirements due to participation in a MAEAP-based CNMP.

Chapter 8

Summary and Conclusions

8.1 Introduction

This chapter totals the costs of participation by five representative Michigan dairy farms as a result of adoption of a MAEAP recommended CNMP to meets GAAMPS requirements. The sections 8.2 and 8.3 offer a review of the simulated results of costs of adoption using the DAFOSYM, policy implications which also highlight avenues for future research.

8.2 Summary

The study profiled the crucial environmental and odor consequences resulting from animal waste and specifically, non point source pollution. Although point source problems have received due attention through federal and state regulatory efforts, non-point source pollution has remained largely unabated. Efforts of the academia, the livestock industry, and other Michigan state agencies helped implement a voluntary environmental assurance program, the Michigan Agricultural Environmental Assurance Program (MAEAP). The chapter concluded with the definition of the primary research question of testing the size neutrality of adoption costs of the MAEAP across five representative farms, 50, 150, 400 and 1,000 cow conventionally managed farms and one 100 cow intensive grazing farm.

Five representative dairy farms were assembled from survey data to examine nutrient balancing. A system based simulation tool DAFOSYM, with an assessment of nutrient inflows, outflows and net nutrient balance, and economic indicators was the primary analysis tool. Nutrient flow analysis showed the 50 and 150 cow farms had an excess supply of on-site nitrogen and deficits of phosphorus and potassium. DAFOSYM results indicated that the 400 and 1,000 cow conventionally managed dairy farms and the 100 cow rotational grazing farms possessed surplus stocks of all three nutrients, nitrogen, phosphorus and potassium. Although the key concern arising out of manure nutrients is one of phosphorus accumulation, the present study also examined surplus nitrogen. As a result, the focus of nutrient management strategies shifted to eliminating nitrogen surplus.

A set of strategies was evaluated to improve the nutrient balance on all five farms. In addition the costs associated with changes in crops, ration, a combination of crops and ration, removal of replacement heifer and a fifth integrated adoption of all above changes was evaluated. The main goal of the analysis was to seek a nutrient balance and in the process track total feeds produced and, sold, feed and manure costs, and finally the net nutrient balance due to the adoption of five management strategies. The integrated strategy was found most effective across all five farms, though, a crop mix and removal of heifer strategy also provided similar results for the 400, 1,000 and 100 cow grazing farm. However, adoption of the integrated strategy reduced net returns (before tax) by 118 percent, 32.3 percent, 9.6 percent, and 26 percent for the 50, 150, 400 cow and 100 cow grazing dairy farms respectively. Only the 1,000 cow conventionally managed dairy farm showed a net positive increase of 25 percent that may be due to advantage in herd size and technology.

According to the GAAMPs recommendations, dairy farms with excessive manure on farms are required to make additional investments in the form of either acquiring additional land or improving manure storage facilities or both. Based on the net nutrient levels of particularly, nitrogen and phosphorus, total land requirement was determined and costs of purchase through ownership control or lease was explored and rental rates were selected as the least cost alternative. Three nutrient strategies, an initial (status quo), best nutrient (most beneficial to alleviation of excessive on-farm nutrients) and best income strategy (least economically expensive) were examined with regard to additional land required. Since the focus of the study was to seek a nutrient balance at lowest economic costs, that strategy was chosen which sought the least additional land in acres for growing corn grain and application of manure and cost of investment into land was estimated.

In addition, optional cost of investments into manure storage systems was also examined. While no regulatory requirements exist for smaller farms to possess manure storage facilities, over the lack of facilities and, subsequent daily haul, allow large amount of nitrogen volatilization and potential run-off that are not likely sustainable in the long run. As expected, economic costs of investment were found to increase with increasing herd size and on an average, annual cost of financing clay lined six month storage was more expensive compared to a regular earthen manure storage facility.

8.3 Adoption costs of the CNMP

Adoption of a best nutrient strategy proved most beneficial with regard to nutrient balance across all five representative farms. Net nutrient levels of nitrogen in particular were used to assess total land required and a rental rate of $75 per acre was used to determine the total cost of investment into additional land. Table 8.2 summarizes costs of participation with the MAEAP.

