Financial Costs and Economic Tradeoffs of Alternative Manure Management Policies on Dairy and Dairy/Poultry Farms in Rockingham County, Virginia

by

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FINANCIAL COSTS AND ECONOMIC TRADEOFFS OF ALTERNATIVE MANURE MANAGEMENT POLICIES ON DAIRY AND DAIRY/POULTRY FARMS IN ROCKINGHAM COUNTY, VIRGINIA

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(ABSTRACT)

This study examines farm-level financial costs and environmental benefits from three alternative manure management policies, incorporating all manure (INCORP), limit nitrogen applications to agronomic recommendations (NLIMIT), and phosphorus applications limited to crop removals (PLIMIT), on representative 60, 100, and 150-cow dairy and dairy/poultry farms. Current nutrient applications are manure-based, with each farm substituting poultry litter for commercial fertilizer. Potential field-level nutrient losses estimated by EPIC, a soil/plant growth simulation model, indicate the highest nitrogen losses on grass hay and pasture and the highest phosphorus losses on no-till corn. The highest nutrient applications and nutrient losses occur on the 60 and 100-cow dairy/poultry farms. INCORP is ineffective at significantly lowering nutrient losses. NLIMIT reduces nitrogen losses by 30% and phosphorus losses by 6%. PLIMIT is the most effective policy, lowering both nitrogen and phosphorus losses over 34%. The largest farm-level reduction in nutrient losses is on the 60-cow dairy/poultry farm. Ryelage was the only crop yield that varies under the alternative policies. Financial simulation with FLIPSIM indicates that INCORP and NLIMIT do not affect farm financial performance. PLIMIT reduces farm net cash income and ending net

worth as farms substitute commercial fertilizer for poultry litter. PLIMIT does not cause dairy farms to go out of business but does significantly reduce their cash available for family living expenses below minimum requirements. Dairy/poultry farms maintain adequate cash incomes under PLIMIT. PLIMIT lowers net cash income on all county dairy and dairy/poultry farms by 8% to 16% under litter disposal costs of $10 to $40 per ton. The smaller land-intensive 60-cow dairy/poultry farm has the largest decrease in cash income while the smallest decrease is on the 150-cow dairy/poultry farm. The 100 and 150-cow dairy/poultry farms maintain higher ending net worth than corresponding size dairy farms at disposal costs of $40 per ton. County net cash farm income declines by $2.57 to $5.16 per pound of reduced nitrogen losses and $15.68 to $31.44 per pound of reduced phosphorus losses. The study indicates that NLIMIT reduces nitrogen losses without affecting farm incomes whereas reducing both nitrogen and phosphorus losses under PLIMIT substantially reduces farm income. Nutrient management plans need to be directed at smaller land-intensive farms to achieve substantial nutrient loss reductions.

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Definitions:

AEU - Animal Equivalent Units, 1 AEU=1000 pounds live animal weight

ANSWERS - Areal Non-point Source Watershed Environment Response Simulation

BMP - Best Management Practices

CREAMS - Chemical, Runoff, and Erosion from Agricultural Management Systems

CSES - Department of Crop and Soil Environmental Sciences

DEQ - Department of Environmental Quality

EPA - Environmental Protection Agency

EPIC - Erosion Productivity Impact Calculator

FAPRI - Food and Agricultural Policy Research Institute

FLIPSIM - Farm Level Income Policy SImulation Model

GLEAMS - Groundwater Loading Effects of Agricultural Management Systems

GIS - Geographical Information Systems

HSPF - Hydrological Simulation Program Fortran

LP - Linear Programming

MSEA - Management Systems Evaluation Area

NMP - Nutrient Management Plan

Simple - Spatially Integrated Model for Phosphorus Loading and Erosion

SMoRMod - Soil Moisture-based Runoff Model

SWAT - Soil and Water Assessment Tool

SWRRB-WQ - Simulator for Water Resources in Rural Basins - Water Quality

VALUES - Virginia Agronomic Land Use Evaluation System

VPA - Virginia Pollution Abatement

WEPP - Water Erosion Prediction Project

N_2 - Elemental Nitrogen

NH_3 - Ammonia

NH_4 - Ammonium

N_2O - Nitrous Oxides

NO_3 - Nitrate

H_2PO_4 - Plant Available Phosphorus

P_2O_5 - Fertilizer Phosphorus

K_2O - Fertilizer Potassium

Chapter I

Introduction

1.1 Introduction

Public efforts to protect the integrity of underground and surface water are increasingly focused on non-point sources as greater numbers of industrial and municipal point sources are meeting water quality standards (Council on Environmental Quality). The shifting concern became more evident with the emphasis on non-point pollution by key provisions of the 1987 Clean Water Act Amendment (Young and Shortle). The act requires states to identify waters that will not reach mandated standards without specific attention to non-point pollution and to develop a state wide plan to control non-point pollution.

The emphasis on non-point pollution promises to impact farming systems as agriculture has been identified by scientists as a major if not the largest contributor to non-point water pollution in the U.S. (Clark). Non-point sources usually affect the water in more indirect and diffuse ways than point sources, which can generally be traced to specific discharge locations (Tietenberg). Surface runoff and leaching of nutrients, as well as soil sediment, pesticides, and bacteria, from many locations within farming regions are contributing to the pollution of downstream and underground water resources in many parts of the U.S.. One study estimates that the drinking water of 50 million people in the U.S. is potentially contaminated by agricultural chemicals (Hallberg). Concentrated livestock operations attract particular attention because of the risk to surface and ground water from the storage and disposal of large amounts of nitrogen and phosphorus enriched manure. The threat to water quality from intensive livestock production has led to policies designed to reduce such risks in Florida, Maine, Pennsylvania, Virginia, Washington, and the New York City watershed region as well as other areas.

1.2 Nitrate and Phosphate Nutrients

Nitrate and phosphates are the nutrients most often associated with water degradation. Both nutrients are naturally present in soils and necessary for plant growth. The nutrients also can leach or run off into ground or surface waters. Environmental damage occurs when nitrate and phosphate levels in ground or surface water exceed safe levels. High nitrate levels can make ground and surface water unfit for human and animal consumption. Excess quantities of nitrate and phosphate in surface water can lead to excessive algae growth and eutrophication, depleting the water of vital oxygen upon which aquatic life is dependent and altering entire water ecosystems.

Environmental damage attributable to high levels of nitrate and phosphate from agricultural production has been documented around the country. High levels of agricultural nitrate have been found in wells in 32 states (O'Hare et al.). Agricultural cropland generates much of the non-point nitrogen and phosphorus flowing into the Chesapeake Bay (US EPA, 1983). Phosphate from dairy herds was responsible for a massive algae bloom in Lake Okeechobee in 1986 (Darling; Boggess et al.; Little, 1988). Other locations around the country have also experienced phosphate damage attributed to animal waste, including St. Albans, Vermont (Little, 1989a; Young and Shortle), Tillamook Bay, Oregon (Little, 1989b), and Erath County, Texas (Leatham et al.).

Farmers add nitrogen and phosphorus to soils in the form of animal manure and chemical fertilizers. Animal manure contains ammonia nitrogen (NH_3) and organic nitrogen and phosphorus compounds as well as other nutrients and organic matter that aid in plant growth and soil fertility. Environmental damage to water sources occurs when nitrogen and phosphorus nutrients are applied to soils in excess of crop needs or by a combination of management practices and field conditions that make nutrients vulnerable to runoff or leaching.[1]

Heavy manure applications are associated with specialized animal production characterized by farming operations that raise large numbers of animals on small acreage and import most of their feedstuffs. Specialization is economically feasible because of farmers' adoption of mechanization, scientific nutrition, breeding advances, and economies of scale. However, the large number of animals in one location creates a concentration of animal manure nutrients that operators traditionally disposed of in the most economical manner. Manure tends to be repeatedly applied to fields in close proximity to the animal center, leading to a concentration of manure nitrogen and phosphorus nutrients.

Animal manure contains varying levels of nutrients, depending upon the animal species, feedstuffs, and form. However, on many farm sites, farmers may not consider the total economic value of manure nutrients when determining manure disposal. Handling and transportation costs incurred during disposal can offset manure's nutrient value, leading farmers to attempt to minimize disposal costs by spreading manure on fields closest to the

[1] The term "excess nutrients" refers to crop nutrients that are not used or taken up by crop. The term "excess nutrient applications" refers to applications that are greater than agronomic recommendations. The agronomic recommendations used in this study are drawn from VALUES (Virginia Agronomic Land Use Evaluation System) which recommends nitrogen applications on a "optimistic realistic yield" which is described in detail in Donohue et al..

farm operations. Young et al. argue that applying nutrients in excess of crop agronomic recommendations is economically rational because of uncertainty of manure nutrients and the lack of adverse effect on crop yields. There is a considerable variation in determining nitrogen availability because manure nitrogen breaks down slowly over time. Manure applications can be highly variable due to spreading rates, speed, and spreading consistency. Studies indicate that few farmers have actually calibrated their manure spreaders (Bowman). Fox and Piekielek report field experimental results indicate a broad range over which corn yields do not diminish with excessive nutrient applications. From the farmer's viewpoint, applying excess manure nutrients on nearby fields limits manure disposal costs and reduces the risk of less than maximum crop yields because of a nutrient deficiency (Babcock; Bitzer and Sims; Young et al.). However, if excess nutrients contribute to nitrogen and phosphorus leaching or running off into ground and surface waters, the costs and implications of degraded water quality are borne by society instead of the farmer.

Additional dangers to surface waters exist from the storage of liquid animal wastes. Manure storage structures holding thousands and millions of gallons of liquid manure are a potent source of water contamination if the structure fails and spills the manure into nearby streams. Numerous cases have occurred around the country, including Floyd County Virginia where over 300,000 gallons of dairy manure drained into a nearby stream (Roanoke Times and World News). Another incident in North Carolina resulted from the failure of an earthen manure storage lagoon spilled 25,000,000 million gallons of hog manure into the New River and Wilson Bay (New York Times). Both spills killed fish downstream and raised concern over the safety of public drinking water that could be contaminated with bacteria. Public outcry over these type of incidents, no matter how rare and isolated, focuses attention on manure nutrient storage and disposal activities of concentrated livestock operations.

1.3 Water Quality Protection Efforts

Nutrient contamination of ground and surface waters in many parts of the U.S. has led to legislative and administrative actions designed to limit potential damage from animal wastes. From California to Texas to Maine, from Washington to Florida, and in New York City's watersheds, efforts are underway to protect water supplies and control the disposal of animal wastes. Efforts to alter manure disposal range from voluntary to mandatory. Many states recommend that farmers have a nutrient management plan that covers all nutrient applications but few have penalties if the plan is ignored. In other cases the circumstances dictate mandatory efforts to prevent further water degradation.

Algae eutrophication in Florida's Lake Okeechobee resulted in legislative action that forced farmers to either comply with nutrient management regulations or move out (Boggess et al.; Darling). Many farmers in surrounding areas in Florida undertook voluntary measures in the hope that the future would not bring on mandatory regulations. For other regions without any manure management controls, farmers are being warned by agricultural leaders that the near future will almost certainly bring about additional public efforts to control manure management practices on most animal operations (Darling).

1.4 Situation in Virginia

Virginia's efforts to protect water quality currently focus on programs associated with the Chesapeake Bay. The eutrophication of the Chesapeake Bay is likely one of the most studied cases of nutrient contamination in the U.S., leading to The Chesapeake Bay Agreement in 1987. The agreement includes goals to "... achieve by the year 2000 at least a 40 percent reduction of nitrogen and phosphorus entering the mainstem of the Bay" (Chesapeake Bay Citizen Report). Initial programs primarily focused on point sources rather than non-point nitrogen and phosphorus nutrient sources. By 1991, studies indicated that total phosphorus in the entire Bay declined by 19% from 1984 to 1990, with only a 10% decline from non-point sources as compared to a 29% decline from point sources. Average monthly concentration of nitrogen was essentially unchanged from 1984 to 1990 (Virginia Department of Environmental Quality).

Policies designed to reduce nutrient inflow into the Bay are being increasingly focused on non-point sources. In 1983, 39% of the phosphorus and 67% of the nitrogen entering the Bay was contributed by agricultural sources, primarily from cropland and animal manure (US EPA, 1983). Geographically concentrated animal agriculture is one of the major contributors to agricultural nutrients flowing into the Bay (Young et al.).

Most efforts to reduce non-point nutrient pollution within the Bay's watershed have centered on educational programs encouraging farmers to adopt Best Management Practices (BMP) and cost-share programs. Virginia has instituted voluntary programs to assist farmers in designing farm management plans to reduce nutrient losses from cropland and pastures. The commonwealth provides nutrient management specialists to assist farmers in developing nutrient management plans to reduce the threat of water degradation from excessive nutrient application and management practices. Virginia also has instituted a state income tax credit for farmers that purchase nutrient management related equipment. All farmers claiming tax credits or applying for cost-sharing assistance for animal waste storage structures must have approved nutrient management plans (Perkinson).

Some farms in Virginia are subject to regulations established by the Virginia Department of Environmental Quality (DEQ). DEQ regulations prohibit any farm from discharging animal waste into rivers or streams except in the case of a 24-hour, 25-year storm. Confined livestock farms (greater than 300 animal units, where one animal unit is 1000 pounds of live animal weight) utilizing a liquid manure collection and storage system require Virginia Pollution Abatement (VPA) permits, are required to have Department of Environmental Quality approved nutrient management plans, and must monitor groundwater if the lagoon is within one foot or below the seasonal high water table. Confined livestock farms handling dry manure and smaller animal production operations generally do not have to obtain VPA permits but may become subject to permit requirements if a water quality problem exists. In the Shenandoah Valley, the center of Virginia's poultry industry, a cooperative effort between local governments and poultry companies requires all poultry producers to have a nutrient management plan. However, there is no enforcement of plans to assure that producers are following recommended procedures.

1.5 Lack of Information: Unknown Policy Impacts

Policymakers face many issues when considering measures intended to prevent water pollution from manure management practices. Intended objectives based on improving overall public welfare can have major ramifications well beyond the original intent. One probable result of some manure management regulations is that farm level production costs will likely increase. Questions as to whether the impact of these costs will impose undue economic hardship on farmers and communities weigh heavily on some officials. Serious questions as to the impacts on farm economies have prevented the passage of some state level manure management legislation (Miller; McGuire). However, many local and state officials across the country have little experience and understanding of agricultural practices and are moved by a large non-farm population that demands little compromise on water quality.

Policymakers are often faced with a lack of information when considering different policy alternatives to prevent or reduce nutrient contamination of water resources. There is a lack of information indicating program impacts on overall water quality. They often lack estimates of current nutrient loss levels and how alternative policies will affect nutrient losses in the future. Often they have no estimates of impacts on farm income. They lack estimates of economic impacts on the overall economy. Studies that can provide estimates to help answer these key questions would greatly aid policymakers. Policymakers would benefit from information indicating present conditions and anticipated results from alternative manure management policies on water quality, farm income, and community economic well-being.

The future may bring more stringent manure guidelines. There is reason to believe that tougher restrictions are only a matter of time. Efforts to date have reduced phosphorus nutrient inflow to the bay but have not significantly reduced nitrogen. To meet Virginia's goals to reduce nutrient inflow into Chesapeake Bay by the year 2000, nutrient losses from controllable non-point sources will have to be greatly reduced (Virginia Department of Environmental Quality). If voluntary measures do not fulfill the mandated reductions, agricultural areas could witness more aggressive efforts to reduce nutrient contamination.

But state and local government policymakers typically do not want to regulate agriculture, especially small farms. There is agreement that agriculture contributes to non-point pollution but there is a lack of knowledge concerning the quantity of nutrients that are attributable to livestock management practices. Policymakers charged with responsibility of the surface and ground waters are faced with several key questions. What guidelines should be considered? Will suggested policies produce declines in nutrient losses and if so, by how much? What will be the farm level economic impacts of suggested guidelines? What regional impacts may result from nutrient management policies?

1.6 Purpose of Study

This study intends to provide policymakers in Virginia with information that will aid them in assessing future policies designed to protect ground and surface water from threatened contamination by nutrients from livestock operations. The information will include multi-year estimates of field and farm level potential nitrogen and phosphorus loadings and corresponding farm economic viability for alternative manure management policies. This information will allow policymakers to consider the changes in nutrient losses and the corresponding farm level costs of alternative manure management systems. The specific objectives of the study are:

1) To estimate potential field and farm level nitrogen and phosphorus losses and net farm returns occurring under current manure management practices on dairy and dairy/poultry farms in Rockingham County, Virginia.

2) To estimate potential field and farm level nitrogen and phosphorus losses and net farm returns under identified alternative manure management policies.

3) To determine the farm level economic costs associated with corresponding changes in potential nutrient losses per manure management policy.

4) To estimate county level nutrient losses and the financial impacts on dairy and dairy/poultry farms.

1.6.1 Study Area: Rockingham County, Virginia

Rockingham County, Virginia, has several characteristics that make it highly susceptible to future efforts to reduce the potential of water contamination from animal manure management practices. First, Rockingham County is Virginia's largest agricultural county for animal production and farm income and is the center of a major dairy, poultry, and livestock production region in the Shenandoah Valley. Second, Rockingham County's geophysical structure makes it vulnerable to contamination of sensitive underground and surface water resources. Third, the county is part of the Chesapeake Bay drainage basin, and may be subject to future efforts designed to reduce agricultural nutrient depositions in the Bay.

Rockingham County is Virginia's most important agricultural county, ranking first in the production of corn silage, alfalfa, other hay, dairy cattle, poultry and farm income ($371 million) (Virginia Agricultural Statistics). From 1978 to 1992, the county experienced rapid growth in animal numbers with increases of 20.7% for dairy cows, 125.2% for broilers, and 136.0% for turkeys (1992 Census of Agriculture). The increase in animal numbers is accompanied by a corresponding increase in animal manure. Manure nitrogen and phosphate nutrients from dairy, broilers, and turkeys increased 67.4% and 76.7%, respectively, from 1978 to 1992. Manure production in 1992 from these animals equaled

219 pounds of nitrogen and 154 pounds of phosphate per harvested cropland acre in the county, far exceeding normally recommended nitrogen and phosphate levels for corn (Donohue et al.). An unusual characteristic of this region is that over 30% of county dairy farms have a turkey or broiler operation, adding to the concentration of manure production on individual farms.

Rockingham County is located in the Shenandoah Valley region of northwest Virginia. The county is bounded by the Blue Ridge Mountains on the southeast, and the Allegheny Mountains on the northwest. The county consists of three major hydrogeological areas: the Blue Ridge, the central valley, and the area west of Little North Mountain. The Blue Ridge and Little North Mountain areas are sparsely developed and have little agricultural activity.

The central valley contains three geological formations: alluvial deposits overlaying carbonates on the South Fork of the Shenandoah River, carbonate formations west of the river, and Martinsburg shale. The central valley area offers the highest potential for water contamination due to its karst-carbonate limestone structure (Hinkle and Sterrett). The sedimentary geology of the central valley area is typical of the Valley and Ridge aquifer which underlies western and southwestern Virginia (Virginia Groundwater Protection Steering Committee; Meng et al.). Water flow corrodes limestone, creating sink holes that allow surface runoff to be directly introduced to underground aquifers. The water table depth commonly ranges between 50 and 300 feet (Meng et al.).

Rockingham County is drained by the North Fork and the South Fork of the Shenandoah River, draining into the Potomac River, which in turn drains into the Chesapeake Bay. Future efforts to reduce nutrient inflow to the Chesapeake Bay will likely consider Rockingham County's growing manure surplus. Current manure management practices may endanger streams and rivers with runoff, as over 80% of farmers in a recent survey reported not incorporating manure into the soil (Pease and Bosch). Over 8% of wells sampled by the Virginia State Water Control Board had nitrate levels above safe levels (Halstead, 1989). The concern within Rockingham county over manure nutrients contaminating water sources has contributed to the enactment of a local ordinance that requires all new poultry operations to have a nutrient management plan before production can begin.

1.6.2 Study Structure

The study will proceed in three main steps to meet objective one. The first part will involve defining representative dairy and dairy/broiler farms of different herd sizes. Each representative farm will have characteristic soil types as identified by county soil surveys, soil specialists from Virginia Tech's Department of Crop and Soil Environmental Sciences (CSES), county Soil Conservation Service personnel, and area farmers. The representative farms will be "typical" with respect to herd size, acreage, crops grown, soil type, crop rotation, current manure management practices, equipment inventory, and financial structure. The parameters for the representative farms will be determined by a panel of county farmers with farming operations of similar size to the representative farms.

The most accurate method to examine the possible impact of nutrient management regulations on field level nutrient losses and farm financial viability would be to examine all individual farms. Given 274 dairy farms in Rockingham County in 1994 (Virginia Department of Agriculture), this method is impractical in terms of time and cost.

Representative farms are useful to evaluate alternative policies on farms that are organized a particular way, possess a certain crop mix, or initial financial position (Richardson and Nixon, Richardson et al.). The dynamic approach in this study was specifically chosen to examine multi-year impacts on field level nutrient losses and farm economic performance.

The second step of the study estimates each farm's crop yields and potential field and farm level nitrogen and phosphorus nutrient losses with the baseline cropping mix and fertilization methods as defined by a panel of farmers whose farm operations are of similar size and scale of the representative farm. The representative farms will be modeled with the Erosion Productivity Impact Calculator (EPIC), a USDA biological soil/crop growth simulation model (Williams et al., 1990). EPIC simulates the multi-year interactions of weather, soil nutrients, plant growth, and management practices. EPIC has been calibrated for use in many sections of the U.S. and can provide estimates of nitrogen and phosphorus availability, plant uptake, and movement with erosion and ground or surface water on a daily, monthly, or annual basis (Williams et al., 1990).

Estimation of field level soil nitrogen and phosphorus losses over a multi-year period requires a through understanding of the complex relationship between the nutrients, their chemical properties, and their relationship within the soil, plant, and animal biochemical systems. Field losses can probably be measured most accurately with crop and soil specialists in a field-like laboratory setting. However, such a study would be both time consuming and expensive. Simulation of complex biological systems provides significant benefits over conducting detailed laboratory style studies (Renard and Marsbach). Simulation models allow examination of varied parameters and relationships within the soil system and can predict outcomes of specified conditions (Williams et al., 1990; Steiner et al.).

However, simulation models must be calibrated to make sure they are reasonably accurate at predicting actual outcomes under varying soil, water, and farming practices.

Calibration of the EPIC model for this study will be done with consultation with CSES soil and crop specialists and previous Virginia studies utilizing EPIC (Parsons et al., 1995a, 1995b; Maiga). EPIC estimated nutrient losses are field edge measurements of nitrogen and phosphorus that have moved through the soil profile, or nutrients that have been carried off by surface water or subsurface lateral water movements. These nutrients are not necessarily loadings to surface and ground water and therefore are described as potential nutrient losses.

The third step of the study will estimate the financial performance of the representative farms under baseline management practices and costs. The farms' multi-year financial performance will be modeled with the Farm Level Income Policy SImulation Model (FLIPSIM). FLIPSIM has been used for numerous financial farm level policy analyzes and is currently used by U.S. Congressional Agriculture committees to analyze the impacts of suggested national agricultural policy impacts on individual farms (Richardson et al.). Each farm will be modeled according to financial and farm production parameters defined by the farmer panel. Projected farm costs, commodity prices, interest rates, and other macro variables will be obtained from the Food and Agricultural Policy Research Institute (FAPRI), University of Missouri. EPIC generated estimated crop yields will be incorporated into FLIPSIM to simulate the impacts of varying weather conditions on the quantity of farm raised feed stocks and purchased feed needs. These steps are necessary to meet objective one and provide policymakers with knowledge of current farm manure management practices and estimates of corresponding farm level nutrient losses and farm financial status.

Objective two will be met by altering the baseline (BASE) EPIC and FLIPSIM models to incorporate changes necessary for the following manure management policies: a) manure applications applied to soils without a growing crop must be incorporated within two days (INCORP), b) total manure and fertilizer nitrogen nutrients cannot be applied in excess of crop nitrogen recommendations (NLIMIT), and c) total manure and fertilizer nutrients cannot be applied in excess of crop phosphorus uptake (PLIMIT). The management changes for the EPIC field level simulations will be identified by the farmer panel and input from soil scientists and extension farm management experts. The costs associated with each alternative manure management policy will be incorporated into each FLIPSIM farm model. This step will produce estimates of nitrogen and phosphorus losses and corresponding farm level financial analysis for each management alternative.

Objective three will produce comparison of the baseline farm results with the results from the different policy. The analysis will provide policymakers with farm level costs associated with changes in nitrogen and phosphorus losses. Policymakers can use this information to evaluate the effectiveness of policies in reducing potential nutrient losses and the corresponding farm level costs and the impact on farm economic viability.

Objective four will be met by estimating the impacts on the county manure balance and how it may impact the county farm economy. The baseline dairy and poultry manure production will be estimated for each policy. Farm level utilization of dairy and poultry manure will be estimated for each policy. Additional estimates will be made of the policy's impact on total county dairy and poultry manure production. The study will specifically examine how poultry litter utilization and disposal costs will affect the profitability of dairy farms adding poultry operations.

1.6.3 Anticipated Results

The information provided to policymakers will include estimates of nitrogen and phosphorus field losses occurring under current crop management practices on intensive dairy and dairy/poultry farms in Rockingham County, Virginia. The estimates will allow them to consider the effectiveness of alternative policies and the corresponding farm levels costs when considering future policy actions which may be taken by governmental agencies to reduce the likelihood of water contamination from animal manure in Virginia. The results of this study are not intended to suggest different management policies but to provide policymakers with reliable estimates of farm costs of specific policies. An additional benefit of this study is to provide tools that can be used for further studies. The models used in this study can be adapted to examine other suggested farm level manure management policies.

1.7 Summary

Nitrate and phosphate nutrient losses from agricultural areas are a significant contributor to non-point water pollution. Water pollution attributed to animal waste has been documented in different regions of the U.S. Despite a lack of information concerning the impacts on water quality and farm financial structure, there are efforts underway in many parts of the U.S. to reduce potential manure nutrient loadings to water resources from concentrated animal production sites. Rockingham County, Virginia, may be subject to future efforts in Virginia due to its growing livestock production and its environmentally sensitive water resources. The objectives of this research are to estimate current nutrient losses in Rockingham County and to examine how possible alternative nutrient management policies will affect nutrient losses, and farm financial viability.

Chapter II

Literature Review

2.1 Introduction

This chapter consists of four major sections. The first section introduces the agronomic, chemical, and biological roles of nitrogen and phosphorus in animal waste, the soil environment, and plant growth. The second section explains how nutrients are lost from the soil, resulting in environmental damage. The third section outlines the structure of animal agriculture, farm level manure management, documented manure nutrient contamination of water resources, current regulatory efforts in the U.S., the current situation in Rockingham County, Virginia, and possible future regulatory policies designed to reduce nutrient losses from manure. Section four presents alternative models used to estimate nutrient losses and describes the selected research tools employed in this study.

2.2 Environmental Roles of Nitrogen, Phosphorus, and Potassium

2.2.1 Complexity of Non-Point Source Water Degradation

Much of the non-point nitrogen and phosphorus nutrients blamed for degradation of surface and ground water sources in the U.S. is associated with the complex, highly capitalized agricultural system that has emerged in the 20th century. Attempts to reduce the threats to water sources become frustrating when the main source of the nutrient losses is the intensive use of nitrogen and phosphorus nutrient by modern agriculture. Is the capital intensive farming system that produces record yields of foodstuffs poisoning the water upon which man must depend to survive? The fruits of our food production systems that are be credited with having benefitted man so immensely are produced by degrading another resource so vital to man's survival - our water supplies. The realization of the causes of the degradation of our water systems may be analogous to Pogo's famous quip "We have met the enemy and he is us."

Identifying the source of water degradation is only one step needed to insure the quality of our drinking water in the future. The more complicated step involves not just identifying the source of nutrients responsible for water quality problems, but also attempting to identify the underlying causes that are creating the nutrient contamination of surface and ground water. The next step is the identification of courses of action that can attempt to solve the problems of water degradation.