Table 8.3 Minimum adoption costs of the CNMP across five representative farms ($)

Characteristics		Herd size				
		50 cows	150 cows	400 cows	1,000 cows	100 grazing farm
Change in soil and manure tests costs		+195.50	+347.50	+571.50	+827.50	+243.50
Change in feed costs		-4,881	+8,935	-48,215	-130,247	-12,855
Change in manure management costs		-2,280	-4,743	-10,684	-68,439	-5,060
Farm sales		+13,455	-15,670	-16,194	+499,336	-14,324
Change in other costs		+21,000	+62,401	+87,600	+20,000	+42,000
Cost of lease based land control		+1,755	+6,690	+25,380	+24,825	+2,550
Total CNMP costs[1]		+29,244	+57,960.50	+34,458.50	-153,213.5	+12554.50
Cost of writing a CNMP[2]		(2,000)	(3,500)	(3,500)	(5,000)	(2,000)
Cost per cow	Include writing cost	+625	+410	+120	-148.20	+145.50
	Without writing cost	+585	+386.40	+96	- 153.20	+125.50

[1] Excludes any miscellaneous /consulting fees and various storage costs.
[2] CNMP writing costs are optional and estimates are obtained from the NRCS.

The costs with a plus sign indicate the positive change in costs and a negative sign refers to a cost saving or pre-tax farm return gains due to the adoption of an integrated nutrient management strategy.

The results indicate that the costs of adoption are not size neutral across the five representative dairy farms. The 50 cow conventional dairy farm required an additional $585 per cow in costs to meet GAAMP s requirements, if the cost to write the CNMP is not included and $625, if included. Similarly, minimum adoption costs were estimated at $386.40 for the 150 cow farm if the cost of hiring a consultant for writing a CNMP was not included but $ 410, if a professional CNMP writer was hired. As herd size increased, the costs of adoption reduced and the 400 cow representative farm incurred only a marginal $96 in costs for successful adoption of the MAEAP, without writing cost, however, assuming the operator hired a CNMP writer, resulted in total cost per cow of $120. The largest herd sized farm, 1,000 cow farm had a cost saving or net gains as a result of possible adoption of the MAEAP due to advantage in herd size and better on-site technology. Since the 100 grazing cows graze for only half of the year, only six months of manure storage and handling may result in lower management costs and investments into assets like land. This is evident in the final cost per cow was $125.50 without including the cost of hiring a professional CNMP writer and $145.50 if included. Adoptions cost were lower than the conventionally managed representative dairy farms in this study. The results confirmed the initial hypothesis of this study that cost of adoption per cow was would be size sensitive or larger adoption costs for smaller herd sized dairy farms.

8.4 Policy Implications and research extensions

None of the representative farms balanced on-farm available manure nutrients with existing farmland. Additional control of farmland was required to balance farm nutrients. In addition, given the current trend in industrialization of livestock industry, manure management posses a serious concern for the future. There are several places where policy makes may facilitate nutrient balancing on Michigan farms.

- **Cost-sharing**

Results as indicated in Table 8.2 indicate that adoption costs were higher for the smaller herd size. Financial assistance in the form of cost-sharing or lower tax rates from the State and/or Federal government may encourage nutrient balancing practices. Cost shares may also be possible with respect to paying for CNMP consultants.

- **State-led initiatives to facilitate manure utilization**

Finding land to spread manure on may involve high transaction costs because of land markets. The state of Michigan, in coordination with MDA, NRCS and other interest groups could create a platform or mechanism, wherein interested parties, namely, landowners and livestock producers, CNMP consultants and state environmental and extension agents interact and possibly fix less expensive agreements. Creation of an electronic database of any available and unused agricultural or fertile land may prove beneficial in the long run.

- **Exploration of innovative or alternative nutrient management practices**

In this study, nutrient management strategies including removal of replacement heifers, combined use of crop mix changes, ration change, and adoption of an integrated were examined to manage manure nutrients. Many other strategies might be considered and future work can explore these options.

- **Precision agriculture**

Better of manure management and reduction of non-point source pollution may also be feasible with adoption of precision agricultural practices on farms. Agronomic manure application, using spatial technology, such as Geographic Information System and Global Positioning System to track land use, and existing flow of nutrients from points of origin to final destination may help policy makers and state environmental agencies be more precise with regard to performance or pollution prevention standards.

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