Initiatives designed to reduce nitrogen and phosphorus losses to areas such as Chesapeake Bay require knowledge of agricultural systems, the role of nutrients within the system, and the complex soil environment in which nitrogen and phosphorus are critical parameters. Both nitrogen and phosphorus are key nutrients for plant growth and also have been blamed as being the limiting factor on algae formation and eutrophication of surface waters as Chesapeake Bay.

Both phosphorus and nitrogen nutrient management problems will be examined in this study. To understand the complexity that each nutrient adds to overall management problems within today's capitalized agriculture, one benefits from a basic understanding of the nitrogen and phosphorus biological cycles and their interrelation with manure, commercial fertilize, and crop yields within the farming systems. The role of nitrogen, phosphorus, and potassium within the soil, plant environment, and their important roles in modern agriculture is explained in the next section.

2.2.2 Nitrogen Cycle

The nitrogen cycle is a series of chemical and biological actions that makes nitrogen available for plant utilization and subject to contaminate water resources. The major steps in the chemical process are: 1) nitrogen fixation, the reduction of N_2 to NH_3, 2) mineralization, the decomposition of organic nitrogen to ammonia (NH_3) and then to ammonium (NH_4), 3) nitrification, the microbiological oxidation of ammonium (NH_4) to nitrates (NO_3), 4) immobilization, the transformation of inorganic nitrogen (NH_4 and NO_3) by plants and soil microorganisms to organic nitrogen compounds, and 5) denitrification, the conversion of nitrate (NO_3) to elemental nitrogen (N_2) and nitrous oxides (N_2O). The process makes nitrogen available to plants as ammonia (NH_3), ammonium (NH_4), and nitrate (NO_3). Nitrogen is lost from the soil environment by ammonia (NH_3) volatilization, denitrification of nitrate (NO_3) to nitrogen (N_2) and nitrous oxides (N_2O), and leaching of water soluble nitrate (NO_3).

Symbiotic *nitrogen fixation* refers to legume Rhizobium bacteria transforming nitrogen, N_2, to plant available form, NH_3. After the plant dies, the fixed nitrogen becomes available to other plants but there is evidence that legume roots may excrete appreciable amounts of nitrogen (Nutman). Non-symbiotic fixation occurs when animal and green manures broken down by microbial organisms combine with the soil's organic matter. The amount of nitrogen (N_2) converted to ammonia (NH_3) depends on the soil's carbon-nitrogen ratio. Nitrogen can also be received from rainfall containing lightning fixed N_2 (Addiscott et al.; Foth; Valiulus).

The second step, *mineralization* or *ammonification*, occurs when decaying organic matter transforms organic nitrogen to ammonia, NH_3. Some of the ammonia produced at the soil surface is volatilized into the atmosphere. Most of the negatively charged NH_3 quickly combines with positive hydrogen ions to form ammonium, NH_4. Ammonium becomes absorbed to soil particles on the cation-exchange process and is not subject to leaching (Foth; Valiulus; Keeney). Ammonium and ammonia are readily available to plants although some young plants seem to grow better if NO_3 is present (Brady).

The *mineralization* rate and the soil's organic matter content determine the nitrogen supplying power of a soil. Soils low in organic matter are poor suppliers of nitrogen while well drained organic soils have the maximum potential to supply nitrogen to plants. In water saturated soils, little nitrogen is mineralized due to oxygen deficiency (Foth).

The third step, *nitrification,* is the oxidation of positively charged ammonium (NH_4) to negatively charged nitrate (NO_3) by autotrophic bacteria. Nitrate is water soluble and readily taken up by plants but is also easily leached to groundwater as it does not readily attach to soil articles. Nitrification begins at 50 degrees F. and occurs rapidly under warm, moist conditions (Foth; Keeney; Valiulus).

The fourth step is *immobilization,* where roots and soil organisms consume and incorporate ammonium (NH_4) and nitrates (NO_3) into organic form. Immobilized nitrogen will not be leached and is subject to a repeated subcycle of mineralization, nitrification and immobilization within the soil (Foth; Valiulus).

The last step of the nitrogen cycle is *denitrification.* Nitrate, NO_3, is converted by anaerobic organisms to elemental nitrogen (N_2) and nitrous oxides (N_2O) which escape into the atmosphere as a gas. Denitrification is responsible for the atmospheric loss of nitrate fertilizer applied to soils (Foth; Keeney).

Nitrogen is added to soils in chemical fertilizers or animal manure. Most nitrogen fertilizer is formed from ammonia or ammonia derivatives. These fertilizers are very stable and readily available to plants as NH_3 or NH_4. However, nitrification quickly converts them to nitrate (NO_3) which is subject to leaching. Nitrogen fertilizer is generally listed as pounds of plant available nitrogen.

2.2.3 Phosphorus Cycle

The most common natural phosphorus in soil is fluorapatite, $Ca_{10}(PO_4)_6F_2$. Apatite weathers slowly to form plant available phosphorus, H_2PO_4. Available phosphorus is immobilized by plants and microorganisms and converted to organic form. Organic phosphorus from decaying organic residue is mineralized back into H_2PO_4 (Foth).

One main difference between nitrogen and phosphorus is that nitrate and ammonium forms are relatively stable ions in the soil environment, remaining available for plant use. However, H_2PO_4 reacts quickly (fixation) with other soil ions and becomes unavailable to plants. An equilibrium is established between the concentration of H_2PO_4 and the fixed mineral forms, resulting in low plant available phosphorus concentration in the soil at any one time. With greater availability of fixed mineral forms, plant availability of phosphorus decreases (Foth).

Plant available phosphorus depends considerably upon the soil's pH. In acidic soils (pH below 5.5) soluble iron and aluminum increase considerably, increasing the fixation of phosphorus as iron and aluminum phosphates. At pH values above 7.0, H_2PO_4 reacts with OH^- to form HPO_4, which is not readily available to plants. The highest availability of plant phosphorus occurs at soil pH levels between 6 and 7 (Foth; Hanway and Laflen; Romkens and Nelson; Sharpley et. al., 1981; Oloya and Logan)

Phosphorus fixation reduces the amount of plant available phosphorus but it also limits phosphate leaching potential. Environmental losses generally occur from erosion of phosphate bonded soil particles. Phosphate leaching is not considered a serious problem to underground water sources in deep soils that bond the phosphate molecules. Water soluble phosphate is considered a potential problem on surfaces of soils that may approach phosphate saturation due to excessive phosphate application from manures and fertilizers (Foth).

Phosphorus fertilizers generally consist of soluble calcium and ammonium phosphates that are subject to fixation with mineral ions, causing the fertilizer to remain stationary after placement in soil. Fixation allows only a small portion of phosphorus fertilizers to be used by the current crop. As a result, phosphorus fertilizer applied within the soil, closer to roots and water availability, is much more effective than surface applications. Fixation also causes farmers to apply extra phosphorus fertilizer to soils to assure adequate plant availability (Foth). Fertilizers express their "P" content as pounds of available P_2O_5, of which 44 percent is elemental phosphorus.

Soil phosphorus levels across the U.S. have been increasing as a result of decades of fertilization and manuring in excess of crop needs (Better Crops With Plant Food). High soil phosphorus levels in Wisconsin are attributed to dairy manure (Motschall and Daniel). Lanyon and Beegle reported excessive high levels of phosphorus on dairy farms in Lancaster County and other dairy intensive regions of Pennsylvania. McCollum estimated that it would take a minimum of 8 to 10 years of cropping without any phosphorus additions to reduce excessive phosphorus levels.

Excessive phosphorus levels are concerning some soil scientists. If upper limits of soil phosphorus holding capacity are exceeded, phosphorus will fail to bond with soil elements, remain water soluble, and leach or runoff with water movement. With high levels of water soluble phosphorus, recommended BMP's to control soil erosion will be ineffective to control phosphorus runoff (Daniel et al.).

2.2.4 Potassium

Potassium is the third most important mineral necessary for plant growth. Plants generally use more potassium than any other nutrient except nitrogen. Naturally occurring potassium is generally in the forms of Micas, Feldspars, and Clay. During weathering the potassium ion, K^+, is released and can be absorbed by plants or can be leached. Potassium is generally in equilibrium between fixation and weathering in micas and feldspar minerals (Foth).

The chief difference between potassium and nitrogen and phosphorus is that potassium does not form an integral part of plants and microbial tissue. Potassium can be leached from plants during rainfall. Thus organic matter is not considered to be an significant source of potassium. Potassium mobility in soils is greater than that of phosphorus but less than nitrogen. Potassium leaching can occur but is not associated with any environmental consequences to date.

Potassium enhances the location of plant carbohydrates and is associated with cell wall thickness and stalk strength. Potassium availability in excess of plant needs can result in luxury potassium consumption by plants, when nutrient uptake increases with mineral availability. One danger with large potassium uptake is high magnesium-potassium ratios in forages which can affect digestion in ruminants. Commercial fertilizer formulations express potassium as pounds of available K_2O of which 83 percent is plant available potassium.

2.3 Environmental Damage From Nutrient Losses

2.3.1 Nutrient Leaching, Erosion Losses, and Environmental Impacts

Non-point source nutrient loadings of water resources, as compared to point sources loadings which are associated with a specific location, affect water in a more diffuse and indirect manner. Non-point nutrient loadings from agriculture are almost totally attributed to modern crop production practices that allow the erosion, leaching, or runoff of soil nutrients. Soil erosion results from tillage that exposes soil to water and wind. Improper tillage methods allows water to carry off nutrient laden soil particles to streams, lakes, and rivers. Minimum tillage, contour, and terrace farming practices are all designed to reduce nutrient losses by reducing erosion (Logan et al.).

Nutrient leaching occurs when water soluble nutrients exit through the soil environment with water movement. Leaching potential is often greatest when cropping practices leave the soil without active plants during the growing season. Nitrogen mineralization and nitrification continue while immobilization stops. The soil continues to build up water soluble nitrate which is easily leached to water resources.

Both nutrient erosion and leaching are increased by fertilization practices. Applying fertilizers, particularly phosphorus, when soils are the most vulnerable to erosion significantly increases the amount of nutrients that can be carried off into surface waters. Fertilizer applications in excess of current crop needs exposes surplus nutrients to leaching. Nitrates are most likely to leach but water soluble phosphate is also capable of being carried with water runoff (Mueller et al.; Baker and Laflen).

However, it must be emphasized that nutrient applications do not equal nutrient losses and that nutrient losses do not necessarily equal nutrient loadings. Nutrient losses only represent ***potential loadings*** to water sources. Nitrate and phosphate losses from farm fields can be absorbed by adjoining land areas, phosphate can be absorbed by deep subsoils, and nitrate can be volatilized into the atmosphere. Actual nutrient loadings into ground and surface waters depends on many environmental factors and can vary greatly between fields. However, if total nutrient losses from agricultural fields are reduced, there should be less potential of nutrient loading into water resources.

2.3.2 Health Dangers Attributed to Nutrient Losses

Adverse health effects can result from nitrate contamination of drinking water. U.S. standards for nitrate in drinking water is 10 milligrams per liter (mg/l or ppm) (US EPA, 1987). Nitrates have been associated with different human health effects including methemoglobinemia, or "blue baby" syndrome, where nitrates convert to nitrites which then bond with oxygen-carrying molecules in the hemoglobin, developing a blue tinge to skin and mucus membranes. This condition can be fatal in infants but rarely occurs in humans over 6 months of age (Amdur et al.). Another risk is nitrosamine, a suspected carcinogen, that causes stomach cancers, reduces motor activity, and damages cardiac vessels (Fraser and Chilvers; Hallberg). Many fresh vegetables also contain high levels of nitrates but diets balanced with vitamins C and E inhibit the formation of nitrites from nitrate (Archer et al.; Kamm et al.). Nitrate has also been associated with abortions, weight losses, and lower milk production in cattle (Fraser and Chilvers).

Drinking water contaminated with agriculture-derived nitrogen levels in excess of Environmental Protection Agency (EPA) standards has been found in 32 states (O'Hare et al.). In 1990, 37 states reported nitrates as their most common groundwater contaminate (Thomas and Boisvert). Wells in Lancaster County, PA, have reported nitrate levels of 30 mg/l (Young and Crowder). Ritter and Chirnside found that 32 percent of water wells in a major poultry production area of Delaware had nitrate levels in excess of 10 mg/l due to improper poultry litter applications. Halstead (1989) reported that 17 percent of a sample of rural wells in Rockingham County, Virginia, reported nitrate levels in excess of 5 mg/l and 8 percent had nitrate levels in excess of 10 mg/l. Manale reports that many agricultural regions in Europe have water nitrate levels exceeding government levels of 50 mg/l and in some cases the water is can no longer be consumed by cattle.

High nitrate levels in water have been directly related to regions of high animal concentration across the U.S.. Daniel et al. established that animal production areas accounted for more nutrients being applied to soils per acre than any other land use in an agricultural watershed. In North Carolina, Duda and Finan found phosphate and nitrate concentrations 50 to 100 times higher for watersheds with high animal densities than for mostly forested watersheds. Frink determined that nutrient content increased substantially in northeastern watersheds as acres per cow decreased or the total area with dairy farms increased (Lanyon, 1992a). Kingery et al. found that high loading of poultry litter resulted in nitrate buildup in the soil to a depth of 3 meters or to the bedrock. Water quality is also threatened by fecal bacteria. In Arkansas, 90 percent of the state's waters contained fecal coliform counts in excess of the primary contact standards (Moore et al.). In Virginia's Shenandoah Valley, some wells have been found to be contaminated with coliform bacteria but the extend of this problem is unknown at this time (Hagedorn). The problem becomes much greater in regions of a high percentage of homes in rural areas drawing untreated ground water from shallow wells.

2.3.3 Eutrophication of Surface and Ground Waters

Phosphates and nitrates promote the growth of algae and water plants, initially increasing oxygen production. Decomposition of organic matter releases nitrogen and phosphorus nutrients, promoting additional plant and algae growth. Decomposition, however, consumes large amounts of oxygen that is essential to fish and other estuary organisms (US EPA, 1983). Identifying which nutrient contributes the most to oxygen depletion is fraught with controversy. Research has indicated that phosphorus is the limiting nutrient in Chesapeake Bay during the spring and fall while nitrogen is the limiting nutrient during most summer months (US EPA, 1983). At other times, light was found to be the limiting factor. Other factors that contribute to eutrophication are seasonal variations in freshwater inflow, water nutrient content, and nutrient needs of algae and aquatic plants. Thus there is a lack of agreement on whether efforts to reduce potential nutrient losses flow from agricultural areas should center on nitrogen or phosphorus (Nutrient Control in the Chesapeake Bay). Policy efforts have centered on nitrogen to this time. The levels of phosphorus and nitrogen for eutrophication are 0.013 mg/l for total phosphorus, 0.601 mg/l for nitrate-nitrogen, and 0.920 for total nitrogen (Moore et al.; Frye). These levels are well below EPA levels for safe drinking water.

2.4 Animal Agriculture and Environmental Policies

2.4.1 Concentrated Animal Production Nutrient Losses

The emerging structure of specialized animal agriculture production is identified as one reason for manure nutrients entering U.S. waters. Animal production units in many parts of the U.S. have become commodity factories, with greater numbers of animals on smaller land areas. Feedstuffs are fed to animals to produce milk, eggs, meat, and a byproduct, manure. Nutrients are imported in purchased feedstuffs and fertilizer for farm grown feedstuffs. Nutrients are exported from the farm in food products. Manure becomes a byproduct left behind on the farmstead to be deposed as economically as possible. The problems created by the nutrient imbalance can be more accurately described as a farming systems problem instead of a farm problem.

Poultry production typifies "industrial production," in which poultry houses contain thousands of birds, all feed is purchased, the birds leave the farm, and the manure remains behind. With total importation of feedstuffs, there is no nutrient recycling, just large amounts of manure.

Individual dairy farms have experienced growth in size and concentration in smaller land areas. Since to 1960, there has been a major shift to dairy farms greater than 100 milk cows and almost a disappearance of farms with less than 30 cows (Lanyon, 1992a). While milk production has tripled, concentrate use per farm has increased 10 fold and 300 percent per cow since 1960 (Lanyon, 1992a). Imported feed nutrients were found to exceed fertilizer nutrient needs by 15 times on a Pennsylvania dairy (Bacon et al.). All of the nutrients excreted by the cows were applied to cropland on the farm, often in excess of crop needs.

2.4.2 Animal Manure

Animal waste contains various forms of nitrogen, phosphorus, potassium, and organic matter, and has traditionally been utilized for its soil fertility properties. Animals use only 20-25 percent of the feed nutrients they consume with the remainder excreted in the urine and feces. The nutrient content varies by the animals' type, age, feed rations, bedding material, storage, and handling (Collins et al.). Manure nutrients increases soil fertility as does fertilizer and manure's organic matter improves soil structure, tilth, and long term fertility.

Manure solids contain about half of the nitrogen, one third of the potassium, and nearly all the phosphorus excreted by the animal. The nitrogen consists of plant available synthesized protein and residual protein bonded to organic matter. Urine contains nitrogen based urea and acids that form ammonium carbonate upon excretion. The ammonium carbonate breaks down quickly, emitting readily volatilized ammonia (NH_3). Most urine ammonia is volatilized within 48 hours if not stored properly or incorporated into the soil. Little or no phosphorus or potash is lost through volatilization.

Manure solids and bedding material have residual effects on soil fertility. The organic matter breaks down slowly and gradually releases mineralized nitrogen. The higher the manure solids content, the greater the long term effects on soil fertility. Organic matter is also added to soils through various bedding materials intermixed with the manure. Bedding materials with high adsorption qualities enhances nutrient value by absorbing urine and reducing volatilization. Bedding material residual effect on soil fertility is due to the increasing the soil's carbon content, which bonds with nitrogen during organic matter decomposition. Soils with wide carbon-nitrogen ratios are less rich in available nitrogen. However, in soils in which little organic matter has been returned to the soil, carbon-nitrogen levels narrow, decreasing the amount of nitrogen held by organic matter.
More nitrogen is available for plant absorption and also for leaching or runoff. Bedding materials can also produce a mulch effect, reducing volatilization and surface runoff, when applied to soil surfaces. The mulch effect increases soil organic matter, stabilizing more nitrogen in the soil (Foth).

2.4.3 Farm Manure Management

Some may conclude that manure nutrient contamination of water resources is due to farm mismanagement. This may be accurate from a environmental viewpoint but not necessarily from a farm management viewpoint. Lanyon (1992b) argues that most dairy farms have survived a 65 percent decline in farm numbers during the last 40 years and most are managed quite well according to performance criteria emphasized for intensive animal production agriculture. Unfortunately manure nutrient utilization and potential resulting environmental impacts have not been considered as a major economic criteria.

Farmers generally apply all manure to their available cropland, even if far in excess of crop requirements. Young et al. argues that applying excess manure nutrients is rational for farm operators. The farmer incurs little risk for over applying manure nutrients. Research indicates that crop yields do not diminish with heavy nutrient application (Fox and Piekielek). In other words, farmers do not risk any adverse yield effects by applying extra nutrients. But society may bear the impact of nutrient pollution through water quality cleanup costs or loss of convenient water sources.

Technical aspects of manure management encourages risk averse farmers to spread excess manure on cropland to assure adequate nutrient application. Manure nutrient content is not nearly as uniform and consistent as compared to commercial fertilizer. Manure nutrient analysis is available but results are only as good as the uniformity of the sample. Manure spreading rates can be highly variable as 75 percent of farmers responding to one survey never calibrated their spreaders (Bowman). Available nitrogen nutrients from ammonia depends upon the timing, temperatures, and incorporation of manure. Manure analysis gives the organic content of the manure but does not help in estimating the amount and rate of mineralization (Young et al.).

With such uncertainties, a risk averse farmer may apply manure above crop nutrient requirements. On some Lancaster County, Pennsylvania, dairy farms studied by Young et al., manure provided twice the plant-available nitrogen and five times the crop phosphorus needs. Total nitrogen application on corn with manure and commercial fertilizer amounted to 350 pounds per acre. Padgitt reported that 40 percent of Iowa farmers did not take *any credit* for manure. In Rockingham County, Bosch et al. found mean excess phosphate applications in excess of 50 lb. per acre with 20 percent of cropland acreage receiving more than 100 lb. of excess phosphate per acre, generally from animal manure. Foth indicated that spreading excess manure on close by fields changes manure management strategies from enhancing soil fertility to utilizing the soil as a waste sink for surplus manure. Manure application becomes more complex when farmers spreading manure for nitrogen requirements exceed phosphorus or potassium requirements. Daniel et al. argued that manure applications should be based on the most limiting nutrient, usually phosphorus, to limit phosphorus buildup in soils.

Part of the problem with manure management is illustrated by examining the nitrogen and phosphorus nutrient balance of a dairy cow. A cow producing 50-100 pounds of milk per day consumes 0.87 to 1.56 pounds of nitrogen and 0.16 to 0.25 pounds of phosphorus per day. Of the nitrogen, 0.26 to 0.52 pounds of nitrogen leave the farm in the milk while 0.60 to 1.03 pounds of nitrogen is excreted in the manure. For phosphorus, 0.05 to 0.10 pounds of phosphorus is exported in the milk while 0.11 to 0.15 pounds are excreted in the manure. Within these ranges, at least 70 percent of the nitrogen and 31 percent of the phosphorus remain on the farm for disposal (Van Horn et al., 1991).

2.4.4 Cases of Animal Agriculture Nutrient Pollution

The increasing number of concentrated animal operations in the U.S. has led to major water pollution occurrence in many sections of the U.S.. One of the most dramatic examples of phosphate pollution in the U.S. may be Lake Okeechobee, Florida. A 1986 algae bloom, which threatened the lake's fragile ecology, was blamed on the watershed's 49 dairies and 28,000 cows - the equivalent of a 450,000 city discharging raw sewage into the lake (Little, 1988; Darling). The state responded to general public's demand for an immediate solution to the lake's pollution. The result was the "dairy rule," intended to immediately lower phosphorus loadings by 90 percent. Each farm was required to devise plans to control all manure phosphorus nutrients. Most farms adopted BMP's and conservation measures recommended by Soil Conservation Service technicians (Little, 1988).

The "dairy rule" resulted in a phosphorus reduction as well as considerable impact on the dairy industry. Of the initial 49 dairies, 19 dairies (one third of cow numbers) took payments to relocate or cease dairying. The remaining dairies received $8 million to defray compliance costs, spending an average of $923 per cow, (cost share was $355 per cow), and $600,000 per dairy (Darling). With costs spread over the life of the system, milk production costs were estimated to increase $1.10 per cwt. (Boggess et al.)

Similar instances of documented surface water contamination attributed to animal agriculture have occurred across the U.S. and have received special cleanup efforts financed by the U.S. Rural Clean Water Program. In the St. Albans Bay watershed in Vermont, runoff from manure spread on frozen fields had made the bay the most polluted portion of Lake Champlain. Manure source phosphorus caused algae outbreaks, eventually closing a once popular state park. Efforts to encourage BMPs, manure storage structures, and waste runoff systems on two thirds of the farms reduced phosphorus export by 85 percent (Little, 1989a; Young and Shortle).

In the Tillamook Bay watershed in Oregon, clams and oysters became unfit for human consumption due to high chloroform bacteria levels. The high bacteria level was attributed to manure washing off of dairy cow loafing areas and pastures during periods of heavy rains and high water (Little, 1989b). Prescribed BMP's, the construction of manure structures and elaborate rainwater drainage systems reduced the coliform count in the bay by

50 percent. Public cost sharing amounted to $4.3 million, with farmers contributing $2.2 million. Farmers received additional encouragement in the form of higher milk payments for those complying with prescribed improved practices (Little, 1989b).

Two recent cases in Virginia and North Carolina reveal environmental risks that exist from concentrated animal operations. In Floyd County, Virginia, over 300,000 gallons of dairy manure drained into a nearby stream when a valve on a storage unit failed (Roanoke Times and World News). Another incident in North Carolina resulted from the failure of a earthen manure storage lagoon that spilled 25 million gallons of hog manure into the New River and downstream to Wilson Bay (New York Times). The Virginia spill was caused by an altered valve but the farm was not under any direct state regulations. Investigation of the North Carolina accident is pending.

The facts behind these events may not be as important as the impacts. These two incidents indicate the potential consequences of manure spills from large animal operations and their effect on water quality and potential contamination of public drinking water supplies. Public attention and concern over the potential danger to water sources is raised by these type of incidents, even if all recommended safety measures are taken. These are important factors in the formation of policies and regulations regarding the production, storage, and spreading of manure from concentrated animal operations.

The determination of whether current environmental regulations are too restrictive toward animal agriculture or are sufficient to protect the environment from potential spills is subjective to individual interpretation. A typical example is the recent concentration in the hog industry that has led to the expansion of large hog operations in North Carolina. Some critics of these operations believe that the industry has located in North Carolina because of lenient animal waste management controls and thus present potential environmental dangers. Supporters of the hog industry cite the economic development and income associated with concentrated animal production units and believe that environmental policies are adequate. These arguments have become common with the location of concentrated animal operations in many states and impact the eventual location of large swine, beef feedlot, poultry, and dairy operations. Some agricultural leaders are cautioning their industries that public concern over potential environmental disasters from animal waste handling procedures as described above, despite extensive safety cautions, will likely become the major deciding factor in the formation of public policy and thus the location of animal agriculture production units (Darling).

2.4.5 Current Manure Management Efforts

Environmental damage attributed to manure nutrients is causing some governmental units to consider policies to reduce the threat of nutrient contamination. Maine requires all farms to have nutrient management plans and prohibits spreading manure on frozen ground (State of Maine). Washington is enacting a program that requires all dairy farms to have an operating permit and to record the location, amounts, rates, and crop where manure was applied. In addition, farmers can not apply manure in excess of crop agronomic needs (State of Washington). New York City has instituted a program to provide technical and 100 percent financial assistance to dairy farmers in their watershed areas. Their multi-goal program desires to assure water quality for the city and to preserve dairy farming within their watershed. Even though dairy farms may be a potential polluter, the city believes that properly managed and profitable farms within their watershed are more desirable than development and industry (McGuire). Texas has enacted strict water discharge regulations for herds greater than 250 cows (Allen et al.).

Environmental problems associated with animal waste practices are not limited to the U.S.. Water contamination from animal agriculture is wide spread in Western Europe and efforts to enhance water quality is directly aimed at animal agriculture. Efforts to control water pollution in Europe are more regulatory than the U.S. at this point but water quality standards appear to be worse than in the U.S.. Nitrate levels in public water supplies in the U.S. are limited to 10 (mg/l). However, in the European Economic Community, the goal is to reduce the incidence of waters with nitrate content exceeding 50 mg/l. Wossink reports that in the Netherlands, it is estimated that 70 per cent of the groundwater in sandy soils used for agriculture and in almost 40 percent of the groundwater in all agriculture areas exceed 50 mg/l. In addition 50 percent of cultivated land in sandy soils are saturated with phosphate, leading to phosphorus leaching into groundwater. Europe is also making efforts to reduce ammonia volatilization, an issue not discussed often in the U.S. (Manale). It is estimated that over 94 percent of ammonia (NH_4) depositions in the Netherlands, a major cause of acid rain, come from dairy, swine, and poultry production (Wossink; Schuurkes).

Efforts to stop the ground water degradation and enhance overall water quality in the Netherlands are concentrating on animal agriculture and manure management practices. In 1994, the estimated manure surplus in the Netherlands was 16 million metric tons. Programs intended to be phased in over several years are designed to reduce manure applications, register current animal production and application rates, limit overall manure application to set levels, trading of manure rights, and establishment of a manure bank for distributing surplus manure. Farmers with surplus manure must document manure transfer to other locations. In addition, there is a tax on surplus manure produced on farms with inadequate acreage to properly dispose of all manure. Farmers must also have six months of manure storage in structures that limit ammonia volatilization (Wossink).

The Dutch have also instituted a novel plan to process raw manure and convert it to dried fertilizer. Although a very expensive alternative, it may be the only feasible method for handling their manure. The alternative for Dutch farmers is to reduce animal populations if environmental nitrate and phosphate levels are not lowered. Building the manure plant also emphasizes how producers and local, regional, national, and ECC officials must work together to solve problems (Manale).

2.4.6 Pennsylvania Nutrient Management Plan

One possible guideline to future legislative efforts on nutrient management has recently occurred in Pennsylvania. Legislative action has enacted the formation of management criteria, planning requirements, and implementation of nutrient management control on all farms that have animal densities greater than two animal equivalent units (AEU=1000 pounds live weight) per farm acre suitable for application of animal manure. One distinction of this plan is that operators of small animal operations located on small acreage are subject to the same rules as larger farms.

The Pennsylvania program provides for development of education programs and technical and financial assistance for nutrient management (Beegle and Lanyon). Farms greater than two animal units per acre are required to develop and maintain a nutrient management plan developed by a certified nutrient management specialist. The plan is to account for manure produced and utilized on-farm and plans for off-farm transfer of manure, if necessary. Nutrient plans will initially be based on nitrogen. Plans would have to be submitted to the local conservation district for review. Farmers with less than 2 animal units per acre are encouraged to have voluntary nutrient management plans. There are provisions in the act for financial assistance to producers in the future. Much of the effect of Pennsylvania's nutrient management act are still taking shape as the State Conservation Commission and the Nutrient Management Advisory Board are developing guidelines and regulations for the act.

2.4.7 Rockingham County Situation

The area of focus in this study is Rockingham County, Virginia, which leads the state in farm income, the number of dairy cows, cattle, turkeys, broilers, corn silage, alfalfa, other hay, and farm income ($371 million) (Virginia Agricultural Statistics). Since 1978 the number of dairy cows have increased over 20 percent and broiler and turkey sales have increased up to 41 percent over five-year periods between agricultural censuses (Table 2.1).

The increasing animal numbers correspond to increasing manure nitrogen and phosphate nutrients production. Manure nitrogen and phosphate per cropland acre increased by 76 and 90 percent, respectively, between 1978 to 1992. The nutrient levels are well in excess of crop needs on soils that have had repeated manure applications. These figures do not represent manure applications but they show the potential for nutrient contamination of county water sources from manure based nitrogen and phosphate.

The procedures for determining and reporting animal manure nutrients can be very confusing. The nitrogen values listed in Table 2.1 differ significantly from estimated manure nutrient values released by the Shenandoah Valley Soil and Water Conservation

Table 2.1. Rockingham County Livestock Numbers, Manure, Nutrients, and Farmland Acres Based on Total Inorganic and Organic Nutrients (1978-1992).

	1978	1982	1987	1992
Dairy Cows	20,811	23,847	24,499	25,125
Percentage Change		14.6%	2.7%	2.6%
Dairy Manure (gals)	136,728,270	156,674,790	160,958,430	165,071,250
Dairy Nitrogen (lbs)	3,091,426	3,542,417	3,639,270	3,732,261
Dairy Phosphate (lbs)	1,654,412	1,895,765	1,947,597	1,997,362
Broilers Sold	33,864,083	45,387,735	57,715,334	76,248,729
Percentage Change		34.0%	27.2%	32.1%
Broiler Manure (tons)	33,864	45,388	57,715	76,249
Broiler Nitrogen (lbs)	2,119,214	2,840,364	3,611,826	4,771,645
Broiler Phosphate (lbs)	2,102,960	2,818,578	3,584,122	4,735,046
Turkeys Sold	4,855,103	6,891,545	8,590,623	11,460,445
Percentage Change		41.9%	24.7%	33.4%
Turkey Manure (tons)	43,696	62,024	77,316	103,144
Turkey Nitrogen (lbs)	2,698,223	3,829,976	4,774,239	6,369,142
Turkey Phosphate (lbs)	2,783,431	3,950,923	4,925,004	6,570,273
Total Manure Produced				
Manure Nitrogen (lbs)	7,908,864	10,212,758	12,025,334	14,873,049
Manure Phosphate (lbs)	6,540,802	8,665,266	10,456,723	13,302,681
Total Nutrients per County Cropland and Pasture Acre				
Harvested Cropland	80,205	85,913	84,661	85,802
Lbs. Manure Nitrogen/Acre	98.6	118.9	142.0	173.3
Lbs. Manure P_2O_5/Acre	81.6	100.9	123.5	155.0
Cropland and Pasture			202,483	202,006
Lbs. Manure Nitrogen/Acre			59.4	73.6
Lbs. Manure P_2O_5/Acre			51.6	65.9

* Animal numbers and acres from U.S. Census of Agriculture. Dairy manure is based on 18 gal/cow/day, 22.6 lbs. of nitrogen and 12.1 lbs. P_2O_5 per 1000 gallons of dairy manure. Broiler litter is based on one ton per 1000 birds, 62.58 lbs. of nitrogen and 62.1 lbs. P_2O_5 per ton. Turkey manure is based on 10 ton per 1000 toms and 8 ton per 1000 hens, 61.75 lbs. of nitrogen and 63.7 lbs. P_2O_5 per ton. Nitrogen and phosphorus values are means of manure tests reported in the Virginia Nutrient Management Handbook.

District in January, 1994. A response by the Virginia Division of Soil and Water Conservation indicated the Shenandoah report had made several major miscalculations and reporting errors (Frye). First, nitrogen values were used for several manure types that were lower than mean values from the Virginia Tech Manure Testing Lab or nutrient availability factors agreed upon by a five state regional panel of experts. Second, the nitrogen values for dairy manure in the Shenandoah report were from manure diluted with parlor wash. Third, the Shenandoah report ignored organic manure nitrogen, significantly under reporting residual nitrogen. These miscalculations and omissions changed the assessment of the Rockingham County nutrient balance from one of a nutrient deficiency to a nutrient surplus.

Much of Rockingham County's animal manure comes from broiler, turkey, and turkey breeder operations. The industry has been supportive of farmers interested in entering operations by providing assistance in arranging financing, negotiating with builders and obtaining proper permits. Agricultural financial institutions are very receptive toward poultry production loans. Potential poultry loans of equal value to dairy production loans are considered to be less risky because of the stable returns and poultry contract terms (Ag First Farm Credit Bank). The financial situation has created a unique situation where greater numbers of dairy farmers are expanding farming operations by adding poultry houses instead of adding additional dairy cows.

Poultry production is characterized with large numbers of animals concentrated on small acreages. All feed is trucked in, and the litter remains behind, creating a nutrient relocation problem. The litter on poultry farms with some crop acreage is utilized as fertilizer. Other manure is sold to neighbors for fertilizer or traded to neighbors in return for help in cleaning out poultry houses. The Shenandoah Valley Soil and Water Conservation

District reported that 30,000 tons of poultry litter was shipped out of the county in 1993 for fertilizer or stocker feed by litter brokers. However, this leaves a large and growing supply of poultry litter that is being used in the county for fertilizer nutrients or stocker feed. No studies indicate the distribution of litter within the county at this time.

Poultry litter has substantial fertilizer value. Broiler litter and turkey litter with nutrient values of 12-51-62-29 and 15-47-64-24 pounds per ton (ammonia nitrogen, organic nitrogen, phosphate, and potassium) have an equivalent fertilizer value of $29.58 and $29.18, respectively. These cash values assume availability of 50 percent of ammonia nitrogen, 60 percent of organic nitrogen, and 100 percent for phosphorus and potassium and values of $0.26 for nitrogen, $0.25 for P_2O_5, and $0.14 for K_2. However, the value of broiler and turkey litter nutrients declines rapidly when applied to fields with high phosphorus and potassium levels. Manure nutrients applied on fields in excess of crop needs have no economical value as fertilizer.

The availability of poultry litter has encouraged many Rockingham County farmers to adopt litter as a primary crop fertilization source, decreasing their use of commercial fertilizer by 32.6 percent from 1983 to 1990 (Virginia Department of Agriculture and Consumer Services.) Conversations with three area fertilizer dealers confirm that many farmers have totally or substantially reduced purchases of commercial fertilizer.

The use of poultry litter coincides with increased soil phosphorus and potassium levels. An analysis of 3,766 soil tests from three fertilizer dealers and Virginia Tech Soil Testing Laboratory for 1993 and 1994 indicate that 55.1 percent of all samples are ranked "very high" and another 33.6 percent of soils are "high" in phosphorus (Tables 2.2 and 2.3 and Graph 2.1). These soils do not need any additional phosphorus. The soil tests indicate that almost two thirds of all fields to be planted or currently planted to corn and 60 percent of alfalfa fields do not need any additional phosphorus. Virginia Tech agronomists indicate that these sites could go up to ten years before any additional phosphorus is needed.

Table 2.2. Rockingham County Soil Test Phosphorus Levels.[1]

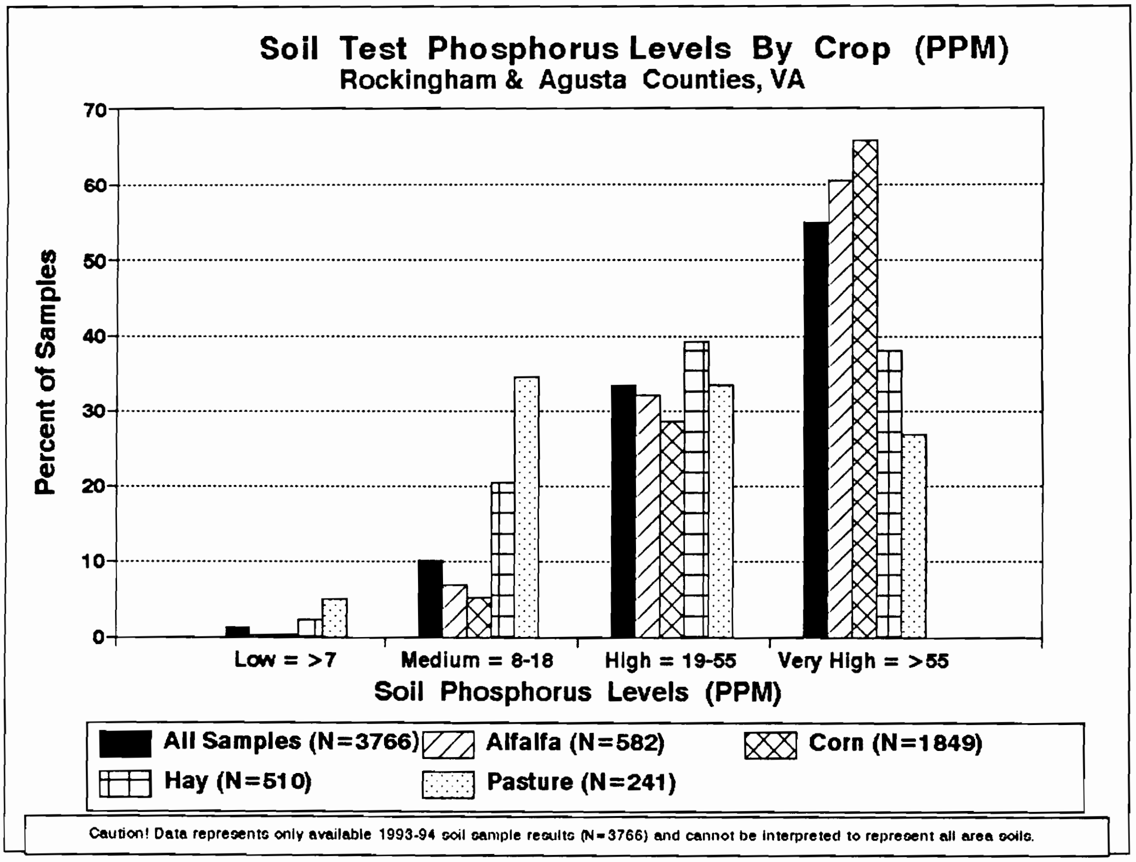
	Phosphorus Soil Test Levels				
	Samples Testing Very High		Samples Testing High		Median
Crop Sample	Number of Samples	Percent of Samples	Number of Samples	Percent of Samples	Soil Test Value (PPM)
Alfalfa	352	60.5	187	32.1	66
Corn	1217	65.8	531	28.7	88
Hay	195	38.2	200	39.2	39
Pasture	65	27.0	81	33.6	24
All Samples	2074	55.1	1260	33.5	

1. Soils tests results of 3766 samples supplied by the Virginia Tech soil testing laboratory and three county fertilizer distributors.

Table 2.3. Rockingham County Soil Test Potassium Levels.[1]

	Potassium Soil Test Levels				
	Samples Testing Very High		Samples Testing High		Median
Crop Sample	Number of Samples	Percent of Samples	Number of Samples	Percent of Samples	Soil Test Value (PPM)
Alfalfa	168	31.7	223	42.2	120
Corn	750	44.9	632	37.8	145
Grass Hay	115	24.5	198	42.1	113
Pasture	82	35.8	73	31.9	119
All Samples	1255	37.6	1311	39.3	

1. Soils tests results of 3766 samples supplied by the Virginia Tech soil testing laboratory and three county fertilizer distributors.



Graph 2.1. Soil Test Phosphorus Levels

Soil tests also indicated high levels of potassium on county fields. Although not considered to be an environmental hazard, the high levels of potassium indicate over one third of the sites tests did not need any additional potassium. Corn fields tested the highest, followed by pastures and alfalfa.

The increasing number of dairy farmers adding poultry operations and dairy farmers acquiring poultry litter from neighboring farms is increasing the concentration of animal manure. Dairy farms produce large quantities of liquid manure (over 85 percent moisture) that has nutritive value but in lower concentration than drier poultry litter. In Rockingham County, dairy farmers are applying increasing amounts of poultry litter in addition to their dairy manure. As a result, many of the high phosphorus levels reported in the above soil tests are found on dairy farms where much of the corn is grown for silage.

Dairy farms confront an additional complication of the high K_2O on the health of freshening cows. High potassium levels in grass hay and pastures is associated with metabolic problems in dry cows. Some nutritionists recommend keeping at least one pasture without any additional manure or potash for dry cows. Dairy farmers are also recommended to restrain from feeding high potassium content grass hay to dry cows (Thomas).

The soil tests confirm that many of Rockingham County's soils are becoming loaded with phosphorus and potassium. The tests indicate the need for research to estimate phosphorus losses occurring from county fields. When applying manure to soils testing high in phosphorus, soil conservation measures become more critical to prevent water degradation (Nutrient Management Handbook). While this does not dissipate the importance of nitrogen, it emphasizes the need for a total nutrient approach by farmers toward manure and farm nutrient management.

Rockingham County's government has taken some initiative to provide environmental guidance on nutrient utilization. Each new poultry house in the county must have a nutrient management plan before building permits are issued. The plan is based on nitrogen agronomic recommendations and identifies the location and quantity of litter production and disposal. Under this ordinance dairy farms who acquire poultry litter would need a nutrient management plan for litter application. Nutrient management plans based on nitrogen, however, totally ignore phosphorus buildup. There are no provisions to compliance with recommended nutrient management plans. All farms that utilize any animal manure are encouraged to have nutrient management plans (Gochenour).

2.4.8 Alternative Manure Management Policies

The expected goal of possible manure management policies in Virginia would be expected to *reduce potential nutrient loadings* to state waters. Policies adopted by other states would be worthwhile examining as these will likely be among the first to be discussed if conditions dictate state action. There is little desire by state officials to regulate farmers' manure management activities but public concern over water quality could possibly force public action. Primary efforts in Virginia to date have concentrated on farmer education and voluntary acceptance of BMPs. The following programs are basic policies that are commonly suggested policies designed to reduce nutrient losses from cropping systems. The approach in this study is not to recommend highly complex programs that would be difficult to implement and control. The approach is to identify current manure management practices and evaluate several possible manure management policies in terms of their impacts on nutrient losses and farm income. The three manure management policies to be evaluated in this study are manure incorporation (INCORP), nitrogen nutrient limitations (NLIMIT), and phosphorus nutrient limitations (PLIMIT).

Manure Incorporation (INCORP). Manure incorporation is a tillage management practice that is a recommended BMP that can reduce nitrogen and phosphorus surface runoff from bare fields. Working the manure into the soil removes nutrients from the surface, eliminating the potential of nitrogen and phosphorus being carried away with rainfall. However, incorporation can cause other problems. Nitrate leaching may increase because nutrients that previously would have volatilized with surface applications are now worked into the soil. Another problem that may arise from incorporation is that tilling the soil surface can loosen soil and encourage soil erosion. Potential leaching can be reduced if manure application and incorporation is timed with crop needs, reducing the amount of nitrate available for leaching at any one time. Comparison of nutrient losses under current manure management practices with losses occurring under manure incorporation can indicate if potential nutrient losses are lowered under manure incorporation practices.

Nitrogen Nutrient Limitations (NLIMIT). Virginia's statewide nutrient management education program bases nutrient management plans on crop nitrogen requirements. The nutrient plan recommends total nitrogen applications not to exceed crop agronomic recommendations as recommended in the Virginia Agronomic Land Use Evaluation System (VALUES) (Donohue et al.). These crop recommendations are based on economical crop yields and not on maximum potential crop yields. The approach matches nitrogen recommendations with crop yields and soil type to prevent the excess nitrogen being subject to leaching or surface runoff. Previous studies have found the best method of reducing nitrogen losses is with lower applications (Hamlett and Epp; Crowder et al.; Young et al.). This study will identify current nitrogen applications on all farm crops and then estimate nitrogen losses under limiting nitrogen applications to crop agronomic recommendation.

Phosphorus Nutrient Limitations (PLIMIT). The Chesapeake Bay Agreement emphasizes reduced phosphorus applications as well as nitrogen. Phosphorus is a complex management problem for manure based fertilization programs because the typical crop nitrogen-phosphorus requirements are much different than manure nutrient content. In addition, while nitrogen is easily carried away with water, phosphorus attaches to soil particles and will buildup in soils over time. Limiting phosphorus applications to crop removals would prevent further buildup in soils and reduce the threat of losses with eroding soil particles and the possible runoff of water soluble phosphorus. Farmers with manure dependent crop nutrient programs would likely be faced with using less manure and supplementing commercial nitrogen and/or potassium fertilizer. For farmers who import manure, the chief difference will likely be additional cash costs for fertilizer. For farms with excess manure, there will be the added complication of how to remove excess manure from the farm. This study identifies the farm's current phosphorus applications, manure balance, and estimates the change in phosphorus losses that with limited phosphorus applications. Additional analysis will examine how disposal costs can impact the farm's financial outcome.

The overall object of this study is to examine how the farm will thrive under different manure management practices while maintaining their same cropping base, not to find the farm's optimal allocation of resources under imposed scenarios. The farm's adjustments to imposed manure management activities will be predetermined. The two important questions being asked in this study are what will happen to field level nutrient losses and what will the impact be on farm economic performance if the proposed scenarios are adopted by farmers.

2.5 Alternative Research Models

2.5.1 Models Used to Estimate Nutrient Loss

There has been considerable research done on various nutrient management issues at the field, farm, watershed, and regional levels and the resulting impacts on water quality. The objectives of the research have ranged from estimating field level nutrient losses to estimating the economic impacts of farm level nutrient management programs. Most studies investigating water quality issues have employed various research methods including linear programming (LP) (Henry et al; Fultz et al.; Westphal et al.), simulation (Crowder et al.; Young et al.; Hamlett and Epp,), or stochastic programming (McSweeney and Shortle). Some researchers have combined simulation with LP to assess farm level nutrient management and economic impacts.

Linear Programming. LP has been used for determining optimal balances between farm crop and animal production systems and the resulting impacts on farm income. Westphal et al. evaluated different combinations of dairy herd size and corn and alfalfa rotations and found that limiting nitrogen applications to crop requirements substantially reduced farm income. The best economic performance allowed unrestricted nitrogen applications that produced the highest potential nitrogen losses. The authors emphasized a crucial point in studying crop/livestock farms was to examine crops and fields as components of a farming system.

Other studies have found that manure management restrictions result in reduced farm income. Garsow et al. estimated that manure storage requirements on Michigan dairy farms reduced farm income by 2.9 to 6.6 percent and manure injection reduced farm income by 12 to 13 percent. Capital costs state-wide were estimated at $118 million with $18 million in annual costs. Young et al. found that a 13 percent reduction in cow numbers on a Pennsylvania dairy farm would lower potential nitrogen losses by 30 percent and reduce farm income by 21.5 percent. Heimlich examined the tradeoffs between farm income and manure practices designed to reduce phosphorus runoff on Vermont dairy farms. Heimlich found that for small farms (35 cows), reducing phosphorus runoff 24 percent lowered net income by 19.3 percent and increased debt by 15.6 percent. Larger farms (54 and 116 cows) achieved a 30 percent reduction in phosphorus applications while maintaining income. Manure storage was profitable and more expensive tillage practices were not required. Absolute income decreases were greater for the larger farms but smaller in percentage terms (8.9 percent and 10.6 percent).

These studies and others generally concluded that farm income declines on dairy farms with adoption of manure management practices. However, most of these studies have preset the relationship between nutrient losses and crop utilization with results from previous agronomic research trials (Westphal et al.; Heimlich; Garcia et al.). Crops yields are most often county or area averages. This approach can give approximate results but fails to include the impact of variability of yields and nutrient availability and losses on farm income that can occur under variable weather conditions. Nutrient losses from cropping systems are inherently stochastic because of the complex biological relationship between plants, soils, and tremendously variable weather conditions (Shortle and Dunn). Consequently, accurate estimates of nutrient availability, uptake, and losses that do not allow for variable outcomes can fail to indicate the range of outcomes that can occur under field conditions.

Simulation. The estimation of field level soil nitrogen and phosphorus losses over a multi-year period under different crops, tillage, soil types, and fertilizer and manure nutrient applications requires a thorough understanding of the complex relationship between the nutrients, their chemical properties, and their relationship within soil, water, plant, and animal biochemical systems. In the absence of lengthy field studies, simulation models are gaining widespread adoption in modeling biological systems.

Simulation, as compared to optimization, is not driven by a single objective to arrive at a optimal solution and thus is not prescriptive in nature. Simulation models derive alternative solutions depending upon the values of key variables in the decision making process and permits incorporation of stochastic variables. In nutrient management research, simulating a site specific management system under different weather conditions produces a distribution of possible outcomes that allows the researcher to appraise the extent of variation produced by the system.

The importance of the possible use of simulation in addressing the issues of water quality, nutrient management, and soil conservation is emphasized by the endorsement for their development in the Soil and Water Resources Conservation Act in which Congress required a report on the status of soil and water resources in the U.S. by 1985 (Sharpley and

Williams). As a result of the act, the National Soil-Erosion/Soil Productivity Research Planning Committee was formed to determine what was known about soil erosion's effect on soil productivity, identify what additional knowledge was needed, and outline an approach to provide the required data (Williams, 1982). One of the most urgent needs was the development of a mathematical model for simulating erosion, crop production, water movement and nutrient disposition. As a result, a modelling team was organized and began developing the Erosion Productivity Impact Calculator (EPIC) simulation model. At approximately the same time other models were also being developed for modeling soil/nutrient processes.

The development of water quality simulation models coincided with the development of computer-based technology and programming that allows modeling of complex biological systems (Renard and Marsbach). Different models have been programmed to analyze soil nutrients under a combination of soil, hydrology, climatic, crop, erosion, physical land characteristics, and management interrelations. These models can be extremely useful for research as they can 1) test an assortment of physical and chemical relations within soil systems, 2) allow the determination of important experimental parameters, 3) assist in the efficient design of field experiments, and 4) predict outcomes of specified conditions (Williams et al., 1990; Steiner et al.).

CREAMS. Simulation models that have been used by various studies to estimate nutrient impacts on farming systems include CREAMS (Chemical, Runoff and Erosion from Agricultural Management Systems), GLEAMS (Groundwater Loading Effects of Agricultural Management Systems), and EPIC. CREAMS is capable of evaluating differences in water, sediment, and chemical reactions under alternative management practices and weather conditions within field size areas (Knisel). Output consists of erosion, surface runoff, evapotranspiration, erosion/sedimentation, and dissolved and absorbed nutrients (Knisel). Some studies that have employed CREAMS are Hamlett and Epp, Young et al., and Crowder et al..

Crowder et al. were among the first to use CREAMS to derive economic impacts of constraining soil and plant nutrient losses. They used CREAMS to develop technical coefficients from restrictions on nutrient and soil management practices for use in a linear programming model for a 75-cow representative farm. Manure applications were assumed to be storage applications and treated as topdressed fertilizer. They found that the use of reduced tillage and no-till planting lowered nutrient losses with little impact on farm income. Similar to Westphel et al., they found that farm profitability was greatest under systems that produced the largest nutrient losses. They ignored the impacts of variable weather by using average crop yields in their LP and predetermining manure ammonia volatilization.

Young et al. employed CREAMS and an linear programming model to evaluate alternative manure storage and handling systems on a Lancaster County, Pennsylvania, dairy farm. Nitrogen and phosphorus losses were substantially reduced by the use of the manure storage, reduced tillage, and soil conservation measures. Economic results indicated the farm incurred less income with adoption of the BMP's. Young et al.'s results indicate the complexity of nutrient management systems by reporting that BMP's that reduced nitrogen runoff led to higher leaching losses.

Hamlett and Epp studied the differences in nutrient losses resulting from different Best Management Practices (BMP's) and nutrient management practices (NMP) on three

Pennsylvania soils. They used CREAMS to evaluate the hydrology, erosion, and nutrient responses of site specific crop rotation over a 30 year simulation period. They found that adoption of specific BMP's generally reduced erosion, nitrate, and phosphorus losses but effectiveness varied widely between soil types and topography. Nutrient management practices (NMP) that reduced nitrogen and phosphorus applications up to 62 and 73 percent were the most effective in reducing nitrogen and phosphorus losses. Hamlett and Epp adapted nutrient applications for input into CREAMS. Nutrient availability from manure and crop residues were predetermined and applications were prorated throughout the growing season as fertilization additions. Some weather variability was lost by using mean monthly temperatures instead of daily high and low temperatures. Failure to model actual high temperatures may affect yields, water availability, and nitrogen cycling. In addition, relying on preset volatilization and nutrient availability may fail to reflect the variability in nitrogen availability and the effects on crop yields.

Crowder and Young used CREAMS to estimate sediment and nutrient losses from various BMP's for various field scenarios in Lancaster County, Pennsylvania. They found that more structural intensive BMP's were most effect in reducing sediment and phosphorus losses. BMP's reduce losses but shifted losses to subsurface losses. Their results agreed with Hamlett and Epp and Young et al. in that BMP's tended to increase nitrate leaching because of decreased runoff. Crowder and Young and Crowder et al. concluded that the most effective method of reducing nitrogen leaching was reducing total nitrogen applications and the most effective method of reducing phosphorus losses was preventing erosion. Neither study reported if soil phosphorus levels increased over the study period.

EPIC. The EPIC model is capable of simulating multi-year interactions of weather, hydrology, erosion, mineral nutrients, plant growth, pesticides, and soil tillage (Williams and Renard; Sharpley and Williams). EPIC is similar to other models in that its hydrologic model is similar to CREAMS and it incorporates the GLEAMS pesticide model, which can trace pesticide movement through the soil profile (Leonard et al.). EPIC is the product of an ongoing USDA project and has incorporated the combined knowledge of specialists in hydrology, soil science, botany, and soil and plant biochemistry.

EPIC has been tested extensively and used in hundreds of local, regional, and national, and international studies including the 1985 Soil and Water Resources Conservation Act (Cabelguenne et al.; Jones et al., 1984, 1985; Smith et al., 1990; Williams et al., 1989). Williams et al. (1989) reviewed 227 tests of EPIC to simulate yields of six major crops. Simulated yields were within 7 percent of mean measured yields and none were significantly different from measured yields. The nutrient cycling predictions have shown general good agreement for nitrogen and phosphorus (Jones et al., 1984, 1985; Smith et al, 1990.). Williams and Kissell found EPIC estimates of water percolation an nitrogen leaching agreed with a leaching indexes based on soil characteristics and seasonal precipitation. The model has been used for erosion impacts and water quality (Putnam et al.; Meisinger et al.; Smith et al., 1983; Williams, 1982; Williams et al., 1985) in the US and other countries (Cabelguenne et al.; Jones et al., 1984).

Bryant et al. found that EPIC reasonably simulated corn yields in fields undergoing various degrees of water stress on the Southern High Plains. EPIC mean yield estimates were not significantly different from actual yields and the standard deviation of EPIC estimates were similar to those of actual yields for all three year. Catus et al. used EPIC to study the effects of different tillage systems in Iowa and Ohio. EPIC predicted the effect of tillage and weather on soybeans but did not simulate crop rotation as well. Benson et al. examined the different water percolation and soil water storage capacity methods in EPIC and found they consistently differed between methods at five locations while across locations percolation and nitrogen leaching varied more due to weather and soil conditions. Estimated nitrogen and phosphorus nutrient and sediment losses were found to be in agreement with the expectations of soil scientists and agronomists in tests comparing soil application of fertilizer and poultry litter (Edwards et al.).

Fultz et al. used EPIC to simulate crop yields and nutrient losses, GLEAMS to simulate pesticide losses, and combined results in a LP to estimate impacts on farm income of crop rotations in the corn belt. The EPIC modelling parameters and results were found to be acceptable by soil scientists. Fultz indicated that CREAMS does not consider the mineralized nitrogen available from crop residues.

Wu et al. adapted the EPIC and GLEAMS models to estimate nitrogen and pesticide losses from irrigated cropland in upland plains and semi-arid region. They took the basic EPIC model and added the pesticide subroutine from GLEAMS. Crops were simulated and compared with known data when available. The results indicated the models were reasonable predictors of nitrogen runoff, percolation, crop yields, and pesticide losses.

Parsons et al. (1995a, 1995b) employed EPIC on two studies in Virginia. The initial study with EPIC simulated 15 years of corn research plots, on three distinct Virginia soils, in which the control plots underwent heavy commercial fertilization application while plots on identical soil received up to 75 tons of hog manure. EPIC simulated yield means were not different from measured yield means for all treatments ($p \leq 0.05$) and generally had smaller standard deviations. The study emphasized the importance of interdisciplinary cooperation between modelers, soil, crop, and nutrient specialists to successfully model a complex bio-environment. (See Appendix A.)

Simulation Concerns. Simulation models offer researchers a tool for examining biological and financial systems. Models calculate the values of many parameters and complex relationships, allowing researchers to examine many different parameters at different points of analysis under user defined combinations of inputs. Consequently, simulation models present many advantages for complex research problems but also have some drawbacks that limit their uses and acceptance. Law and Kelton listed the following advantages and disadvantages of simulation: 1) simulation is often the best tool to study complex systems with stochastic elements; 2) discrete alternative systems can be compared to see which best fits certain criteria; and 3) simulation allows greater control over parameters of interest, such as time horizon, than can be achieved in field experiments.

Law and Kelton also point out several major disadvantages of simulation: 1) models are often time consuming and expensive to develop; 2) model results are not optimal, depending upon the judgement of the modeler to choose the best method among alternatives; and 3) simulation models are only capable of providing information as useful as the model's specification. In other words, simulation data and relationships must be calibrated against reality.

These advantages and disadvantages provide guidelines for adoption and use of simulation models. The complex relationships of biological systems lends itself to simulation because of the large number of parameters and stochastic variables. However, Law and Kelton's note on model calibration should warn researchers from blindly accepting results from simulation and other mathematical models. Simulation models must be calibrated and verified against known research results to make sure they are reasonably accurate at predicting actual outcomes. With respect to environmental models, the output needs to be verified to assure the model replicates results from field research. In many cases where models such as CREAMS and EPIC produce results on many parameters for which very limited field research is available, verification procedures rely on expert appraisal by crop or soil scientists to assure results are what the experts would expect under the simulated conditions.

In most cases involving simulation models, the terms verification and validation are misused and confused. Verification is at best a confirmation of measured results while model validation infers that the model is soundly grounded on facts, evidence, logic and is therefore free from errors (Oreskes et al.). Konikow and Bredehoeft argue that validation does not have a place in simulation because models are an mathematical abstraction of a complex process or biological system. Simply due to their construction simulation models are subject to errors that can commonly occur. Konikow and Bredehoeft argue that models can never be validated, but that individual models are calibrated by the modeler in a process of adjusting mathematical relationships until the difference between observed and computed results is minimized. Perfect agreement only proves that the numerical model can accurately solve the equations, not that it always will. Similar to the scientific method, calibrating models is the process of attempting to disprove a model's reliability, not to prove its validity (Konikow and Bredehoeft).

In this study EPIC is being used because of its ability to model complex soil biological systems. EPIC presents the advantage that it has been constantly refined and calibrated as updated field research becomes available and has been successfully used under varying weather, soil, and cropping systems. In addition to the model updating, an important consideration in model selection is the availability of technical support. Simulation models with many integrated processes and requiring large amounts of technical input parameters demands a learning process by the user in which the availability of technical support is invaluable. As compared to CREAMS, EPIC presents the advantage of being able to model individual manure components. Rather than defining manure nutrients as equivalent fertilizer nutrients, EPIC allows specification of manure organic and inorganic nitrogen and phosphorus.[1] In addition, EPIC specifies the ammonia portion of inorganic nitrogen and models volatilization within its nitrogen cycle.

Watershed Models Many studies have attempted to analyze water quality issues at the field level, which is the unit size at which management decisions are generally made. Other researchers approach water quality issues from a regional or watershed basis. While the former research studies are concerned with the micro impacts of nutrient management policies, policymakers are also very interested in the macro effects at the watershed level. Numerous watershed models are being tested at various governmental and university institutions. Some models include AGNPS (AGricultural Non-Point Source), HSPF (Hydrological Simulation Program Fortran), MSEA (Management Systems Evaluation Area),

[1] The terms "inorganic" and "mineral" both refer to readily plant available nitrogen and phosphorus. The terms are both used in the literature.

Simple (Spatially Integrated Model for Phosphorus Loading and Erosion), SMoRMod (Soil Moisture-based Runoff Model), SWAT (Soil and Water Assessment Tool), SWRRB-WQ (Simulator for Water Resources in Rural Basins - Water Quality), WEPP (Water Erosion Prediction Project), and others (Heatwole).

Many of the watershed analytical models are linked to Geographical Information Systems (GIS), a computer-based system of coordinated databases that allows the user to coordinate and manipulate large sets of physical and natural science data such as soils, precipitation, vegetation, slope, land use, and administrative information with computers. GIS develops spatially referenced (digitized) electronic overlays comparable to simple thematic maps that are organized according to an integrated theme known as a coverage or layer. Computer imagery allows the user to compile, merge, sub-divide, overlay, and update maps with ease as well as estimating other site-specific parameters from established mathematical relationships among known variables.

The GIS database provides users a two-way interface with analytical models. For example, GIS interfacing with satellite imagery maps, soil type, and surface characteristics with crop management, nutrient, and weather data can provide the data for input into a mathematical model to estimate relations between individual parameters and present the output in mapping format. The system facilitates planning and decision making for individuals involved in environmental and resource management because of its capability to integrate, combine, and update environmental data in various "what if" scenarios (SARSA).

A study in Northeast Wisconsin incorporated a regional model with GIS to estimate a cost-effective management strategy to enhance water quality in the 6,640 square mile Green Bay-Fox-Wolf watershed (North East Wisconsin Waters for Tomorrow). Excessive loadings of phosphorus and total suspended solids were believed to contribute toward algae blooms and other water quality problems. The goal of the project was to estimate how to achieve a 30 percent reduction in phosphorus loadings in Lower Green Bay. The analysis of the watershed with SWRRB-WQ estimated that 73 percent of total phosphorus and 89 percent of total suspended solids entering Lower Green Bay came from agricultural sources.

The researchers estimated that it was significantly less expensive to reduce phosphorus loadings from agriculture than from other sources. Targeting cleanup efforts on agricultural areas in downstream sub-watersheds and adjoining waterways would be the most cost-effective but would not achieve the desired reduction in phosphorus loadings without also targeting other upstream agricultural areas. Annualized costs of implementing BMP's to reduce soil erosion and optimize fertilizer and manure applications is relatively significant, ranging from an estimated $2400 to $4200 for a farm with 200 cropland acres ($12 to $21 per acre). The study concluded that a watershed analysis was quite useful but there was a significant need to combine the analysis with micro-based models to specifically examine the effects of different BMP's on phosphorus loadings and on farm profitability, a major factor of farmer acceptance of programs that increase farm costs but do not directly increase farm returns.

Farmscale models are being developed that aggregate field level studies to the farm level. Nutrient management decisions on many farms are driven by the resources and the demands of the overall farm performance, not by individual fields. Thus a model that can incorporate farm level constraints into the nutrient and crop management decision process would be beneficial to the farm operators, policymaker, and researcher. One model being developed by agricultural engineers at Virginia Tech is FARMSCALE, which combines a non-point source pollution model, ANSWERS (Areal Non-point Source Watershed Environment Response Simulation), with a GIS database. The system enables landowners to develop land management systems that consider all of their site specific conditions, meet water quality goals, and minimize the impact on the landowners's production requirements. The planning system focuses on improved non-point source pollution control at the farm level at which management plans must be implemented (Wolfe et al.).

The FARMSCALE model is designed to 1) to provide a tool for making decisions regarding nutrient management, 2) be used by farmers and consultants to determine the water quality impacts of contaminants from farm practices, 3) compare the impacts of alternative systems, 4) enable farmers to choose practices that satisfy site specific constraints to meet water quality goals. ANSWERS simulates the effects of BMP's on runoff, sediment, and nutrient losses from a watershed by dividing the watershed into a uniform grid of squares that characterizes the movement of water, sediment, and nutrients between squares. The GIS integrates a spacial mapping system of site specific spacial data including soil parameters, topography, slope, and channels. The output includes estimates on sediment losses, nitrogen runoff, nitrogen leaching, and phosphorus losses. This particular model is currently being developed at Virginia Tech and being tested for field use (Wolfe et al.).

Virginia Environmental Simulation Studies. Considerable research has been done on aspects of nutrient management and water quality impacts in Virginia. Much of the research has centered on nitrogen management with some emphasis on animal manure. One aspect missing from previous Virginia research is the examination of the impacts of managing phosphorus buildups in regions of high animal densities. Studies that have concentrated on manure management include Halstead (1989), Bosch et al., Bosch and Napit, and Parsons et al. (1995a, 1995b). Other studies examined water quality issues on fertilizer based farm operations (Norris; Diebel; Maiga).

Diebel employed a 15 year non-linear mathematical programming model to determine optimal farming practices under various agronomic and policy scenarios in the predominately grain producing Northern Neck of Virginia. Diebel used GLEAMS to estimate annual soil erosion, pesticide losses in the surface runoff and percolation. CREAMS was used to estimate nitrogen losses. Diebel did not examine any issues related to manure management. Diebel concluded that fewer inputs reduced potential contamination of groundwater and runoff but profitability pressures on farmers greatly limit their adoption.

Norris examined environmental and farm profit impacts due to alternative nitrogen management strategies with grain production in eastern Virginia. Norris used a multi-year linear program with a nitrogen balance sub-model that calculated nitrogen carryover. Split nitrogen applications and the use of poultry litter transferred from poultry production areas resulted in higher net returns and lower potential nitrogen losses. Norris found that farmer education efforts were needed for greater litter utilization by grain farmers.

Maiga examined nitrate loss to ground and surface water on several soils in predominately grain producing Richmond County with EPIC. Maiga found that estimated nitrogen losses were lowest under multiple fertilization applications. Maiga calibrated EPIC under the direction of Virginia Tech soil and plant scientists to assure results were within bounds expected by the experts.

Most of the studies that examined the use of manure or litter were based in Rockingham County, Virginia's leading animal agricultural county. Halstead conducted a mail survey of county dairy farmers that gathered information on farmers attitudes, farm characteristics, and farm cropping and manure management practices. From the survey, Halstead developed two representative dairy farms and estimated farm level economic impacts of nutrient management practices. The economic analysis was done with a chance-constrained linear programming model which incorporated nutrient loadings estimated by CREAMS. Halstead (1989) examined various nitrate loading reduction strategies on estimated farm level net returns over variable costs. Results indicated that substantial reductions in nitrate loadings were possible with only minor impacts on farmers' net incomes through the use of cost sharing for manure storage and nutrient management planning. Greater reductions were possible through land use restrictions and banning fertilizer purchases but at greater losses in net returns. The model's results indicated that programs that reduced nitrogen losses by 40 to 70 percent also reduced net farm returns by 1 to 19 percent. Halstead (1989) incorporated rainfall variability into the CREAMS simulations but did not have temperature variability because average monthly temperatures were used. Manure applications are not handled explicitly by CREAMS so manure applications must be represented as fertilizer applications. Estimated nitrogen volatilization is preset by the researcher (Heatwhole et al.).

Bosch et al. report that a 1991 survey of Rockingham County farms indicates that 60 percent of sampled sites where manure was applied had nitrogen applied at below recommended rates while phosphate was applied at rates exceeding recommendations. The authors reported that 22 percent of the sites applied phosphorus in excess of 50 lb. per acre and 20 percent in excess of 100 lb. per acre.

Parsons et al. (1995b) used EPIC to model nitrogen losses from 120 environmentally sensitive sites in Rockingham County, Virginia. The sites were surveyed by Bosch et al. and were modeled to estimate the potential nitrogen losses and identify soil and management characteristics associated with high nitrogen losses. The results indicated a wide variance of nitrogen losses over the different soil types. The study found that the most significant variables were operational variables as tillage and the amount of fertilizer and manure applied. Parsons et al. also found that farmers who imported poultry litter applied the most nitrogen and had the highest nitrogen losses. The study suggested that water quality polices should be based primarily on management practices than on soil characteristics. The study also indicated the importance of examining the manure application procedures of farmers importing poultry litter.

Bosch and Napit studied the feasibility of transferring poultry litter from poultry production areas in Rockingham County to surrounding regions for fertilizer and animal feed. The value of poultry litter for fertilizer was estimated at $20 to $29 per ton. The litter's feed value for stocker rations was worth $66 to $74 per ton. At these values, the authors estimated that it was economically viable to transfer poultry litter to many areas of the state, depending upon acquisition costs. However, transfers were not occurring on a wide scale, implying that policy actions to stimulate transfers may be needed. Subsidies and regulatory strategies would be effective in encouraging litter use. The authors concluded that additional research on effective litter use and farmer education were needed to increase awareness of litter's fertilizer value.

2.5.2 Estimation of Farm Level Financial Impacts

The measurement of the farm financial performance depends greatly on the objective of the research. Optimization identifies the optimal outcome of a given set of parameters and objectives. However, the primary goal of much of the previous nutrient management research is to identify systems that reduce nutrient losses without much consideration of the farms financial or production constraints. The economic impact on the farm's financial structure is subject to the constraints imposed by the nutrient management system. Optimization can identify the management system that produces the highest income subject to the crop yields permitted by the nutrient system. However, crop yields can vary tremendously among different management systems as well as between management systems because of weather variability. Livestock farms also encounter price risk for their output and purchased inputs, as well as multiple production risks associated with biological production processes. Consequently, livestock farms can experience a wide distribution of financial returns due to the variation in production processes, output prices, and cash input prices under preset crop production levels as well as variable crop yields. From a farm level perspective, it can be more beneficial to know the range of financial impacts that can be generated with simulation under different nutrient management systems and other stochastic farm financial variables.

FLIPSIM. One simulation model that was developed to allow the analysis of probable outcomes of alternative farm policies on representative farms is the Farm Level Income Policy Simulation Model ((FLIPSIM), a firm level, recursive model which simulates the annual production, policy, marketing, financial management, and tax aspects of a farm over a multi-year planning period. The model is a simulation instead of a optimization programming model because it does not include an optimization function but instead analyzes the outcome of a given set of input data and assumptions for the farm. The model is composed entirely of accounting equations and identities (Richardson and Nixon). Recent programming additions to FLIPSIM allow the incorporation of EPIC generated crop yields. The model formerly had an LP option for crop acreage but this option has been discontinued (Richardson).

The model has been calibrated and verified on various farm studies at Texas A&M University, the USDA, and around the U.S. The U.S. Congressional Agriculture Committees use FLIPSIM to examine the impacts of suggested policies on models of 75 representative farms from different regions and commodities across the U.S.. Boggess et al. used FLIPSIM to calculate the long term farm level financial impacts of nutrient management regulations on four different size dairies in Florida. Boggess et al. calibrated the model by simulating a previous year's finances for which they had detailed records. Allen et al. employed FLIPSIM to examine five year economic impacts of required manure structures on Texas dairies. They examined two dairy farm sizes (300 and 720 head) under varying debt/asset ratios, milk production levels, milk prices, and investment requirements. Allen et al. calibrated their model from detailed farm financial records.

2.5.4 Representative Farm

Many of the studies mentioned above that analyzed farm level nutrient management utilized a representative farm approach. Those not using a representative farm generally modeled farms from which detailed crop, soil, and nutrient information was available.

Given the large number of farms in most regions of interest, many researchers attempt to model farms that are representative of farms of similar size, production level and mix, technology, soil types, cropping mix, and business structure. Representative farms have been used extensively for many types of studies and are used by the U.S. Congress for evaluation of the farm level impacts of agriculture and soil conservation policies (Richardson and Nixon, Richardson).

The use of representative farms allows researchers to estimate the impact of a policy, change in production sets, or environmental actions. Of course, the applicability of any research results depends upon the detailed parameterization of the farm and its true characterization of the farm sector it represents. There is criticism of the use of representative farms for policy analysis. Miranowski and Reichelderfer question the applicability of representative farm analysis to natural resource policy research because most studies are static rather than a dynamic analysis and most studies assume risk averse farm operators.

These criticisms are important considerations for studying environmental effects of manure nutrient management policies. A static approach severely limits a study's relevance when examining a topic as dynamic as nutrient losses from the soil environment. Farmers' production decisions in year one with regard to crop mix, tillage methods, and nutrient application amounts and methods significantly affect nutrient losses in following years. In addition, static studies fail to consider weather variation that can significantly affect nutrient losses within a year and between years.

Risk aversion is an important issue with regard to nutrient management since the high application of nitrogen and phosphorus nutrients can be interpreted as risk reducing behavior (Halstead, 1989; Young et al.). There could be different methods of measuring risk on farms. Risk on a dairy farm can be measured by acres of corn silage planted to assure minimum forage needs, number of young stock raised as herd replacements, and definition of crop mix and nutrient applications. In formulating the representative farm, if the model's parameters are confirmed by farmers to reflect the production mix, physical attributes, and financial structure they would expect of a typical farm under a typical farmer's risk perceptions, one could assume that the representative farm has incorporated risk into the farm's formulation (Richardson and Nixon, Richardson).

The approach used in this study to define representative farms follows the procedure used at Texas A&M University. The specific farm parameters are specified by a panel of farmers whose own operations closely match the representative farm's physical structure. The farmers will define the farm size, field allocations, crop acreage, crops grown, crop rotation, animal numbers, feed rations, feeding and production technology, machinery inventory, and financial characteristics. The validation that the model farm accurately typifies an area's production and operation practices rests with the farmers themselves.

Aggregation Issues. Assessing county level impacts on county dairy farms will involve aggregating across representative farms. However, aggregation from microeconomic budget models is theoretically complex. Careful attention needs to be given to the assumptions employed in the study. For example, aggregation for the different manure management policies will require acknowledging that: 1) all policies are imposed equally on all farmers, 2) all farms fit into one of the representative farms, 3) all farms fitting into one representative farm all comply to the same cost structure, and 4) actions on representative farms do not effect industry wide supply and demands functions. The last assumption must be examined carefully. The price of some products like feed would not be affected because they are used widely by several industries. But products, such as manure, with limited alternative uses and high transportation costs could be affected significantly by changes in manure handling policies.

Day specified that, theoretically, farms of varying scales and expected net returns can be aggregated without any bias provided the farm had identical technical coefficients and homogenous production functions. For empirical applications, Day specified that aggregation of farms within stratified groups with proportional resources, net return expectations, and institutional behavior would be "accurate with only a tolerable degree of distortion." Barker and Stanton raised two key questions regarding Day's aggregation conditions, a) how does a researcher know how many groups are needed to reduce bias to a tolerable degree, and b) what is the primary criteria for defining representative farm groups. Stanton and Baker raise key questions regarding how to apply theoretical relations to applied research. In diversified farming regions, farms can range over a wide array of operating and physical characteristics and production methods. Separating these farms into many small groups with similar production characteristics may be beyond the resources of the study. Hazell and Norton indicate that in practice that farm aggregation criteria are reduced to several simple criteria such as 1) similar proportions in resource endowments, 2) similar yields, and 3) similar technologies. Following Hazell and Norton's criteria allows separation of farms within a region into groups with similar production resources and technologies. Separating farms by more specific criteria may not necessarily reveal additional information that is crucial to the study's results. In this case the researcher may proceed with aggregation procedures that violate Day's exact conditions but still attain the desired objectives meet the research objectives (Stanton and Baker; Hazell and Norton).

The criticism of representative farms and aggregation issues are valid but do not necessarily prohibit its use in this study. Conversely, the criticisms emphasize the necessity for careful specification and application of the representative farm approach and aggregation procedures instead of its abandonment. The results from this study will be subject to a degree of aggregation and specification bias but the results will still provide important guidelines on the implementation nutrient management policies.

2.6 Summary

This chapter has explained the chemical and biological relations of nitrogen and phosphorus nutrients with soil, plants, and animal manure. Nutrient contamination of water resources in many locations is attributed to manure management practices on concentrated animal production sites. Previous research has examined different aspects of manure and nutrient management but few have examined phosphate losses and the longer term impacts of manure management policies on water quality and farms financial viability. Simulation of nutrient losses incorporates daily weather variability on crop yields, erosion, and nutrient losses. Simulation results will not necessarily be validated but rather calibrated to known research results and to expectations of soil, crop, and nutrient specialists when research data is lacking.

This study's objectives, stated previously in Chapter I, are to evaluate the impact of alternative manure management policies on long term nutrient losses and farm financial viability. This is done with the formulation of representative farms and the use of two simulation programs. EPIC is used to model field level crop yields and nutrient losses and FLIPSIM is used to model the farms' financial performance. Results from EPIC and FLIPSIM are aggregated to determine county level farm impacts. The exact formulation of the representative farm and key parameters are explained in Chapter III. EPIC and FLIPSIM results are reported in Chapter IV. County level results are reported in Chapter V.

Chapter III

Models and Methods

This chapter presents an overview of individual component linkages of this study, and how they are combined to meet the research objectives presented in Chapter I. Each component of the study and its relation to the study's objectives are explained in detail. The alternative manure management policies examined in the study are defined and related to the study area. The formulation procedure and characteristics of the three representative farms are explained in detail. The next section explains the implementation and calibration of the EPIC model for the estimation of crop yields and nutrient losses. The FLIPSIM financial simulation of each representative farm is then described in the last section.

3.1 Research Procedures and Overview

This study employs the EPIC and FLIPSIM simulation models to estimate farm level nitrogen and phosphorus losses occurring on dairy and dairy/poultry farms in Rockingham County, Virginia, and the financial costs incurred by these farms with the adoption of three alternative manure management policies. An overview of individual steps, components, and linkages of the study is shown in Figure 3.1. The study follows the same research procedure to examine the nutrient management practices on three different size representative farms. Step 1 specifies each farm's physical and financial parameters which is done in cooperation with a farmer panel and county soil experts. Key parameters include the soil types, crops, acreage, nutrient applications, dairy production and rations, expenses, and debt structure. In

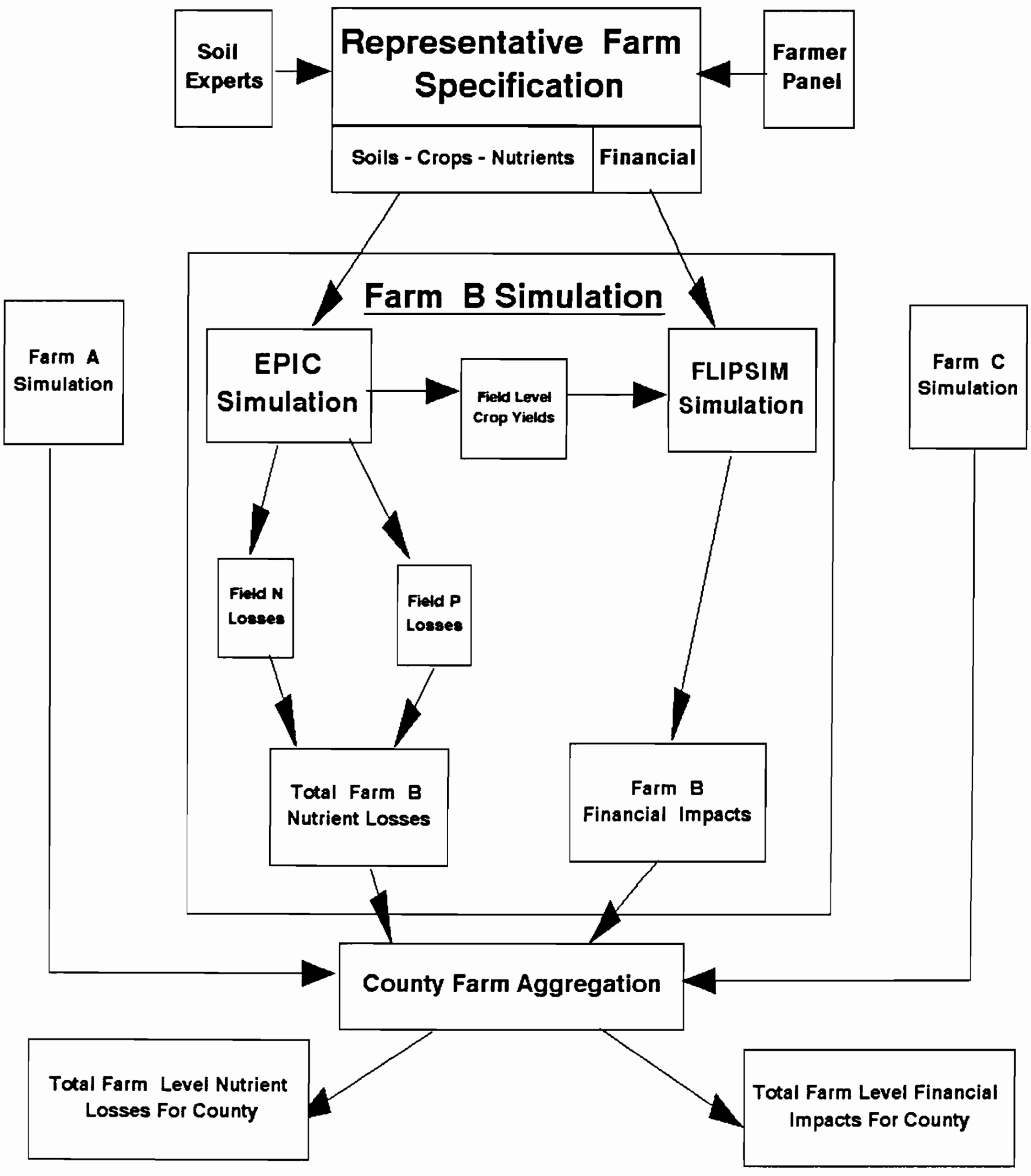


Figure 3.1. Overview of Study Framework

step 2, the farm's crop and nutrient production practices are simulated with EPIC which estimates crop yields, erosion, and field level nitrogen and phosphorus losses. In Step 3, FLIPSIM incorporates the EPIC crop yields with the farm's debt, cost structure, and dairy production parameters to simulate the farm's financial operations. For step 4, nutrient losses estimated by EPIC are consolidated from individual field estimates and compared to the farm's financial results estimated with FLIPSIM. The last step combines the results from the three farms to estimate county wide nutrient losses and the financial impacts. This procedure is followed to estimate field and farm level nitrogen and phosphorus losses, and net returns under current farm practices on county dairy and dairy/poultry farms, and the corresponding nutrient losses and net farm returns under three alternative manure management policies. The comparison of changes in nutrient losses estimated with EPIC under each policy with the corresponding changes in the representative farms' financial returns estimated with FLIPSIM provides the farm-level costs of achieving the changes in nitrogen and phosphorus losses per policy.

3.1.1 Research Objectives

The first objective of this study is to identify nutrient losses and the financial performance of Rockingham County dairy and dairy/poultry farms under current farming practices. This is accomplished by modeling representative farms of defined size and production characteristics. Key farm characteristics include the number of cows, milk production levels, crop acreage, production practices, and financial structure. Additional factors necessary to estimate farm level nutrient losses are the identification of soil type, fertility levels, and past fertilizer and manure fertility regimes followed for each crop.

Virginia Tech dairy experts and county extension personnel assisted in selecting the herd sizes for each representative farm.

The next step defined the parameters associated with each representative farm. This procedure required input from soil experts, USDA Natural Resources and Conservation Service (NRCS) personnel and Virginia Tech soil specialists familiar with specific characteristics of soils commonly found in Rockingham County, and a farmer panel. These experts agreed to the soil types associated with cropland and pastures to be modeled on each representative farm.

The farm panel consists of a group of farmers whose own farms are similar to the specified herd size. Each farmer panel member is selected in cooperation with the local Virginia Cooperative Extension Service dairy specialist. The farmer must be familiar with other farmers in the area, have good production, financial, and tax records, and be willing to share their records with the researchers.

The farmer panel defined all of the farm's production parameters - acres and fertility regimes of each crop grown, herd production and feed rations, financial structure, production costs, receipts, and manure management practices. The use of the farm panel assures the model farm is specified to what the farmers believe is typically found on a representative county farm of that herd size. Each dairy farm is also modeled with the addition of a poultry operation. The validity of the study's results depends largely on the precision and detailed formulation of each representative farms.

Nutrient losses and corresponding financial outcome of each representative farm are estimated with two simulation models. The first simulation model, the Erosion Productivity Impact Calculator (EPIC) is used to estimate field level nitrogen and phosphorus losses and crop yields over the study period. EPIC requires detailed knowledge of the representative farm's soil types, productivity level, slope, crops grown, fertility regimes, and fertility history. Specific soil data is provided by the soil experts. The crops, fertilization, manure applications, and crop management practices are provided by the farmer panel. The EPIC simulations produce field level estimates of nitrogen and phosphorus movement and crop yields under differing soil specifications and weather. The field level estimates are combined by crop to provide farm level estimates of nitrogen and phosphorus losses under current farming practices.

The second simulation model, FLIPSIM, estimates farm level financial performance over the study period. FLIPSIM requires detailed farm financial and production data that is defined by the farmer panel. Data include dairy herd management parameters, feed rations, machinery inventory, asset values, dairy and crop production costs, income, and debt levels. Crop yields are drawn from the EPIC simulations, determining annual crop production and thus determining feed inventories and required feed purchases. FLIPSIM produces estimates of the farm's income, taxes, cash flow, probability of survival, returns on assets, and debt levels. The FLIPSIM results define the farm's baseline financial performance needed to complete Objective 1.

The results from the two simulation models are combined to provide estimates of the corresponding farm level nitrogen and phosphorus losses and the farm's economic results under current management practices for representative farms A, B, and C. The results from the individual farms are combined to provide estimates for nutrient losses and financial returns on all county dairy and dairy/poultry farms.

The research procedure first estimates current nutrient losses and financial returns currently occurring on county dairy and dairy/poultry farms (Objective 1). The same simulation procedure used for Objective 1 is repeated with the changes associated with each policy added to the representative farm's parameters. The results from each additional farm simulation produce estimated nutrient losses and corresponding economic returns for each alternative policy (Objective 3). Associating the farm's nutrient losses with financial returns provides estimates of the farm level costs of achieving changes in nitrogen and phosphorus losses for each alternative manure management policy.

Objective 4 is accomplished by extrapolating representative farm results to county farm numbers. Each model farm represents a given farm size and is assumed to represent a certain number of corresponding county dairy and dairy/poultry farms. Summing representative farms' results provides an estimate of nitrogen and phosphorus losses occurring on county farms under current and alternative policies and the county level financial economic impacts associated with each alternative policy. The approach followed in this study provides information to policymakers with a measure of potential nutrient losses associated with alternative manure management methods and the corresponding farm level economic costs associated with each policy.

3.2 Alternative Manure Management Policies

The manure management policies examined in this study are general agronomic guidelines recommended to reduce nitrogen and phosphorus losses from agricultural production. The current practices defined by the farmer panels are referred to as the BASE farming operations. The first alternative manure management policy (INCORP) examined is the impact of manure being incorporated when applied to cropland without any growing crops. The second policy (NLIMIT) limits nitrogen applications to agronomic applications as for the specific crop and soil in VALUES (Virginia Agronomic Land Use Evaluation System) (Donohue et al.). The third policy (PLIMIT) limits phosphorus applications to estimated crop phosphorus removals reported in VALUES.

INCORP eliminates no-till planting of corn and rye when manure is applied. Since the manure is being applied to cropland without a growing crop, the manure must be incorporated into the soil. This is done with a tillage operation defined by the farmer panels. Tillage operations on fields normally planted no-till requires less use of pesticides, reducing overall chemical costs. Additional tillage, however, increases equipment operation and repair costs.

NLIMIT limits plant available nitrogen applications to soil type and crop agronomic recommendations. Under this policy all farmer panel defined crop and soil specific nitrogen applications that exceed agronomic recommendations are reduced to the agronomic recommendation. The agronomic recommendations followed in this study are set in VALUES, a publication of Virginia Tech's Department of Crop and Soil Environmental Sciences (CSES).

PLIMIT limits phosphorus applications to average removals by specific crops as reported in VALUES. Soil phosphorus levels are not reduced under this policy, but, do not increase, either. Under the phosphorus limitation, phosphorus fertilizer applications are reduced first, followed by poultry litter, and then dairy manure. Any additional nutrients that need to be added because of reductions in poultry or dairy manure are replaced by commercial fertilizer.

3.3 Representative Farm Models

The basic research unit employed in this study are the representative dairy and dairy/poultry farms. These farms typify a number of farms with the same production size, following the same general practices, and the same basic cropping systems. The representative farm is used in this study to determine the current nutrient practices and financial returns of Rockingham County farms. Modeling representative, or typical, farms can give approximate results for farms with similar characteristics. The farm is represented by characteristics such as machine inventory, acreage, crops, livestock numbers, production costs, and financial status.

Representative farms are developed to answer the study's first objective by identifying current manure management practices and nutrient losses on Rockingham County dairy and dairy/poultry farms. The interrelationship of crops, livestock, and nutrient flows to and from the farm are shown in Figure 3.2. The representative farm includes livestock and crop production sectors. Nutrients from farm-grown crops and purchased feedstuffs are inputs to the livestock sector. Nutrients leave the livestock sector as animal products and as manure that is generally recycled to the crop sector. Additional nutrients are imported to the farm as fertilizer for the crop sector. Nutrients are lost from the farm through nutrient losses. When nutrient imports exceed nutrient exports, the possibility of nutrient losses increases substantially.

To assess the current level of nutrient losses, each farm must be specifically defined with respect to farm size, field allocation, soil, acreage, crops grown, crop rotation, animal numbers, feed rations, feeding and production technology, machinery inventory, and financial characteristics. Defining the individual representative farm characteristics is done

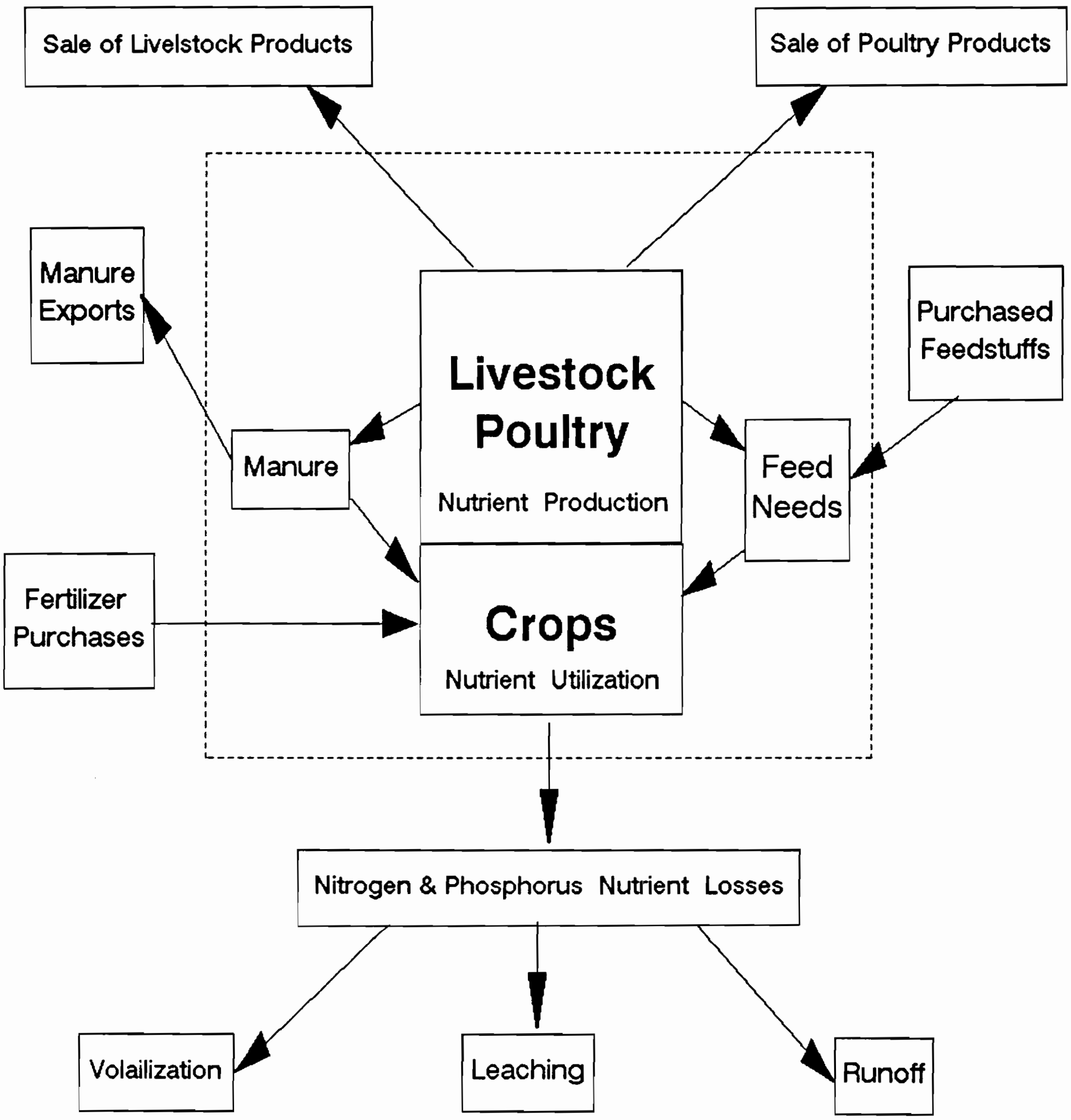


Figure 3.2. Farming System Nutrient Flow

by the procedure suggested by Richardson et al. (1994). The representative farm characteristics are determined by a panel of operators who possess and are willing to open detailed production and financial records. The concept of validation is straightforward - farmers themselves define and validate farm models which they believe represent typical farms in their region. The farmers themselves are considered to be the experts. However, before the farm panel defines the individual farm parameters, the representative farm's herd size and soil type are selected by experts familiar with the county.

3.3.1 Soil Physical Characteristics

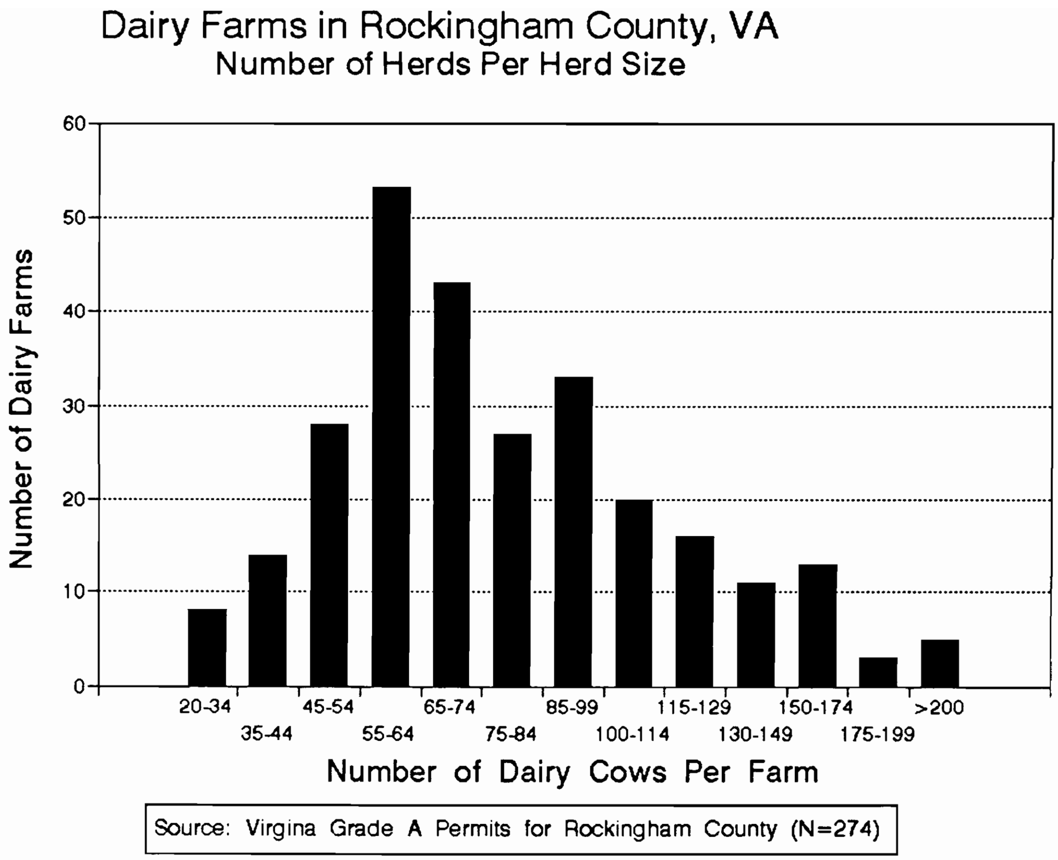
The representative farms for this study have soils typical of livestock production regions of Rockingham County. An examination of the USDA Soil Survey of Rockingham County indicates many crop and hay production areas are intermixed with soils of varying productivity levels. Using three soil types simplifies the simulation process and allows for more precise model calibration and is not expected to invalidate the results.

Virginia Tech soil specialists and county NRCS personnel recommended Frederick-Lodi silt loam soils as the soils for the representative farms. Soil classifications drawn from VALUES, identify Frederick-Lodi silt-loam-based soils as the most characteristic soil in Rockingham County, accounting for 43 percent of the cropland and 46 percent of the pasture acreage. The specific soils for the representative farm are Frederick-Lodi silt loam, 7 percent slope, for cropland (normally tilled), Frederick-Lodi cherty silt loam, 12 percent slope, for hay/pasture (land rarely tilled), and Frederick-Lodi rock outcrop, 15 percent slope, for permanent pasture (land too rough for tillage and haying). Detailed descriptions of the soil characteristics and parameters are included with the description of the EPIC model below.

3.3.2 Herd Sizes for Dairy and Dairy/Poultry Farms

Rockingham County has 274 Grade A dairy herds (Virginia Department of Agriculture), ranging in size from 22 to 700 dairy cows (Graph 3.1). Four herds are under 30 cows, four herds have between 200 and 252 cows, and one herd has 700 cows. Examining the distribution of herd sizes reveals the majority of herds are between 45 and 75 cows. Another cluster is found at 85 to 99 cows. Herd size frequency declines as the herd size increases. Area dairy extension agents and Virginia Tech dairy experts recommended herd sizes of 60, 100, and 150-cows as mid-points of groups expected to have similar farm sizes, production practices, and technology. Herd sizes up to 75 cows (146 herds) are modeled with the 60-cow representative farm. Herds sizes from 76 to 125 cows (92 herds) are modeled with the 100-cow representative farm. Herd sizes greater than 126 cows (36 herds) are modeled by the 150-cow representative farm.

The exact number of combination dairy/poultry farms in Rockingham County is not known but different sources indicate that there are between 59 and 107 dairy/poultry farms. Geographical Information Systems (GIS) surveys identify 107 (39.1 percent) county dairy farms with poultry structures. Halstead et al. (1988) reported that 30 percent of respondents from a 1987 survey of county dairy farmers had poultry operations. Bosch et al. reported that 32 percent of dairy farms surveyed in 1990 reported having poultry operations. Rockingham County nutrient management plans identify 59 (21.5 percent) dairy farms with



Graph 3.1. Dairy Herds in Rockingham County

poultry operations. Virginia's Department of Environmental Quality (DEQ) has written nutrient management plans for 19 dairy/poultry farms in Rockingham County (Shiflett). From these sources, the high number of 107 farms listed in the GIS files does not account for the likelihood that some farms are not currently operating dairy and poultry operations. On the low side, farmers filing nutrient management plans are not the sum of county and DEQ totals as there is a possibility of double counting farms from these two sources. It is also likely that some operating dairy/poultry farms have not filed for current nutrient management plans.

This study assumes that 30 percent of the county's dairy farms have broiler or turkey operations and herd sizes are proportional to the breakdown of dairy farms listed above. This assumes that the county has 83 dairy/poultry farms, 44 60-cow farms, 28 100-cow farms, and 11 150-cow farms. The dairy farms without poultry operations are distributed as 102 60-cow farms, 64-100-cow farms, and 25 150-cow farms.

3.3.3 Farm Specification

Representative farms are formulated by a "farmer-panel", a process that is followed by research scientists at the Agricultural and Food Policy Center (AFPC), Texas A&M University, for use with examining alternative farm policies with FLIPSIM. AFPC uses farm production, cost, and financial information gathered from farmer panels to simulate the economic impact of alternative policies on more than 75 nation-wide representative farms. These FLIPSIM farm models are used to analyze farm level policy alternatives for the United States Senate and House of Representatives Agriculture Committees and have been utilized during the 1985, 1990, and 1995 farm bill debates (Richardson et al., 1994).

The panel farm process followed by Texas A&M researchers elicits farm level data from a group of full time commercial farmers whose own farm operations are approximately of similar size and enterprise mix. Their process starts with asking state extension specialists to cooperate in defining a typical farm for their area. The specialists, in cooperation local extension agents and other area farm experts, identify producers who are considered to be typical operators within the study area. One key to the process is the ability of extension personnel to identify farmers who are willing to share their farm production, financial, and tax records with researchers.

Data supplied by the farmer panel includes production size, acreage, crops and animal units, variable production costs, farm fixed costs, expected yields, and machinery inventory. Once the panel's data is collected, the information is processed and returned to the panel for review and agreement on individual components. The data is then used in FLIPSIM to develop pro forma farm financial statements. The financial data is resubmitted and reviewed by the farmer panel and changes are made upon panel recommendation via conference call. The process is repeated until the panel is satisfied that the financial projections are reasonable for the type of full time commercial farm operation being modeled. This procedure uses the producers' expertise to validate the model's ability to simulate a representative farm and to assure that the simulated farm is considered by producers to be typical of actual farming conditions. The interaction with the farmer groups assures that the farmers themselves believe that the models are representative of area farms. In this process, the farm parameters depend on experts who are most familiar with the farm parameters and include actual farm costs and receipts. Panel farms have been compared to the USDA-ERS Farm Cost and Returns Survey and have generally proven to be representative of the farms in the study areas (Richardson et al., 1994).

3.3.4 Farm Parameter Elicitation Process

Following the guidelines suggested by Richardson (1994), a panel of three Rockingham County farmers were selected for each representative dairy farm. The selection procedure involved an initial farmer contact by extension agent and then by phone with the researcher to outline the objectives and requirements of the project and obtain the farmers' cooperation and involvement. The second step involved a one-on-one meeting with the researcher and the farmer at a time of his choosing. The third step brought the farmer panel together for a dinner and established the final parameters for each representative farm. This session allowed an interchange between the farmers and expression of opinions. The last step had the panel confirm the results of the representative farm financial simulation as put together by the researcher. The panel elicitation process was conducted during April, May, and June of 1994.

The district extension dairy management agent made the crucial initial farmer contact. This step is of great assistance as the extension agent knew which farmers might be cooperative, which farmers have the required detailed records and knowledge of area farming practices, and who would share their records with researchers. The assistance of the extension agent assured receiving greater initial cooperation from local farmers.

The researcher contacted each farmer identified by the dairy extension agent by phone and explained the research project's objectives and the importance of farmer involvement to model representative farms. The farmer was assured that access to all production and financial records for 1993 was necessary and the interview session required about 3 hours of time. Upon the farmer's approval farm interview appointments were made at the farmer's convenience. The on-farm interviews all followed a set pattern. Initial introductions opened the interviews with a general explanation of the project's goals and specifically the importance of the role of representative farms. The researcher and the farmer briefly examined the 10-page data form together so the farmer could determine what records they needed to complete the data form.

The interview began with defining farm and crop acreage. The second part of the form requested crop production practices as type, amount, and dates of manure, fertilizer, and pesticides applied, tillage, harvesting, and yields. Cost information was requested on fertilizer, pesticides, and custom harvesting. Difficulty was incurred in obtaining detailed pesticide and fertilizer application cost because many farmers employed custom fertilizer and pesticides applications from dealers. With regard to pesticides, farmers generally do not want to deal with regulations, storage, and record requirements of handling hazardous pesticides. None of the farmers allocated machinery repair and fuel costs on a per acre basis. This is expected as dairy farms grow multiple crops and interchange tractors for a multitude of uses and rarely calculate costs on a per acre basis.

The data form requested additional information farm assets, including land, machinery, and cattle, and liabilities. Farm machinery inventory is determined from the farm's machinery tax depreciation schedule. Farm expenses are requested for all farm operations. Correct cost elicitation requires that specific farm expenses are defined the same by all the farmers. For example, animal drug costs are incurred by all dairy farmers but some may list drug costs under general farm supplies, another under dairy supplies, and another under veterinary services.

The farmer's final 1993 DHIA summary sheet provided most of the data for the dairy herd. The farmers did have some problem breaking herd replacements into specific age groups and determining total calvings per year. Seasonal feed sources such as ryelage and pasture complicated elicitation of the dairy herd rations. FLIPSIM determines ration requirements on an annual basis so all rations have to be determined for annual feeding to specific age groups.

The third step in formulating the representative farms is to have the farmers meet as a group and agree on the specific parameters of the representative farm. The three farmers and their spouses in each panel were invited to a restaurant for dinner for the session. Each farmer received a form that listed the high and low values for each parameter and county average figures when available. The farmers went over each parameter and came to an agreement on what they believed are typical for county farms of the specific herd size. The panel gave serious thought to the process, rarely selecting average values and at times selected values above or below the highest or lowest figure.

The procedure followed in this study differed somewhat from that described by Richardson et al. (1994). Richardson et al. (1994) normally has the farmers bring their records to a central location. This study obtained all farm records at the farm where the farmer had access to all of their records and benefitted from other family members being available for input. The reason for this procedural change was that farmers are more willing to open their records to a stranger in their own homes. The personal home visits also presents less chance of unanticipated problems. Overall, the data collection procedure went quite well and all farmers were extremely cooperative at offering their assistance. The specific parameters specified by the farmer panels are listed in Table 3.1. The dairy/poultry farms are modeled by adding two poultry houses to the existing dairy farm. Data for the poultry operations are determined from Virginia Tech poultry production budgets (Zhu).

Farm acreage is divided among cropland, hay-pasture, and permanent pasture to conform with the soils defined by the soil experts. Cropland is the most productive soil, conductive for normal tillage, and generally used for corn and alfalfa. Land used for hay and pasture is the steeper, more shallow Frederick-Lodi cherty silt loam. This soil is generally not tilled except for seeding but is conducive for machinery operations for harvesting hay. Permanent pasture is land rarely tilled and characterized by rock outcroppings, partially wooded, and too steep and rough for hay equipment. All three farmer panels agreed that approximately 50 percent of permanent pasture is too rough to apply manure or fertilizer. Other acreage is defined as acres used for the loafing area, farmstead, and non-farm use.

The cropland acres for the representative farms are 70, 125, and 200 acres, respectively. Acres per dairy cow ranged from 1.17 to 1.33, from the smallest to the largest farm. When pasture acreage is added to total available acreage, the animal density becomes more variable, 1.83 (60-cows) to 1.95 (100-cows) to 2.46 (150-cows) acres per dairy cow. These numbers reflect observations by the farmer panels that the 60 and 100-cow dairies are close to the feasible animal densities without obtaining additional land. Their conclusions are based on land needed for forage production, not on the land base necessary for manure application. A general rule expressed by the farmers is the need to have one acre of corn silage per cow.

Table 3.1. Representative Farm Parameters

Farm Parameters	60-Cow Dairy	100-Cow Dairy	150-Cow Dairy
Farm Cropland, Hay, and Pasture (Acres)			
Corn Silage/Ryelage	50	50	60
Corn Silage/Rye Cover	0	50	60
Corn Silage/No Cover	0	0	30
Total Silage Corn	50	100	150
Established Alfalfa	15	18.75	30
New Alfalfa Seeding	5	6.25	10
Alfalfa	20	25	40
Grass Hay	0	0	10
Total Cropland (Acres)	70	125	200
Hay/Pasture	20	45	60
Pasture	20	25	110
Sacrifice Lot	5	10	10
Total Hay, Pasture, and Other	45	80	180
Total Farm Acreage	115	205	380
Owned Land (Acres)			
Cropland	70	94	140
Hay/Pasture	20	34	42
Pasture and Sacrifice Lot	25	29	87
Rented Land (Acres)			
Cropland	0	31	60
Hay/Pasture	0	11	18
Pasture	0	6	33
Rental Rates ($/Acre)			
Cropland	0	45	45
Hay & Pasture	0	35	35
Dairy Herd Parameters (Annual)			
Total Milk Cows	60	100	150
Calves Over 1 Day Old	65	112	168
Calving Loss (%)	4	4	4
Average Number of Dry Cows	9	16	23
Cows Culled	21	36	54
Death Loss (Cows)	1	2	3
Dairy Bulls	0	2	2
Calving Interval (Months)	13.5	13.5	13.9
Average Days Dry (Per Cow)	65	70	66
Age First Calving (Months)	27.5	28	28
Value of Cows	1200	1200	1200
Pounds Milk Sold (Cow/Year)	18,000	18,000	18,400
Milk Sold (Pounds Per Year)	1,080,000	1,800,000	2,760,000

Table 3-1. (Continued) Representative Farm Parameters			
Farm Parameters	60-Cow Dairy	100-Cow Dairy	150-Cow Dairy
Farm Expenses ($/Year)			
Property Taxes	2250	2745	3548
Personal Taxes	340	525	800
Other Taxes	70	300	300
Accountant & Legal Fees	450	800	1000
Repairs & Maintenance	8500	12,400	19,000
Insurance	2500	3500	5000
Phone, Fuel, Utilities	6900	10,300	14,600
Building Depreciation	4500	7000	8800
Machinery Depreciation	8500	14,000	17,000
Total Cash Expenses (Less Depreciation)	21,010	30,570	44,248
Total Expenses (Including Depreciation)	34,010	51,570	70,048
Farm Labor			
Number of Partners	1	2	2
Full Time Employees	0.5	0	1
Salary Per Employee ($)	15,000	0	18,400
Part Time Labor Costs ($)	6000	11,500	17,000
Labor Costs	13,500	11,500	35,400
Dairy Costs ($)			
Vet & Medicine	4200	4500	6750
Breeding	2700	3500	6000
Milking Supplies	4380	8000	12,530
DHIA	1320	2200	3300
Livestock Sale Fees & Bedding	1500	1950	2550
Manure Hauling	2025	3202	4427
Total Dairy Costs	16,125	23,352	35,557
Farm Assets			
Real Estate	210,000	316,300	522,000
Dairy Facilities	150,000	175,000	200,000
Residences	80,000	120,000	160,000
Farm Machinery	70,000	110,000	170,000
Beginning Feed Inventory	18,500	33,600	59,500
Cash on Hand	1000	1500	5000
Livestock	84,800	143,000	245,000
Total Assets	614,300	899,400	1,361,500
Liabilities			
Long Term Debt	108,000	180,000	270,000
Intermediate Debt	72,000	120,000	180,000
Total Debt	180,000	300,000	450,000
Net Worth	434,300	599,400	911,400
Debt/Asset Ratio	0.293	0.333	0.331

The panels indicated that the larger farms commonly rented additional land but few of the smaller farms had open land available in close proximity to their farms. The farmers agreed that the majority of the 60-cow dairy herds are in an area predominated by members of the Mennonite religion. Dairy farming is very intensive in this region and very little acreage is available for rental.

Land values (per acre) are estimated to be very similar for the 100 and 150-cow farms while the estimates for the 60-cow farm are lower. The value of dairy facilities is relatively lower on a per cow basis for the 100 and 150-cow herds. Owners's residences are higher for the larger herds as residences are required for two families. Residence values presented some difficulty for the panels as the farmers tended to think of the total value for land and buildings. Other asset values are beginning feed inventories and market value of farm machinery. The machinery value is relatively higher for the 150-cow dairy farms because of additional acreage.

Repairs and maintenance costs are considerably higher for the 150-cow farm, which is expected with a larger machinery inventory. The annual deprecation value for buildings decided upon by the farmer panel is assumed to be constant over the study period at the recommendation of Richardson. The farmers indicated that building depreciation on most farms varies very little because of the long term depreciation periods. Initial machinery depreciation begins at the panel's specified level and varies over the study period because machinery ages beyond depreciation periods and the addition of new machinery. The farmers indicated that annual depreciation on individual farms can vary widely, influenced by recent replacement of high price machinery and the use of Section 179 expensing. Property and personal taxes are determined from tax rates obtained from the Rockingham

County Tax Assessment Office. Other taxes included personal property taxes on personal vehicles used for farm uses.

Each farm is assumed to be owner-operated. The common exception to this case is farmers renting from parents or other family members in which case the farmer is generally planning to acquire the property by purchase or inheritance. The 60-cow dairy is defined as a single family operation with some part-time paid family help. The 100 and 150-cow farms are defined as being two-family partnerships. The panels indicated that the farms may not be in a formal partnership but both members contribute toward labor and management needs. The 100-cow farm has one half-time employee and additional paid family labor. The 150-cow dairy farm has 1 full-time employee plus part-time family and non-family labor.

The farms in this study are assumed to remain at the same herd size over the study period. The farmer panels set milk production at 18,000 pounds of milk sold per cow for the 60 and 100-cow herds and 18,400 pounds for the 150-cow herds. Although there is a wide variation of milk production across the county, the typical producer is considered a progressive manager with respect to dairy management. The larger herds tended to use bulls for some breeding and had a higher age at calving and a longer calving interval. None of the farmers are using bovine somatotropin (bST) and they do not expect many farms in the area to adopt it in the near future.

Farmers agreed upon feed requirements for forages and used Virginia Tech's dairy ration budgets as a guide for concentrate use because of the variation in feed rations between farms (Virginia Cooperative Extension). The committee selected feeding corn silage year around, with ryelage and pasture utilized when available. Grain corn is used when available and most concentrate is purchased. Farmers expressed that in most years all corn acreage is harvested for silage and only occasionally for corn grain.

Dairy expenses include costs of dairy and feeding equipment maintenance and repairs, nutritional consultant, and general miscellaneous costs attributed to the dairy operation. Per cow DHIA costs are obtained from the state association office at Virginia Tech. Livestock commissions and hauling costs are lower for the larger herds, as these herds hauled their own culls. Manure hauling costs are listed under miscellaneous costs. The panels agreed with county extension estimates that most county dairy farms (85 percent) have a manure storage structure (Roller, 1994). The general consensus is that custom manure hauling service in the county is common and economical for the farmer. The custom hauler spreads with two or three trucks and operates up to 18 hours per day. This saves the farmer considerable time at a time of the year when his labor and equipment are in high demand and saves the cost of owning and operating an agitator, a large liquid spreader, and another large tractor.

The farmer panels agreed on the machinery inventory, market value, and typical annual machinery depreciation. However, the individual values of each machine are assigned by the researcher and reviewed by the farmer panel for specified market value and annual depreciation. Richardson recommended this method because, as the panelists confirmed, the actual age of specific machines varies tremendously across farms while the market value and annual depreciation are less variable.

The farmer panels indicated they did not have very much knowledge on the debt levels of individual farms. They did agree that debt levels vary tremendously between farms and are not believed to be necessarily correlated with herd size and adopted technologies.

However, the each farm's debt structure is a key factor determining whether a farm survives financially and its capability to adopt new management practices. Lacking direction from the farm panels on farm debt, the researcher consulted agricultural lenders in Rockingham County. They indicated that typical dairy farm debt is around $3000 per cow. Higher debt levels are common for farmers who recently purchased farmland or built new production facilities. However, it is rare for farms to support debt levels above $4500 per cow without off-farm income providing extra cash. For the financial analysis in this study, baseline representative farm debt is set at $3000 per cow.

3.3.5 Crops, Cropping Practices, and Nutrient Applications

Corn silage is the primary forage crop on dairy farms in Rockingham County, and is commonly fed to cows year round. A few acres of alfalfa are grown on most farms. The relatively small alfalfa acreage limits crop rotation, causing most of each farm's cropland acreage to remain in continuous corn for several years. Assuming a four year life for alfalfa, only 5, 6.25, and 10 acres, respectively, are commonly rotated from alfalfa to corn each year for the 60, 100, and 150-cow farms. Rotations based on the alfalfa turnover requires most cropland to remain in corn for up to 15 years.

Dairy needs for forage have led to the utilization of winter rye cover crops planted after corn as a supplemental spring forage source. Rye can be planted later in the fall than wheat, barley, or grasses. This gives farmers a longer time period in which to remove corn crops and still have time to sow a winter cover crop. Rye also begins active growth in the spring before most plants, attaining quality forage stage (pre-boot) early in the growing season. Farmers can harvest rye to provide additional forage production without delaying spring corn planting. However, rapid spring growth of rye allows for a narrow harvest window which, in combination with adverse weather conditions, limits farmers' ability to harvest all acreage in a timely manner to assure quality forage. Consequently, the farmer panels estimated that harvested rye acres changes little with farm size. The larger farms are not able to harvest a greater proportion of ryelage in a timely manner that preserves feed quality because of other cropping and dairy production demands on their time and labor. However, the panels noted that farmers make greater efforts to harvest additional ryelage when the previous year's corn silage harvest is deficient.

Land used for grass hay increases with herd size. This land consists of mixed grasses with a hay crop removed in early summer, either pastured or harvested for hay later in the summer, and used for fall grazing when available. The main cropping limitations on this land are the slope and rock content which makes it less suitable for tillage. Yields are susceptible to drought conditions that commonly occur during summer months. Pasture acreage is relatively small on the 60 and 100-cow farms while the 150-cow dairy has a much larger pasture acreage. Each of the farmer panels agreed that approximately 50 percent of permanent pastures are too steep, rocky, or rough for normal manure spreading or fertilizer application and thus received minimal management. Each farm had an area estimated at 5 acres for the 60-cow farm and 10 acres for the 100 and 150-cow farms for as "sacrifice area", a loafing area for the dairy herd where vegetation is not sustained.

Crop practices are fairly constant across farms. Each farmer panel decided that corn tillage methods are split evenly between no-till and minimum tillage, which is defined as two passes over the field: one pass with an off-set disk and one with a finishing disk. The rye is planted with a rented seeder after corn silage harvest and a dairy manure application, with the acreage split evenly between no-till and minimum tillage. Corn that is planted no-till in the spring is followed in the fall by minimum till rye. Corn undergoing minimum tillage in the spring is followed by no-till rye in the fall. Alfalfa is generally planted with a rented no-till planter.

The panels agreed all representative farms' fertility regimes are primarily based on the use of dairy and poultry manure. All the panel farmers used their dairy manure on all crop acreage and all but one farmer acquired poultry litter to supplement crop nutrient needs. The farmer panel for the 60-cow herd indicated that many of the smaller herd owners in the county are located close to family members who operate poultry operations on small acreage. A common practice for these farmers is to exchange labor and equipment to clean the poultry house in exchange for the litter. This arrangement allows the farmer to acquire the litter for only the variable cost of operating his equipment. The cleaning is usually done during a slack time period so labor costs are not considered by the farmer. The 100 and 150-cow farms normally acquired from a neighboring poultry operation or broker. Costs depended upon the amount of work provided by the dairy farmer with respect to loading, cleaning, and transporting. The cash costs for the 60-cow farm (fuel and repairs) are considered to be incorporated into the farm's operating expenses. The 100 and 150-cow farms pay $6 per ton for litter from neighbors or litter brokers.

The use of commercial fertilizer on corn is limited to starter nitrogen and trace minerals for the 100 and 150-cow farms. Only trace minerals are applied to corn on the 60-cow farm. Alfalfa receives 50 pounds of phosphate and 200 pounds of potassium per acre per year. Grass hay and pastures receive only dairy manure and poultry litter. Pesticides are applied at rates recommended by crop consultants or fertilizer dealers on corn and alfalfa. Farm elicited pesticide and fertilizer costs and Virginia Cooperative Extension farm budgets provided guidelines for the farmers' specification of crop production costs.

The farmer panels indicated that the typical farm follows good conservation practices. The farmers' interpretation is generally related to soil conservation through crop and land management. The farmers agreed that most farmers used commonly accepted best management practices such as contour tillage, strip cropping, sod waterways, filter strips, and reduced tillage on slopes and water drainage channels. Overgrazing is not thought to be a major problem on most pastures. The farmers did indicate that the dairy sacrifice lot near the barn presented the greatest threat from erosion although they did not directly relate this lot to reduced water quality if the eroding soil is filtered out in an adjoining sod field. Based on farmer opinions, each representative farm is modeled with good conservation practices to reduce potential erosion.

3.3.6 Farm Manure Production, Storage, and Application

The farmer panels estimated their total farm manure collection and storage but could not estimate the relative proportions that came from manure, parlor and milkhouse wash water, and surface runoff involved. The proportion of each ingredient collected in the manure storage is estimated to match the farmer estimates of total liquid collection. The amount of manure collected is determined with the assistance of Virginia's Nutrient Management Handbook (Virginia Department of Conservation and Recreation), MidWest Plan Service, extension dairy agents, and agricultural engineers. The figures were then presented to the farmers again, and were accepted with only minor changes. Calculated farm manure and runoff collection values are shown in Table 3.2.

Table 3.2. Farm Manure Production.

	60-Cows	100-Cows	150-Cows
Manure Structure Specifications[1]			
Height (ft)	15	15	15
Width (ft)	50	60	66
Capacity (gals)[2]	205,617	296,089	358,267
Total Manure[1]			
Cows (14.5 gal/hd/day)	317,550	529,250	723,875
Calves (5.2 gal/hd/day)	51,246	87,308	132,980
Yearlings (8.8 gal/hd/day)	73,876	131,692	195,932
Springers (11.4 gal/hd/day)	24,309	44,567	81,030
Total Manure Produced (gal/yr)	466,981	792,817	1,203,697
Manure Collected Per Year			
Cows (70%)	222,285	370,475	555,713
Calves (50%)	25,623	43,654	66,430
Yearlings (20%)	14,775	26,338	39,186
Springers (25%)	6,077	11,142	20,258
Total Manure Collected (gal)	268,760	451,609	681,586
Parlor Wash (gal/year)[3]	131,400	182,500	219,000
Gal/cow/day	6	5	4
Lot Runoff (gal/year)[3]	16,633	27,721	41,581
Surface Rainfall (gal/year)[3]	29,481	42,453	51,368
Total Liquid Collected Per Year	446,274	704,283	993,536
Structure Capacity (months)	5.5	5.0	4.4
Cleanout Ratio (times per year)	2.2	2.4	2.8

1. Manure structure specifications and daily animal manure values are from MidWest Plan Service.
2. Structure capacity does not include one foot freeboard.
3. Parlor wash, lot runoff, and surface rainfall collection values are from the Virginia Nutrient Management Handbook.

It is assumed that 70 percent of manure from milking cows is collected. This figure is used by Halstead (1989) and found acceptable by the farmer panels and extension personnel. Lesser amounts are used for calves, yearlings, and springers. These animals are generally kept on pasture when possible and some are kept inside during winter months or brought into barns for feeding. The farmers and dairy experts conceded that manure collection varies widely between farms; but in all cases the amount of manure attributed to the dairy herd accounts for over 80 percent of the collected manure.

Additional liquid collected in the manure pits includes parlor wash, lot collection and runoff, and pit surface collection. Parlor wash and surface rain collection are determined from formulas provided in the Virginia Nutrient Management Handbook. Lot runoff consists of surface drainage running into dairy loafing areas and runoff from exposed paved or concrete areas that collect rainfall. It is assumed that 20 percent of recommended square footage gathered surface rainfall. The collected runoff, pit surface rainfall collection, and factoring surface evaporation are calculated by formulas in the Virginia Nutrient Management Handbook.

Manure storage structures on panel members' farms ranged from earthen basins to fiberglass structures. The panels indicated that the typical structure is a round concrete structure. The 150-cow farm is the most restricted by manure storage. The farmers believed these farms are generally the first ones to install manure structures and have since expanded their herds. Based on estimated manure storage capacities and collection, the typical 150-cow herd barely exceeded 120 day storage capacity. The 60 and 100-cow herds are more likely to have the newest structures, with an estimated 150 day or more storage capacity. The 120 day capacity is barely sufficient to prevent applying manure to non-growing crops, equivalent to the time period between mid-November and mid-March. The 150 day storage capacity of the 60 and 100-cow herds is adequate to prevent applications on non-growing crops.

The nitrogen, phosphorus, and potassium nutrient values for the dairy and poultry litter used in this study are mean sample values from Virginia Tech's Manure Testing Laboratory and are listed in Table 3.3. The values for poultry litter are based on the proportions of turkey and broiler litter produced in the county (See Table 2.1). Farmers are assumed to apply poultry litter that is 57.5 percent turkey and 42.5 percent broiler litter, and nutrient values are proportionally credited (1992 Census of Agriculture). The values reported in Table 3.3 are used as the nutrient content of manure applications in the EPIC simulations.

Table 3.3. Manure Nutrient Fractional and Quantity Values.[1]

	Units	Percent Moisture (%)	Dry Weight (lbs.)	Nutrient Weights Per Unit MN[2] (lbs.)	ON[2] (lbs.)	Phos[3] (lbs.)	K_2O (lbs.)
Dairy Manure	1000 gal	94.5	457	8.6	12.3	5.3	18.5
Poultry Litter	Ton	66.2	1323	14.6	49.0	27.8	20.5

1. All values are means from manure samples at the Virginia Tech Manure Testing Lab.
2. MN refers to mineral or inorganic nitrogen and ON refers to organic nitrogen.
3. "Phos" refers to phosphorus (P) content, not phosphate (P_2O_5).

The calculation of total plant available nitrogen applied to individual fields is determined by the procedure recommended by the Virginia Nutrient Management Handbook.

The expected fractional amount of mineral nitrogen available from dairy manure and poultry litter, respectively, in the year of application, are 0.65 and 0.80 for incorporation within 2 days and 0.25 and 0.50 for surface application without incorporation. The fractional amount of organic nitrogen available in the year of application is 0.35 for dairy manure and 0.60 for poultry litter. The formula for determining residual values of manure organic nitrogen when detailed manure history is available is:

$$\text{Plant Available Nitrogen in Year t} = 0.12 * ON_{t-1} + 0.05 * ON_{t-2} + 0.02 * ON_{t-3} \quad (3\text{-}1)$$

where ON is total organic nitrogen applied in year t (i=1,2,3).

An example of the calculation of total plant available nitrogen for the 60-cow dairy is shown in Table 3.4 and is based on nutrient values reported in Table 3.3. The calculation of residual nitrogen is based on panel recommendations that manure applications have been identical over the previous three years. The 60-cow farm applies three tons of poultry litter in early spring. The plant available nitrogen from this application equals 50 percent of the mineral nitrogen (not incorporated) plus 60 percent of the organic nitrogen. The residual nitrogen from previous litter applications is calculated from formula 3-1. Following the same procedure for the dairy manure and summing equals 211.6 pounds of nitrogen from current and past manure applications.

Baseline dairy manure and poultry litter applications, nutrient content, and plant available nitrogen for each farm's crops are listed in Table 3.5. Dairy manure is applied at equal rates to corn in the spring before corn planting and in the fall between harvest and planting rye. Corn silage has the highest priority for application, followed by grass hay, and then pasture. The 60-cow farm applies the heaviest manure application per acre and has adequate manure to apply to cropland and pastures. None of the farms apply manure to established alfalfa (years 1 to 3) because they believed manure encourages weed growth. Depending upon manure availability, the 60-cow dairy is likely to apply manure in the fall to alfalfa (years 4 of alfalfa stand) being rotated to corn in the following year. The 100-cow farm spreads dairy manure on all cropland and grass hay acreage but did not have adequate manure to apply on pastures. The 150-cow dairy had adequate supplies to apply manure to cropland, grass hay and pastures but at lower rates than the other dairies.

Table 3.4. Calculation of Plant Available Nitrogen for Corn Silage/Ryelage on the 60-Cow Dairy Farm.[1]

	Nitrogen Availability Mineral		Organic	Manure Applied		Available Nitrogen
Poultry Litter	(0.5 * 14.6)	+	(0.6 * 49.0)	* 3.0 tons	=	110.1
Dairy Manure	(0.25 * 8.6)	+	(0.35 * 12.3)	* 3500 gal	=	22.6
Dairy Manure	(0.65 * 8.6)	+	(0.35 * 12.3)	* 3500 gal	=	34.6
Total First Year						167.3
Residual Nitrogen	Coefficients		Org Nitrogen	Quantity		
Dairy Manure	(0.12 + 0.05 + 0.02)		* 12.3	* 7000 gal	=	16.4
Poultry Litter	(0.12 + 0.05 + 0.02)		* 49.0	* 3 tons	=	27.9
Total Available Nitrogen (lbs/acre)						211.6

[1] Nutrients include 3500 gallons of dairy manure and 3 tons of poultry litter surface applied in spring and 3500 gallons of incorporated dairy manure in the fall.

Table 3.5. Dairy Manure and Litter Applications, Nutrient Content, and Plant Available Nitrogen.

Crop[2]	Dairy Manure (gals/acre)	Poultry Litter (tons/acre)	MN	Manure Nutrients[1] ON	P	K_2O	Fertilizer Nitrogen (lbs/acre)	Plant-Avail Nitrogen (lbs/acre)
				(Pounds Per Acre)				
60-Cow								
Corn/Rlge	7000	3.0	104	235	124	191	0	211
Hay	2600	2.5	59	155	85	99	0	138
Pasture	2500	2.5	58	153	84	98	0	137
100-Cow								
Corn/Rlge	6000	2.0	81	171	88	152	25	180
Corn/Rye	6000	2.0	81	171	88	152	25	180
Hay	2500	3.0	65	178	99	108	0	160
Pasture	0	2.0	29	98	57	41	0	138
150-Cow								
Corn/Rlge	5000	2.0	72	161	83	134	25	170
Corn/Rye	5000	2.0	72	161	83	134	25	170
Corn	5000	2.0	72	161	83	134	25	170
Grass Hay	3500	3.0	74	190	103	126	0	169
Hay	1500	1.5	35	92	51	48	0	82
Pasture	1500	1.5	38	92	51	48	0	82

1. MN is mineral nitrogen, ON is organic nitrogen, P is phosphorus, and K_2O is potassium.
2. Nutrients applied to alfalfa included 50 pounds of P_2O_5 for all alfalfa and 125 pounds of K_2O for new seedings and 200 pounds of K_2O for established seedings. Fertility regime is the same for each representative farm.

All three dairies apply poultry litter to their cropland, grass hay land, and pastures. Rates varied from 3 tons per acre on corn to 1.5 tons per acre on pastures. All the farmers expressed satisfaction with poultry litter and believe that litter increases soil fertility and structure. The representative 60, 100, and 150-cow dairy farms annually apply 225, 360, and 502 tons, respectively, of poultry litter per farm.

Modeling the financial adjustments made by the farms for different levels of litter and nutrient applications under each alternative management system begins with defining base costs. The 60-cow farm is currently cleaning and spreading their relative/neighbor's poultry house in exchange for the litter. The total variable costs are included in the farm's baseline operation costs.

The farmer panels indicated that poultry litter acquisition for the 100 and 150-cow dairy farms varies widely. Procurement ranges from the exchange procedure used by the 60-cow dairies to buying and having the litter custom spread in the field. The swap arrangement is less common among larger farms because they less flexible labor demands from their farming operations. However, farmers characteristically utilized their own equipment when time and cash opportunities are present. The farmer panels decided that the typical farmer purchases litter for an average cash cost of $6.00 per ton and spreads the litter in their own fields. The farmer panels believed this combination balanced out the procurement and spreading variation across county dairy farms. The variable costs incurred for applying the litter are included in the baseline 100 and 150-cow farm operation expenses.

Spreading litter can be done with the farmer's manure spreader or with a rented spreader. The rented spreader is a six-ton capacity spinner spreader that rents for $85-100 per day (Roller, 1995). According to custom renters, two-to-three six-ton loads can be hauled and spread per hour with a 70 horsepower tractor, depending on distance to fields. Many farmers use their own spreaders but cannot attain the spreading precision or capacity achieved with the spinner spreaders. The farmer panel indicated that spreader rental is fairly common and many individuals operate around the clock to reduce rental costs. For this study the panels agreed it is feasible to operate rented spreaders for 10-12 hours per day and attain 2.5 loads per hour. The 60-cow farm likely uses fewer hours while the 100 and 150-cow farms use longer hours during the day due to greater labor availability.

The farmer panels did not have estimates of direct farm expenses for spreading litter. This required calculating costs from Virginia Cooperative Extension farm equipment budgets and obtaining agreement with the farmer panels on budgeted costs. The variable costs for spreading poultry litter for each farm's baseline and with the NLIMIT policy are listed in Table 3.6. The farmer panel indicated that these costs seem reasonable. The panel members agreed that actual costs vary from farm to farm depending on the type, age, and maintenance of individual equipment. Several members of the farmer panel indicated that repair costs are hard to allocate, and the typical farmer does not think of added repair costs when operating equipment additional hours.

Table 3.6. Poultry Litter Spreading Costs for BASE and NLIMIT Policies.[1]

	Farmer Incurred Variable Costs for Spreading Poultry Litter					
	60-Cow Dairy Farm		100-Cow Dairy Farm		150-Cow Dairy Farm	
	BASE (225 tons)	NLIMIT (195 tons)	BASE (360 tons)	NLIMIT (320 tons)	BASE (503 tons)	NLIMIT (454 tons)
Hours Spreading	15	13	24	21	34	30
Loader ($5.21/hr.)	26	23	42	37	59	52
Spreader ($100/day)	200	200	200	200	300	300
Tractor ($5.89/hr.)	88	77	141	125	198	178
Total Costs	314	300	383	362	557	530
Cost Per Ton	1.39	1.53	1.06	1.13	1.11	1.17

1. Costs are direct equipment operating costs incurred by the farmer. No cash charges are included for labor or litter.
2. Estimated equipment operating costs are from Virginia Cooperative Extension farm budgets. Costs include fuel and repairs for a 60 horse power tractor for the loader and a 70 horse power tractor for pulling the spreader. The loader is assumed to operate during one third of the spreading hours. Spreader cost is current rental rate by spreader rentals. The spreader is a six-ton capacity spinner spreader, assuming 2.5 loads per hour, and 10-12 hours of use per day.

Manure spreading costs are identical under the manure incorporation because manure application amounts and methods do not change. With the PLIMIT policy, no poultry litter is being applied so the farms do not incur spreading costs.

3.3.7 Poultry Operation Specification

For this study it is assumed that 30 percent of Grade A dairy herds in Rockingham County have poultry operations. The reasons for this phenomenon are a combination of the need for farms to increase farm income and the stable income opportunity presented by the addition of a poultry enterprise. Projections from FAPRI (Food and Agricultural Policy Resource Institute) for the 1995 farm bill predict dairy prices to decline over the next five years while most production costs are expected to increase. Dairy farmers facing a decline in gross income have limited choices to remain economically viable. Basically they can either lower production expenses, increase milk sales per cow, or add additional cows. However, these options may not be able to provide enough additional income to maintain farm viability due to additional debt or management constraints.

Dairy farms have several characteristics that make the addition of poultry operations appealing. One characteristic is a synergistic employment of assets, in which utilization of underemployed resources can result in greater returns when the two production sectors are combined. Many of the dairy farms depend primarily upon family labor, which is considered more of a fixed rather than a variable cost. The goal of the farm is to provide income for family members, not necessarily to minimize labor costs for the farming operation. Thus some farms are likely to have under utilized labor resources. Poultry, to a lesser extent than dairy, requires some labor each day of the year. Since dairies have someone milking and feeding every day, not much additional time is required to fulfil labor requirements of the poultry operation. The dairy farm can meet the labor requirements without adding additional labor costs.

The majority of the equipment required for the poultry operation is specialized. However, a major variable cost of broiler and turkey operations is the use of loaders, scrapers, and skidloaders used for removing litter and replacing bedding. The equipment must be rented or bartered if not owned by the operator. This equipment is already present on most dairy farms. Fixed costs are already incurred and any additional equipment operation increase only operating variable costs.

Another advantage for a dairy farm considering the addition of a poultry operation is the utilization of the poultry litter. One problem confronting poultry operations that are on small land acreage is the disposal of litter. Dairy farms tend to have enough acreage to allow disposal of their dairy manure and still require additional nutrients for crop production. Dairy farmers in Rockingham County have been utilizing poultry litter as a crop nutrient source several years, reducing county fertilizer sales over 32 percent from 1984 to 1990 (Virginia Agricultural Statistics; Roller, 1994). Adding a poultry operation allows the dairy farmer to capitalize on the nutrient value of the poultry litter by reducing fertilizer purchases.

An additional factor that makes poultry operations viable on dairy farms is the land needed for placement on the farm. County zoning requires a minimum of 15 acres for one poultry house, and 5 additional acres for each additional house (Roller, 1994). Dairy farms generally have the acreage to meet requirements for minimum area and the distance buildings are setback from property lines, highways, and neighboring residences. The land provides an additional advantage to the land owner by providing the collateral for obtaining financing for the poultry operation.

Besides the utilization of labor and equipment, dairy farmers have found that adding a poultry operation can be considered less risky than expanding their dairy operations. The poultry industry has created a strong presence in the county, with an excellent infrastructure for poultry operations. The industry is committed to the area by establishing hatcheries, feed processing, and bird processing. The industry has created a favorable relationship with county agricultural financial institutions that benefits both parties. Farmers anticipating poultry production are given assistance in meeting county building and site requirements, obtaining reputable builders, and cost budgeting. These factors reduce the risk to the financial institution. With a proven history of consistent and reliable contract payments to area growers, financial institutions regard poultry as less of a risk than dairy. Therefore, the capitalization loss for a poultry facility is only 15 percent while the loss for new dairy facilities is approximately 50 percent (Ag First Farm Credit Bank).[1]

The benefits to the producer are obtaining a fairly steady income with limited risk. As compared to dairy, returns to poultry are considered very steady due to the contract basis. Dairy production has the variability of product price and feed input costs. Dairy farmers who raise much of their own feedstuffs are subject to weather variations that determine crop yields. So dairy farmers face risks from farm supplied inputs, purchased input costs, and product prices. In addition, the dairy farmer has a high investment in

[1] Capitalization loss is defined as the loss of market value incurred on the purchase of new assets. In this study, a farmer purchases poultry facilities for $273,000. His debt increases by the amount of purchase but assets increase by the purchase price less $40,950 - the 15% capitalization loss.

specialized production facilities in an industry that is slowly losing producers each year. The poultry farmer, on the other hand, has very limited risk in input prices and weather variability. Output prices have been proven to be very steady over time. The industry has more than doubled since 1978 and is still expanding. The vitality of the business makes the ownership of poultry buildings to be a fairly safe investment. With these differences, there is reason to believe that more dairy farms will continue to add poultry operations.

This phase of the study examines the financial impacts of alternative nutrient management policies of dairy farms with a supplementary poultry operation. Cost and revenue estimates are obtained from Virginia Tech poultry enterprise budgets (Zhu). Several key assumptions determine the farm operation. The dairy farm is assumed to add the poultry houses without requiring any additional labor. Area agricultural lenders confirm that very few dairy farms hire additional labor when starting or expanding a poultry house (Ag First Farm Credit Bank). Equipment needs include the specialized equipment located in the poultry house. The farm is assumed to have loaders, tractors, and skidloaders needed for any mechanized operations such as cleaning and spreading bedding.

Budgeted costs for the added poultry operation are shown in Table 3.7. The costs are calculated proportionally according to poultry produced in Rockingham County (1992 U.S. Census of Agriculture). The budgets are based 57.5 percent on tom turkey and hen budgets and 42.5 percent on broiler budgets. The buildings, equipment, and site preparations are mortgaged for 15 years at 9.0 percent interest. This is the mid-point of interest charged by agricultural lenders over the past three years (Ag First Farm Credit Bank).

Table 3.7. Costs and Returns for Poultry Enterprise.[1]

	Two Buildings[2]
Tons Litter Produced	408
Gross Income	66,598
Fixed Costs:	
Building and Equipment[3]	252,458
Land Preparation[4]	21,000
Total	273,458
Annual Costs:	
Building & Site Payment (15 years @ 9%)[5]	33,925
Taxes & Insurance (1.5% of Loan)	4102
Total Annual Costs	38,027
Annual Variable Costs:	
Repairs & Maintenance	2052
Electricity	4232
Fuel	6476
Bedding	3402
Equipment - Cleaning[6]	1516
Total Annual Variable Costs	17,678
Net Cash Returns[7]	10,893
Net Cash Returns W/Litter Disposal Costs[8]	
$10 Per Ton	6813
$20 Per Ton	2733
$26.69 Per Ton	0
$30 Per Ton	-1347
$40 Per Ton	-5427

1. Budget is proportionally based on 57.5% turkey tom and hen budgets and 42.5% on broiler budgets. These percentages represent the proportional amount of turkey and broiler litter produced in Rockingham County, 1992 U.S. Census of Agriculture. This is a cash flow budget and does not account for income taxes and depreciation. Turkey and broiler budgets are from Virginia Cooperative Extension enterprise budgets (Zhu).
2. Rockingham County broiler and turkey farms average 2 poultry houses.
3. Equipment includes heaters, waterers, feeders, bulk bins, ventilation, alarm, alternator, plumbing, and wiring.
4. Site preparation includes bulk bin pad, well, pump, and electric drop.
5. The total loan for the building and site preparation are amortized over 15 years at 9 percent interest.
6. Equipment rates include variable operating and repair costs from Virginia Cooperative Extension farm budgets.
7. Net cash return is the gross income less total annual costs and less annual variable costs.
8. Disposal costs assume poultry producer pays for removal of 408 tons of litter from farm.

The repayment schedule is shown in Table 3.8. The changes in farm assets and expenses for the dairy/poultry farms are shown in Table 3.9. Litter application and spreading costs are shown in Table 3.10.

Equipment costs for cleaning are entered as variable operating costs. This study assumes that labor needs are met without hiring additional labor. The gross income reflects average flock turnover, mortality rates, and integrator payments. The budgets include variable costs of litter disposal. This study examines policies in which the base dairy/poultry farm attempts to utilize their litter on the farm, and under the situation where the farm has to find alternative sources for the litter. The 100 and 150-cow farms utilize all litter generated while the 60-cow dairy farm has inadequate farmland for utilizing all the litter produced without over applying nutrients.

The expenses and revenues for poultry are combined with those of the dairy farm for the financial simulation in FLIPSIM. The mortgage is entered with the existing long term debt. The building and equipment are added together and entered as building depreciation. The structure qualifies as a specialized livestock building and is depreciated by the straight line method over a 10-year period. The gross return is entered as other farm income. Adding the poultry operation into FLIPSIM as described allows the cash flows from the dairy and poultry sectors to be combined to determine total farm level costs, income, cash flow, depreciation, tax liability, and financial viability.

Table 3.8. Mortgage Repayment Schedule for Two Poultry Buildings.[1]

	Year of Repayment				
	1	2	3	4	5
Principal	9,314	10,152	11,066	12,061	13,147
Interest	24,611	23,773	22,859	21,864	20,778
Payment	33,925	33,925	33,925	33,925	33,925

[1] Loan is for $273,458 at 9% interest for 15 years and assumes 100% financing. Repayment for years one to five are shown because the study period is for five years.

Table 3.9. Changes in Farm Assets and Expenses with the Addition of Two Poultry Houses.

	Value	60-Cow Farm		100-Cow Farm		150-Cow Farm	
	Change	Dairy	D/Poultry	Dairy	D/Poultry	Dairy	D/Poultry
Assets:							
Buildings & Equipment[1]	232,439	150,000	382,439	175,000	407,439	200,000	432,439
Fixed Costs:							
Farm Debt[2]	273,458	180,000	453,458	300,000	573,458	450,000	723,458
Building Depreciation[3]	27,346	4500	31,846	7000	34,346	8800	36,146
Insurance	2452	2500	4952	3500	5952	5000	7452
Real Estate Taxes[4]	1650	2250	3900	2745	4395	3548	5198
Variable Costs:							
Repairs & Maintenance[5]	3568	8500	11,231	12,900	16,468	19,000	22,568
Utilities & Fuel	10708	6900	17,608	10,300	21,008	14,600	25,308
Miscellaneous (Bedding)	3402	1200	4602	2100	5502	2500	5902

[1] Buildings and equipment subject to 15% capitalization loss.
[2] Assuming base debt level at $3000 per cow and 100% financing utilizing owner equity for capitalization loss.
[3] Straight-line depreciation used, 10 years for building and 7 years for equipment.
[4] Rockingham County taxes are $0.71/$100 for building and $0.44/$100 for equipment basis.
[5] Includes repairs and maintenance and equipment operating costs for cleaning and bedding. Value for 60-cow dairy farm base includes $837 for acquiring 225 tons and is not added to the dairy/poultry farm.

Table 3.10. Litter Spreading Costs for Dairy/Poultry Farms.

	60-Cow Dairy/Poultry BASE 318 Tons	60-Cow Dairy/Poultry NLIMIT 215 Tons	100-Cow Dairy/Poultry BASE 408 Tons	100-Cow Dairy/Poultry NLIMIT 370 Tons	150-Cow Dairy/Poultry BASE 503 Tons	150-Cow Dairy/Poultry NLIMIT 454 Tons
Hours Spreading[1]	21	14	27	25	34	30
Loader ($5.21/hr.)[2]	36	24	47	43	59	52
Spreader ($100/day)	200	200	200	200	300	300
Tractor ($5.89/hr.)	124	84	160	145	198	178
Total Costs	360	308	407	388	557	530
Dairy Farm Costs	314	300	383	362	557	530
Difference[3]	46	8	24	26	0	0

1. Spreading assumes 2.5 six-ton loads per hour.
2. Loader is used for purchased litter. Litter from poultry house is covered by loader charge under cleaning. Loader runs 1/3 time of spreader hours.
3. Represents the litter spreading cost difference between dairy farms acquiring litter and dairy poultry farms spreading their own litter. The 60 and 100-cow farms are spreading more litter.

Ex ante evaluation projects an increased farm cash flow of $10,893. The poultry operation provides a stable return as the budgeted income covers mortgage payments, expected variable costs, and insurance. Current farm equity is required to acquire 100 percent financing for the poultry building and equipment. Farm equity increases by 85 percent of the value of the poultry house, less the 15 percent capitalization loss. The cash value of the litter is not included in the budget. The 60-cow dairy farm is presently assumed to incur cleaning costs to acquire litter. The 100 and 150-cow herds utilize farm produced litter instead of purchasing litter for $6 per ton. These farms still incur spreading costs but reduce crop production costs by $6 for every ton of litter produced, realizing an additional positive cash benefit. The farm can derive other tax-based cash flow benefits from increased depreciation and interest deductions. This is explored further in the financial analysis of the dairy/poultry farms in Chapter IV.

Additional changes incorporated into crop production costs for the 60-cow dairy/poultry farm includes higher costs of spreading an additional 93 tons of poultry litter. Assuming the need to rent a spreader for an additional day, the added cost of spreading an additional 93 tons of manure is $137, $100 for the spreader and $37 for tractor operating costs. Cost adjustments for the 100 and 150-cow farms result from fewer hours for operating their loader.

The additional costs are incorporated for the three farms to examine the impacts of adding two poultry houses. Each model is run the same as described above for the dairy farms. The only differences is the additional costs, income, and debt level incurred with the poultry operation.

3.4 Modeling Field Practices and Nutrient Losses With EPIC

The EPIC simulation model is used to estimate field level nutrient losses and crop yields under current and the alternative manure management policies on the representative dairy and dairy/poultry farms under varying soils, crops, fertility regimes, tillage methods, and weather over a multi-year period.[2] The EPIC crop yield estimates are then utilized in the farm financial analysis. The EPIC model as employed in this study is displayed in Figure 3.3.

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[2] EPIC (Erosion Productivity Impact Calculator) DOS Version 3090, July 23, 1993. USDA/ARS, Grassland, Soil, and Water Research Laboratory, Blackland Research Center, 808 East Blackland Road, Temple, TX. 76502.

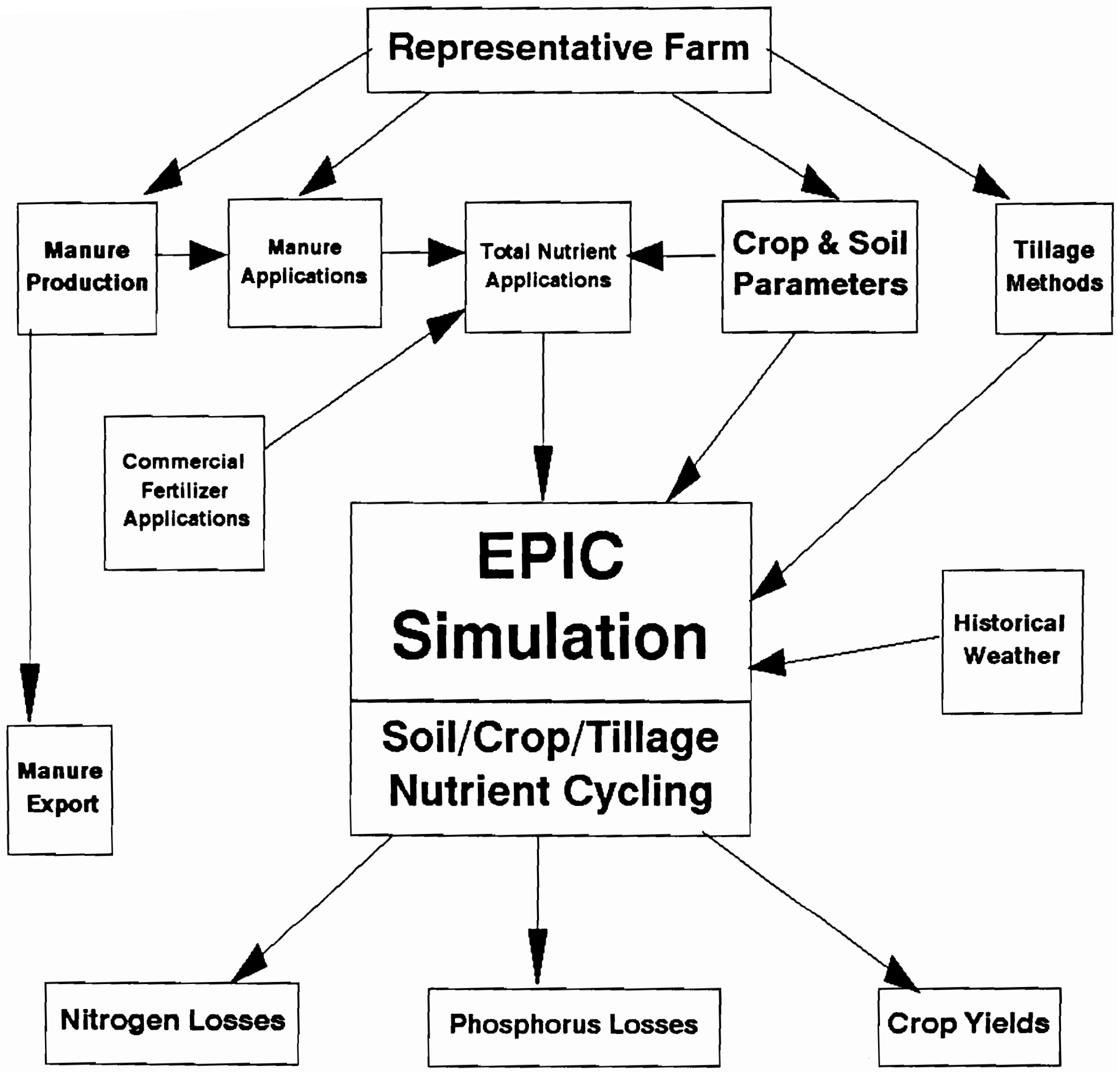

Figure 3.3. Modeling Nutrient Flow With EPIC

Animal manure production and applications, fertilizer applications, crop acreage, and tillage methods are specified by the individual representative farms. The nutrient needs of the crops are determined from baseline or policy specified limits. Manure production is used for application to crops or exported off the farm if manure applications are restricted. The manure and commercial fertilizer combine to provide total nutrients applied to individual crops. Crop parameters, nutrient applications, and physical management operations such as tillage and harvesting, and weather and soil parameters are the primary inputs into the EPIC model. Each specific field model is simulated for 100 five-year periods with random draws from available county historical weather. The results for each field model are summed by crop and combined to estimate farm level crop yields and nutrient losses.

EPIC simulates detailed nitrogen and phosphorus movement and deposition in the soil and plant. Estimated values for nitrogen are available for ammonia volatilization, nitrogen contained in leachate, subsurface lateral water flow, surface runoff, organic nitrogen attached to eroding soil particles, denitrification, mineralization, immobilization, fixation, plant uptake, and nitrogen from rainfall. EPIC also simulates soluble and mineral phosphorus, and phosphorus immobilization, transport, stress, sediment loss, runoff loss, and uptake. EPIC's estimates of crop yields are used for the financial simulation. Estimates of nitrogen and phosphorus depositions are used for estimates of field level nutrient losses for each crop and management policy.

The EPIC calibration efforts undertaken by Parsons et al. provided the necessary guidance to employ EPIC for the soils in this study. Parsons et al.'s results were a joint effort between the researcher, crop and soil specialists, and EPIC's model developers that assured soil, crop, and nutrient input parameters fully reflected specific characteristics of Virginia coastal, piedmont, and upland soils. The close interaction between the modeler and physical scientists is necessary to increase the reliability of successfully modeling field crops under varying soil types, weather conditions, and nutrient applications. (See Appendix A.)

This study utilizes input parameters for the three Frederick-Lodi based soils supplied by NRCS soil specifications. CSES soil experts examined individual soil parameters. They recommended specific adjustments in the values for sand and silt percentage, coarse fragment content, pH, bulk density, organic carbon, cation exchange capacity, and saturated conductivity to match Rockingham County soil characteristics. Soil profile water holding capacities are characterized through previous research at Virginia Tech soil scientists to match characteristics of Virginia's clay based soils (Starner). Final soil parameters are listed in Appendix B.

EPIC simulates energy interception; energy conservation to roots; above ground biomass; root, grain, and fiber production; and nutrient uptake for over 60 crops. Daily growth, development, and maturity are controlled by weather parameters, heat unit requirements, and individual crop files that contain over 40 parameters specific to each crop. These parameters include optimal temperatures, energy to biomass conversion, plant height, root depth, leaf area index, nitrogen and phosphorus uptake and content at different stages of maturity, and points on the frost damage curve. Virginia Tech CSES crop specialists examined EPIC's crop files for corn silage, rye, alfalfa, grass hay, and pasture and made minor specific recommended adjustments to assure that the crops reflected regional crop characteristics.

Crop specifications for rye are adapted from EPIC's barley file and adjusted with input from EPIC's agronomists who based calculations on growth and yield research results from Virginia Tech's Orange Research Farm. Grass hay and pasture presented a different problem for crop yield calibration because EPIC simulates the growth of one specific crop. Grass hay and pastures modeled in this study commonly contain several varieties of grasses and intermixing of legumes. EPIC and Virginia Tech agronomists suggested adjustments to optimal temperature, leaf area, and biomass conversion to calibrate improved and unimproved grass pastures to reflect a mix of seasonal grasses.

EPIC's weather model is driven by five specific variables: precipitation, air temperatures, solar radiation, wind speed, and relative humidity. EPIC is capable of generating its own weather parameters from latitude/longitude specifications, from user supplied data, or repeating year-specific weather (Sharpley and Williams; Williams et al., 1990). For this study, daily temperature and rainfall parameters are randomly selected from weather data collected during 1949-92. The weather information is from the Dale Enterprise weather station, located approximately 4 miles east of Harrisonburg, Virginia. Other weather parameters are estimated by EPIC from these input parameters.

EPIC simulates changes in surface roughness, soil mixing, and residue cover occurring from different tillage and harvest operations. Soil settling and smoothing is also simulated after each rainfall event. Specific crop management parameters that must be set for each activity include tillage, planting, harvesting, and fertilizer, manure, and pesticide applications. EPIC requires precise activity input as to the date, amounts, and the type of cropping activity for each field. For example, a fertilizer application includes the specific nutrient value, volume applied, date applied, and depth incorporated into soil. The farm operational data used in the study are defined by the farmer panels. Surface runoff curves are set as specified in Wischmeier and Smith for fields that follow good conservation practices.

The simulations follow detailed farm level operational data specified by the farmer panel. Labile (water soluble) phosphorus is set at the median phosphorus level of available soil tests reported in Chapter II. Organic nitrogen, organic phosphorus, and nitrate levels are determined by the following procedure recommended by Williams (1994) and Sharply. EPIC simulations are run for four years with each of the examined crops under current fertility regimes with EPIC generated stochastic weather. The same stochastic weather is used for each crop. This allows for the model to simulate the buildup of organic matter in the soil because of continuous manure applications. The ending organic nitrogen and phosphorus, and nitrate concentration from the preliminary four year stochastic simulations are used as beginning values for the baseline simulations.

Soil and crop specialists examined the results of the initial runs. The specialists recommended changes in the soil and crop specifications when the simulation results did not reflect expected outcomes. The process involved repeated simulation runs, and evaluations at different combinations of parameter settings to calibrate the final settings. Only after each crop's results were double checked by soil and crop experts did the study continue.

Each farm's crops are simulated for 100 six-year periods. The first year of each six-year simulation for each crop is under identical stochastic weather. For example the first year's weather is stochastically generated and identical for all 100 replications. The following sequential five years of weather are randomly drawn from the forty-four years of weather data. The random order is preserved so all crop models experienced the same randomly drawn weather. The six-year simulation is necessary for two reasons. One, the procedure assured that each five-year simulation period followed identical weather conditions that established identical beginning soil and moisture conditions. Second, six years must be simulated to record five ryelage harvests because rye is planted in the fall of one year and harvested in the following year.

Each model is simulated for 100 five-year periods to eliminate the possible bias that can occur from small sample sizes and to assure that the results present a valid distribution of what is likely to occur based on historical weather parameters. Based on weather history, there is the possibility of drawing five dry years or five years of favorable weather, both of which are not necessarily representative of probable weather conditions. The repeated random selections from the weather database reduces the probability that any one drought or highly productive season seriously affects the simulation results. The drawing order is identical for each EPIC simulation.

EPIC produces specified output for many different parameters that can be examined on a daily, monthly, annual, or average value. The output for this study includes 500 annual parameter estimates, 100 estimates each for years one to five. The output includes crop yields, annual rainfall, surface runoff, soil erosion, nitrogen losses through nitrate contained with surface runoff, organic nitrogen attached to sediment, nitrate losses with subsurface flow, nitrate losses with the leachate, and nitrogen volatilization. Phosphorus losses include soluble phosphorus contained in surface runoff and organic phosphorus attached to eroding sediment. Nitrogen losses through organic nitrogen attached to eroding sediment are defined as surface nitrogen losses. Nitrogen contained in the subsurface lateral flow and leachate are defined as subsurface nitrogen losses. Nitrogen volatilization included only ammonia volatilization occurring from manure applications. Phosphorus losses include soluble and organic phosphorus. All nutrient losses are measured at the edge of the field or below the root zone.

The output is compiled by the mean, maximum, minimum, and standard deviation per five-year period. Annual averages are determined from the average of the five-year replications. Losses are summed to determine nitrogen volatilization losses, surface nitrogen losses, subsurface nitrogen losses, and total phosphorus losses. Values are summed across crops to estimate farm level and per acre nutrient losses. Individual annual crop yields per farm are collected into a separate file for use as crop yield input in FLIPSIM financial simulations.

3.4.1 Crop Management Changes Required by Alternative Policies

The farmer panel defined the nutrient applications and cropping practices for the BASE simulations. The nutrient applications that accompany the INCORP, NLIMIT, and PLIMIT are defined by the restrictions imposed under each policy. The nutrients applied on each crop on each representative farm for BASE and the alternative policies are shown on Table 3.11.

Each crop is modeled initially with the base farm production practices (BASE). Nutrient applications remain at base levels for the manure incorporation policy (INCORP). The only difference from BASE practices is that all manure applied to bare ground is incorporated into the soil within 2 days. This requirement eliminates no-till corn and rye.

Table 3.11. Manure, Litter, and Fertilizer Nutrient Quantities Applied to Each Farm and Crop Under Alternative Management Policies.[1]

Farm and Crops	Acres	BASE Farm Applications: Dairy Manure Gals/Acre	BASE: Poult Litter Tons/Acre	BASE: Fertilizer N (Pounds Per Acre)	BASE: Fertilizer P[2] (Pounds Per Acre)	BASE: Fertilizer K[2] (Pounds Per Acre)	BASE: Plant[3] Avail N	NLIMIT Policy: Dairy Manure Gals/Acre	NLIMIT: Poult Litter Tons/Acre	NLIMIT: Fertilizer N (Pounds Per Acre)	NLIMIT: Fertilizer P (Pounds Per Acre)	NLIMIT: Fertilizer K (Pounds Per Acre)	NLIMIT: Plant Avail N	PLIMIT Restriction: Dairy Manure Gals/Acre	PLIMIT: Poult Litter Tons/Acre	PLIMIT: Fertilizer N[4] (Pounds Per Acre)	PLIMIT: Fertilizer P (Pounds Per Acre)	PLIMIT: Fertilizer K (Pounds Per Acre)	PLIMIT: Plant Avail N
60-Cow Farm																			
NT Crn Sil/Rlge	25	7000	3.0	0	0	0	211	7000	3.0	0	0	0	211	7000	0	138	0	60	211
MT Crn Sil/Rlge	25	7000	3.0	0	0	0	211	7000	3.0	0	0	0	211	7000	0	138	0	60	211
Alfalfa Seeding[5]	5	2500	0	0	50	125	0	2500	0	0	50	125	0	2500	0	0	0	125	0
Alfalfa	15	0	0	0	50	200	0	0	0	0	50	200	0	0	0	0	0	200	0
Hay/Pasture	20	2600	2.5	0	0	0	138	2600	1.75	0	0	0	103	2600	0	77	18	40	100
Pasture[6]	20	2500	2.5	0	0	0	137	2500	1.0	0	0	0	60	2500	0	38	0	0	60
Total	110	439,500	225					439,500	195					439,500	0				
100-Cow Farm																			
NT Crn Sil/Rlge	25	6000	2.0	25	0	0	180	6000	2.0	25	0	0	180	6000	0	117	0	55	180
MT Crn Sil/Rlge	25	6000	2.0	25	0	0	180	6000	2.0	25	0	0	180	6000	0	117	0	80	180
NT Crn Sil/Rye	25	6000	2.0	25	0	0	180	6000	2.0	0	0	0	155	6000	0	97	0	0	160
MT Crn Sil/Rye	25	6000	2.0	25	0	0	180	6000	2.0	0	0	0	155	6000	0	97	0	0	160
Hay/Pasture	45	2500	3.0	0	0	0	160	2500	2.25	0	0	35	102	2500	0	78	18	40	100
Pasture	25	0	2.0	0	0	0	92	0	1.5	0	0	10	69	0	0	60	18	40	60
Total		712,500	360					712,500	320					712,500	0				
150-Cow Farm																			
NT Crn Sil/Rlge	30	5000	2.0	25	0	0	170	5000	2.0	25	0	0	170	5000	0	117	0	100	170
MT Crn Sil/Rlge	30	5000	2.0	25	0	0	170	5000	2.0	25	0	0	170	5000	0	117	0	100	170
NT Crn Sil/Rye	30	5000	2.0	25	0	0	170	5000	2.0	17	0	0	161	5000	0	108	0	30	160
MT Crn Sil/Rye	30	5000	2.0	25	0	0	170	5000	2.0	8	0	0	161	5000	0	108	0	30	160
NT Crn Sil/No Rye	15	5000	2.0	25	0	0	170	5000	1.75	0	0	0	124	5000	0	86	0	25	130
MT Crn Sil/No Rye	15	5000	2.0	25	0	0	170	5000	1.5	0	0	0	128	5000	0	77	0	25	130
Grass Hay	10	3500	3.0	0	0	0	169	3500	2.0	0	0	0	118	3000	0	94	14	55	120
Hay/Pasture	60	1500	1.5	0	0	0	82	1500	1.5	0	0	0	82	1500	0	69	18	60	82
Pasture	110	1500	1.5	0	0	0	82	1500	1.0	0	0	0	62	1500	0	47	12	20	60
Total		982,500	502.5					982,500	454					982,500	0				

[1] The manure incorporation restriction (INCORP) is not included in the table because manure and fertilizer applications remain the same as the BASE applications. Abbreviations are: NT=no-till, MT=minimum till, Crn Sil=corn silage, and Rlge=ryelage.
[2] P refers to pounds of commercial phosphate fertilizer (P_2O_5) and K refers to commercial potassium fertilizer (K_2O)
[3] Plant available nitrogen available during the current year in fertilizer, manure inorganic and organic nitrogen applications, plus that available from residual nitrogen from past manure applications.
[4] Nitrogen listed is the maximum amount of commercial nitrogen applied. Amounts applied in years 1 to 3 are smaller because of residual nitrogen from litter applications
[5] Alfalfa is not listed for the 100 and 150-cow dairy farms because fertilizer nutrient applications per acre are the same as the 60-cow dairy farm. However, the 60-cow dairy farm applies 2500 gallons of dairy manure per acre prior to alfalfa seeding.
[6] Amounts listed for pasture are amounts applied per acre but only on 50% of pasture acreage.

Limiting plant available nitrogen to crop agronomic recommendations (NLIMIT) reduces dairy and poultry manure and fertilizer applications to VALUES nitrogen recommendations for all crops. It is assumed that the farm will meet crop nutrient requirements first from dairy manure, then from poultry litter, with final needs met by fertilizer. NLIMIT does not consider the phosphorus content of the manure or litter. NLIMIT restrictions do not affect any corn silage/ryelage crops on the dairy-only farms. Corn silage/rye cover acreage on the 100 and 150-cow dairy farms have less nitrogen fertilizer applied. The biggest change occurs on hay and pasture where less litter is applied, reducing application and acquisition costs. The 60-cow dairy farm reduces litter applications from 2.5 tons per acre on hay/pasture and pasture crops to 1.75 and 1.0 tons per acre, respectively. Total litter application drops from 225 tons to 195 tons, a reduction of 30 tons. The 100-cow dairy farm reduces litter applications on hay/pasture from 3.0 tons per acre to 2.25 tons per acre and on pasture from 2.0 tons per acre to 1.5 tons per acre. Nitrogen fertilizer applications are eliminated on the corn/rye acreage. The 150-cow dairy farm reduces liter applications on no-till corn/no rye cover from 2.0 to 1.75 tons per acre and on minimum till corn/no rye cover from 2.0 to 1.5 tons per acre. Grass hay applications are reduced from 3.0 to 2.0 tons per acre. Nitrogen fertilizer applications are eliminated on the corn silage/no rye cover and reduced for the corn silage/rye cover crops.

PLIMIT limits phosphorus applications to no more than the amount of phosphorus removed by crops. This requirement is met on most soils by dairy manure applications. The minimum dairy manure application on corn silage is 5000 gallons per acre, containing 26.5 pounds of phosphorus. One ton of litter, however, contains 54.9 pounds of phosphorus, 10 pounds greater than the amount removed by corn silage/ryelage. The result is the elimination of litter applications because poultry litter applications less than one ton per acre are not considered to be practical. CSES soil specialists confirm that most of the soils could sustain crop production up to 10 years without any additional phosphorus. Dairy manure applications should not increase phosphorus levels but does prevent soil phosphorus levels from dropping significantly.

Eliminating litter also reduces nitrogen and potassium applications, requiring additional commercial fertilizer. Commercial fertilizer is applied at rates that meet the lesser of base nitrogen applications or crop nitrogen recommendations. Commercial fertilizer is applied to all crops because nutrient requirements are not met by dairy manure. Phosphorus applications are also eliminated on alfalfa. Additional phosphorus fertilizer is applied to 'pasture on the 100-cow dairy farm according to VALUES recommendations because this crop does not receive any dairy manure.

Nitrogen and phosphorus losses are also estimated for each dairy/poultry farm. The 60-cow dairy/poultry farm produces more litter than can be utilized on the farm based on nitrogen recommendations. The farmer panel specified that the BASE 60-cow dairy/poultry farm applies 281 pounds of plant available nitrogen per acre versus 211 pounds for the BASE 60-cow dairy farm on corn silage/ryelage, exceeding nitrogen recommendations by 51 pounds per acre. The 100-cow dairy/poultry farm utilizes all the litter it produces but litter applications are higher than on the BASE 100-cow dairy farm. No nutrient applications change on the 150-cow dairy/poultry farm because the farm applies all farm produced litter and still needs to acquire additional litter to apply at the same rate as the 150-cow dairy farm.

Under NLIMIT, nitrogen restrictions reduce litter applications on all crops for the 60-cow dairy/poultry farm. This reduces overall litter use by 90 tons. On the 100-cow dairy/poultry farm, NLIMIT restrictions requires the farm to redistribute litter applications but all litter is still utilized on the farm. No litter export is necessary. Nutrient applications on the 150-cow dairy poultry farm remain the same as for the 150-cow dairy farm. Nutrient applications under PLIMIT for the dairy/poultry farms are identical to applications for the dairy-only farms. Because litter applications are not permitted, all litter on the dairy/poultry farms must be removed from the farm. All nutrient applications on the dairy/poultry farms under PLIMIT are identical to the applications on the dairy farms. All nutrient applications for the dairy/poultry farms and corresponding nutrient applications for the dairy-only farms under BASE and NLIMIT are shown in Tables 3.12 and 3.13.

3.5 Modeling Financial Outcomes with FLIPSIM

The simulated EPIC yields are inputs into FLIPSIM which estimates farm financial performance over a multi-year period under current and alternative manure management policies.[3] The FLIPSIM model produces a distribution of outcomes subject to a given set of input data and assumptions for the farm. The model is composed entirely of accounting equations and identities (Richardson and Nixon).

A description of the FLIPSIM simulations is shown in Figure 3.4. Current practices and policy alternatives define the farm's physical and financial parameters. The farm

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[3] FLIPSIM (Farm Level Income Policy SImulation Model) version 1.0, October 10, 1993, Update, August, 1994. James Richardson, Department of Agricultural Economics, Texas A&M University, College Station, Texas 77843-2124. Copyright 1991, Texas Agricultural Experiment Station.

Table 3.12. Manure and Litter Nutrient Quantities Applied for 60-Cow Dairy Farm and 60-Cow Dairy/Poultry Farm Under BASE Applications and NLIMIT.[1]

Farm and Crops	Acres	Dairy Manure (gals/acre)	Poultry Litter (tons/acre)	Manure Nutrients MN	ON	P	K_2O	Plant-Avail Nitrogen (lbs/acre)
				Pounds Per Acre				
BASE Dairy								
Corn Sil/Ryelage	50	7000	3.0	104	235	124	191	211
Hay/Pasture	20	2600	2.5	59	155	85	99	138
Pasture[4]	20	2500	2.5	58	153	84	98	137
Total	110	439,500	225					
Dairy-NLIMIT								
Corn Sil/Ryelage	50	7000	3.0	104	235	124	191	211
Hay/Pasture	20	2600	1.75	48	118	63	84	103
Pasture	20	2500	1.0	36	80	42	67	60
Total		439,500	195					
BASE Dairy/Poultry								
Corn Sil/Ryelage	50	7000	4.56	127	310	167	223	283
Hay/Pasture	20	2600	3.0	66	179	99	110	160
Pasture	20	2500	3.0	65	178	98	108	160
Total		439,500	318					
Dairy/Poultry-NLIMIT								
Corn Sil/Ryelage	50	7000	3.4	110	253	134	200	230
Hay/Pasture	20	2600	1.75	48	118	63	84	103
Pasture	20	2500	1.0	36	80	42	67	60
Total		439,500	215					

1. The manure incorporation restriction is not included in table as manure and fertilizer applications remain the same as the base applications. PLIMIT nutrient applications are identical for dairy and dairy/poultry farms.
2. Plant available nitrogen manure inorganic and organic nitrogen, and residual nitrogen.
3. Amounts listed for pasture are actual amounts applied per acre but only on 50% of pasture acreage.

Table 3.13. Manure and Litter Nutrient Quantities Applied for 100-Cow Dairy Farm and 100-Cow Dairy/Poultry Farm Under BASE Applications and NLIMIT.[1]

Farm and Crops	Acres	Dairy Manure (gals/acre)	Poultry Litter (tons/acre)	Manure Nutrients MN	ON	P	K_2O	Fertilizer Nitrogen (lbs/acre)	Plant-Avail Nitrogen (lbs/acre)
				Pounds Per Acre					
BASE Dairy									
Corn Sil/Ryelage	50	6000	2.0	81	172	89	152	25	180
Corn Sil/Rye	50	6000	2.0	81	172	89	152	25	180
Alfalfa	25	0	0	0	0	0	0	0	0
Hay/Pasture	45	2500	3.0	65	178	98	108	0	160
Pasture	25	0	2.0	29	98	57	41	0	92
Total	195	712,500	360						
Dairy NLIMIT									
Corn Sil/Ryelage	50	6000	2.0	81	172	89	152	25	180
Corn Sil/Rye	50	6000	2.0	81	172	89	152	0	155
Alfalfa	25	0	0	0	0	0	0	0	0
Hay/Pasture	45	2500	2.25	54	141	77	92	0	102
Pasture	25	0	1.5	22	74	43	31	0	61
Total	195	712,500	320						
BASE Dairy/Poultry									
Corn Sil/Ryelage	50	6000	3.0	95	221	117	173	25	226
Corn Sil/Rye	50	6000	2.0	81	172	89	152	25	180
Alfalfa	25	0	0	0	0	0	0	0	0
Hay/Pasture	45	2500	3.0	65	178	98	108	0	160
Pasture	25	0	2.0	65	98	57	41	0	92
Total	195	712,500	410						
Dairy/Poultry-NLIMIT									
Corn Sil/Ryelage	50	6000	3.8	107	260	140	189	0	232
Corn Sil/Rye	50	6000	2.0	81	172	89	152	0	155
Alfalfa	25	0	0	0	0	0	0	0	0
Hay/Pasture	45	2500	2.25	54	141	77	92	0	102
Pasture	25	0	1.5	22	74	43	31	0	61
Total	195	712,500	410						

1. The manure incorporation restriction is not included in table as manure and fertilizer applications remain the same as the base applications. PLIMIT nutrient applications are identical for dairy and dairy/poultry farms.
2. Plant available nitrogen manure inorganic and organic nitrogen, and residual nitrogen.
3. Amounts listed for pasture are actual amounts applied per acre but only on 50% of pasture acreage.

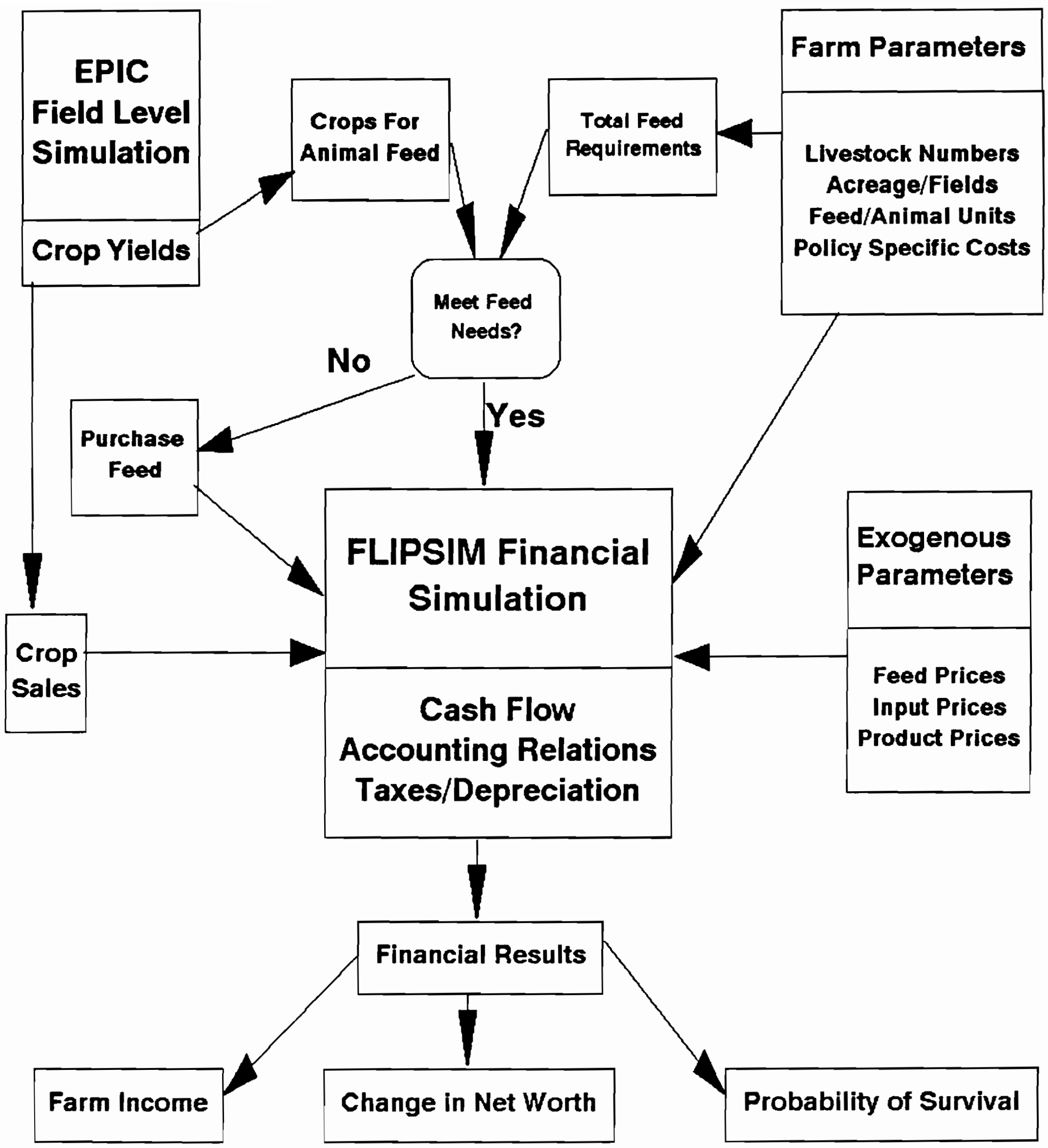


Figure 3.4. FLIPSIM Simulation Model

parameters determine dairy herd feed needs. EPIC generated crop yields determine the amount of farm produced feedstuffs available for consumption by the dairy herd. The difference between the feed produced and feed required determines the amount of feed purchased for the dairy herd. The FLIPSIM model utilizes the farm parameters, feed requirements, and exogenous parameters to determine the farm's financial performance over a multi-year period. FLIPSIM produces estimates on farm income, taxes, change in net worth, and probability of survival. The farms' probability of survival is defined as the ability to maintain established equity ratios. The farm goes out of business, or is foreclosed, if it can not meet current debt payments, exhausts all cash sources, and the debt/asset ratio exceeds an established level. Each farm model is simulated for 100 five-year periods which is coordinated with the five-year period simulated with EPIC. Initial modeling for each representative farm incorporates the data specified by the farmer panels (Table 3.1). Other data is shown in Appendix C. Farm real estate is entered as cropland, pasture, buildings and other investments. The value of the residence is entered as a separate asset. The dairy facilities are expected to depreciate in market value during the simulation period while the value of the residence is expected to increase (Rockingham County Assessment Office).

Individual machinery items are entered separately with the market value and the purchase date and price. FLIPSIM determines the depreciation of the machinery for income taxes according to the tax laws in effect at the time of machinery purchase. Market value of farm machinery, without any replacements, decreases during the simulation period. Each farmer panel determined an annual amount that is likely be spent for machinery replacement. This value is used for minor machinery replacement. The panels determined that major new machine replacements such as tractors, trucks, and new milking equipment are not made during the study period. FLIPSIM determines the feasibility of purchasing machinery by the cash balance. If there is not enough cash for the required down payment, the purchase is postponed, affecting total machinery market value and tax depreciation. Depreciation for buildings and dairy facilities are entered as a specific annual amount that remains constant over the simulation period.

The farm's real estate and personal property taxes are determined from county tax rates (Rockingham County Assessment Office). Accountant fees, insurance, and fuel and utilities costs are set by the farmer panels. Fuel, electrical, and phone costs are entered as utility costs. Building and machinery repairs and maintenance are entered as one cost. Labor costs entered into FLIPSIM account for social security taxes. Workers compensation insurance costs are included with insurance. Federal and social security taxes are estimated within FLIPSIM according to current tax laws. Virginia income tax rates are entered, accounting for both tax brackets and deductions for dependents. The state income tax credit for purchasing conservation equipment is not enacted because none of the farm panels designated the purchase of qualifying equipment. FLIPSIM requires input data for annual changes in interest rates and changes in input costs such as fertilizer, seeds, and chemicals, fuel, and labor. The estimates for these values are obtained from Richardson and FAPRI. Current crop input costs include seed, fertilizer, herbicide, insecticide, irrigation, and other equipment rental.

FLIPSIM handles only 20 crops and feedstuffs that can be consumed by farm animals, purchased, or sold. The designated crops are corn silage, ryelage, rye cover, alfalfa hay, alfalfa seeding, grass hay, hay/pasture, and pasture. The designated feedstuffs are corn grain, corn distillers grain, 24 percent concentrate, soybean oilmeal, calf starter, milk replacer, and minerals. The EPIC simulations, however, estimates up to 6 different models for corn silage. Entering each specific crop and tillage combination separately requires handling each one as a specific feedstuff, tremendously complicating the formulation of feed rations and exceeding the allotted 20 crops and feedstuffs. Consequently, EPIC-simulated crop yields are averaged in proportion to allotted acreage for input into FLIPSIM. This process is recommended by Richardson to assure incorporation of crop yield variability while simplifying formulation of the cattle rations.

The different EPIC models are required because corn silage is evenly split between minimum tillage and no-till planting and rye is split between ryelage and rye cover. For FLIPSIM simulation, each farm's corn silage acreage is assumed to be equally divided between the EPIC models. For the 60-cow herd, 50 percent of the corn silage is assumed to be no-till and 50 percent minimum till. For the 100-cow farm, 25 percent of the corn silage is assume to be no-till with ryelage, 25 percent minimum till with ryelage, 25 percent no-till with rye cover, and 25 percent minimum till with rye cover. The 150-cow dairy farm's corn silage acreage is determined to be 20 percent no-till with ryelage, 20 percent minimum till with ryelage, 20 percent no-till with rye cover, 20 percent minimum till with rye cover, 10 percent no-till without any cover, and 10 percent minimum tillage without any cover.

The dairy herd parameters used in FLIPSIM are listed in Table 3.1. The dairy costs are entered on a per cow basis. Feed rations are entered for milking cows, dry cows, replacements under 12 months, replacements 13-24 months, and springers over 24 months. Feed rations include raised crops as well as purchased feedstuffs. FLIPSIM is an annual accounting model so feed requirements are determined on a yearly basis. For example, total corn silage availability is determined by adding the beginning inventory and crop production (proportional EPIC simulated yield times total acres). Total annual corn silage fed is subtracted and the difference is the ending inventory which is used to calculate ending assets and the next year's beginning inventory. Beginning crop inventories are determined by the farm panel and no crops are sold during the simulation period.

FLIPSIM's specification of herd rations in relation to corn silage forced a change in crop acreage allocation. The farmer panels indicated that it is common for farmers to cut all of their corn for silage. In years of higher yields, some corn is harvested as grain. In addition, it is not uncommon for farmers to carry over corn silage from one year to the next. Left over corn silage results in a smaller harvest of corn silage as farmers strive to have a minimum amount of corn silage in storage. In years of lower corn silage yields, farmers make a effort to cut additional ryelage to supplement deficient corn silage stocks.

To assure enough corn silage stocks with FLIPSIM, all corn acreage is being harvested as silage. Ryelage acreage is set at levels defined as being typical by the farmer panels with the understanding that the amount harvested can vary from year to year. This permits some carryover of corn silage and ryelage for the rations defined in FLIPSIM. Corn silage and ryelage stocks in years of higher yields are carried over to the next year. In years of lower yields, carry over stocks are used. If more silage or ryelage is required than available stocks plus harvested, the model purchases feed stocks to make up for the shortfall. Farmers normally purchase additional feedstuffs to stretch feed supplies in years of poor yields.

FLIPSIM draws future feedstuff and crop prices from an empirical distribution determined from the combination of predicted future prices and an empirical factored co-variance probability distribution generated from historical yields and prices. The co-variance probability distribution is estimated with DEVIATE, an auxiliary program within FLIPSIM. DEVIATE requires the input of historical crop yields and prices, and prices of milk, livestock, and feedstuffs from the previous ten years. The program calculates ten points on each empirical probability distribution for use in the FLIPSIM data file. FLIPSIM uses supplied expected future prices as the expected mean and draws specific prices for each simulated year based on the factored co-variance probability distribution. For example, the mean milk price of year one for the 100 simulations equals the user supplied input predicted milk price for year one. However, milk prices used for individual simulated years are based on the distribution determined by historical milk prices and their co-variance with prices of crops, feedstuffs, and cull cow prices. This method incorporates price variability into the simulated results by relating the EPIC yields with historical variation and co-variation of other crop, milk, livestock, and feedstuff prices. Historical prices and yields for use in the DEVIATE program are obtained from the Virginia Agricultural Statistics (1983-92) and Rockingham and Augusta Farm Bureau. Expected future prices are obtained from FAPRI through Richardson.

Other model requirements are set as specified by the farmer panel. Farms are not participating in government farm programs. Farms have to utilize all acreage and Mennonite farmers are not inclined to directly participate in farm programs. Deductions are made from milk receipts for Commodity Credit Corporation deductions, advertising, and cooperative retained earnings.

The simulation period is for a five-year period with 100 iterations of the model performed for each policy. One iteration is a simulation of a five-year planning horizon. The simulation estimates the farm's probability of survival and the probability of the farm business being an economic success. The probability of survival is measured as the number of successful iterations out of 100 the farm completes without the debt/asset ratio exceeding 0.75. (Kohl, 1995). This ratio is reached when the farm cannot meet current debt obligations, exhausts refinancing options, or cannot sell land to meet debt obligations. Periodic farm cash flow deficits are covered by refinancing intermediate loans. When intermediate debt payments cannot be met, intermediate debt and the cash deficit is refinanced as long term debt.

The probability of economic success is a measure of the probability of the farm's present value of ending net worth being greater than the present value of beginning net worth. The farm is not an economic success if the present value of net worth increases, shows financial profits, but does not achieve the expected return on assets. The producers expected rate of return is set by adjusting the 30-year Treasury Bill interest rate by the 28 percent tax rate. The 30-year T-Bill interest rate for November, 2022, is 7.46 percent (Wall Street Journal). Adjustment for the 28 percent tax bracket gives a long term expected rate of return of 5.37 percent.

Farm family living expense affects farm economic viability. Research has shown that family living expenses are the fastest growing area of expenses on family farms (Kohl, 1992). FLIPSIM permits the option of setting family living expenses at a fixed level or the use of a consumption function that allows family living expenses to increase as gross farm income increases. Utilizing the consumption function requires minimum and maximum family living expenses to be input. FLIPSIM calculates consumption equal to minimum living expenses plus the marginal propensity to consume times the sum of after tax disposable income plus machinery depreciation less minimum living expenses. The marginal propensity to consume used in this study is 0.24 as recommended by Richardson and Kohl (1995). In the accounting procedure in FLIPSIM, minimum family living expenses are met even if borrowing is required. Additional living expenses are incurred only on the disposable income that is available after taxes allowing for machinery replacement.

The minimum and maximum per family living expenses are set at $26,000 and $35,000, respectively, for the 150-cow farms (Kohl, 1992). The minimum family living expenses for the 100-cow farm are set $26,000 and $23,000 with an additional $18,000 in off-farm income for the 100-cow farms. The lower family cost of living for one family for the 100-cow farm reflect lower health insurance provide with the off-farm income. Family living expenses for the 60-cow farm are set at $16,000 and $22,000. The levels are set lower by the farm panel to match the demands of a typical Mennonite family. Key variables examined for sensitivity analysis include debt levels, milk prices, and milk production per cow, and reduced gross income for the dairy/poultry farms.

Each farm's initial parameters are used to establish the farm's baseline for Objective 1. Then the farm model is run again with the necessary changes to reflect the change in nutrient management practices for Objective 3. For example, switching to manure incorporation includes additional costs for tillage operation and adjustments for pesticide costs on no-tillage acreage. The farm model is rerun with the new cost data and the results compared to the base model. Each policy analysis follows the same procedure and is simulated with the EPIC generated yields for that respective policy.

The FLIPSIM results from individual policies are compared to base policy results to estimate the farm level costs of adjusting to the alternative manure management policies for each representative farm. These values can then be applied to the change in nutrient losses for each policy to derive the cost per unit of change in nutrient losses. These values thus allow determination of the relative cost for expected benefits derived from manure management guidelines.

3.5.1 Changes in Cropping Costs Under Alternative Policies

The implementation of the INCORP, NLIMIT, and PLIMIT policies requires changes in each representative farm's cropping practices and cropping cost structure. The specific crop production costs are listed on Table 3.14 for BASE. Changes in the crop production cost structure for INCORP, NLIMIT, and PLIMIT are shown on Table 3.15. The changes on farm level crop production and litter acquisition costs are listed for BASE and each alternative manure management policy on Table 3.16.

INCORP eliminates no-till planting of corn and rye when manure is applied. Cropland currently being planted no-till is disked twice after manure application. The farmer panels believed that the 60 and 100-cow dairy farms can generally handle the additional tillage requirement without hiring additional labor in the spring. The 150-cow dairy farm needs to hire additional part-time labor for fall tillage. Fixed costs do not vary because the farms already possess tractors and tillage equipment. Additional costs include fuel, repairs, and maintenance of operating equipment. The farms reduce cash expenses because less pesticides are used for corn.

Manure incorporation costs are determined from Virginia Cooperative Extension crop budgets. The estimated variable costs for the disking plus the use of the tractor is

Table 3.14. BASE Farm Crop Production Expenses.[1]

Farm Crop	Seed Costs ($/acre)	Lime and Fertilizer Costs[2] Lime ($/acre)	Fertilizer ($/acre)	Total ($/acre)	Chemical Costs ($/acre)	Planter[3] Costs ($/acre)	Litter Costs ($/acre)
60-Cow Dairy							
NT Cr Sil/MT Rlge[4]	19.50	7.50	2.00	9.50	43.00	0.00	0.00
MT Cr Sil/NT Rlge[5]	19.50	7.50	2.00	9.50	29.00	0.00	0.00
Ryelage[6]	18.75	0.00	0.00	0.00	0.00	10.20	0.00
Alfalfa Seed-NT	48.50	47.50	37.00	84.50	54.30	10.20	0.00
Alfalfa Maint	0.00	9.50	48.50	58.00	21.75	0.00	0.00
Hay/Pasture	0.00	5.00	0.00	5.00	4.00	0.00	0.00
Pasture[7]	0.00	0.00	0.00	0.00	4.00	0.00	0.00
100-Cow Dairy							
NT Cr Sil/MT Rlge	19.50	7.50	8.50	16.00	43.00	0.00	12.00
MT Cr Sil/NT Rlge	19.50	7.50	8.50	16.00	29.00	0.00	12.00
NT Cr Sil/MT Rye	19.50	7.50	8.50	16.00	43.00	0.00	12.00
MT Cr Sil/NT Rye	19.50	7.50	8.50	16.00	29.00	0.00	12.00
Ryelage	18.75	0.00	0.00	0.00	0.00	10.20	0.00
Rye	11.75	0.00	0.00	0.00	0.00	10.20	0.00
Alfalfa Seed-NT	48.50	47.50	37.00	84.50	54.30	10.20	0.00
Alfalfa Maint	0.00	9.50	48.50	58.00	21.75	0.00	0.00
Hay/Pasture	0.00	5.00	0.00	5.00	4.00	0.00	18.00
Pasture	0.00	0.00	0.00	0.00	4.00	0.00	12.00
150-Cow Dairy							
NT Cr Sil/MT Rlge	19.50	7.50	8.50	16.00	43.00	0.00	12.00
MT Cr Sil/NT Rlge	19.50	7.50	8.50	16.00	29.00	0.00	12.00
NT Cr Sil/MT Rye	19.50	7.50	8.50	16.00	43.00	0.00	12.00
MT Cr Sil/NT Rye	19.50	7.50	8.50	16.00	29.00	0.00	12.00
NT Cr Sil	19.50	7.50	8.50	16.00	43.00	0.00	12.00
Ryelage	18.75	0.00	0.00	0.00	0.00	10.20	0.00
Rye	11.75	0.00	0.00	0.00	0.00	10.20	0.00
Alfalfa Seed-NT	48.50	47.50	37.00	84.50	54.30	10.20	0.00
Alfalfa Maint	0.00	9.50	48.50	58.00	21.75	0.00	0.00
Grass Hay	0.00	10.00	0.00	10.00	4.00	0.00	18.00
Hay/Pasture	0.00	5.00	0.00	5.00	4.00	0.00	9.00
Pasture	0.00	0.00	0.00	0.00	4.00	0.00	9.00

1. Abbreviations for crops: MT=minimum till, NT=no-till, Cr Sil=corn silage, Rlge=ryelage, and Maint=maintenance.
2. Fertilizer costs for corn silage includes trace minerals. All fields do not receive lime and trace minerals each year so costs are averaged over the five-year simulation period.
3. The planter cost is the rental rate of no-till seeders used for rye and alfalfa.
4. NT Cr Sil/MT Rlge refers to no-till corn silage/minimum till ryelage.
5. MT Cr Sil/MT Rlge refers to minimum till corn silage/no-till ryelage.
6. Values for ryelage and rye include only seed and planting costs. Fertilizer, litter, and chemical costs are included with silage corn. Seed costs are higher for ryelage plant because farmers plant higher seeding rates and are more likely to use certified seed for rye as a forage crop.
7. Amounts listed for pasture are actual amounts applied per acre but only on 50% of the pasture acreage.

Table 3.15. BASE Crop Costs and Cost Changes Required for the Alternative Management Policies.[1]

	Base Farm Crop Production Costs			Changes in Costs Under Alternative Policies					
				INCORP		NLIMIT		PLIMIT	
Farm and Crops	Fert Total ($/ac)	Chem Costs ($/ac)	Litter Costs ($/ac)	Till[2] Costs ($/ac)	Chem Costs ($/ac)	Fert[3] Total ($/ac)	Litter Costs ($/ac)	Fert[3] Total ($/ac)	Litter Costs ($/ac)
60-Cow Dairy									
NT Cr Sil/MT Rlge	9.50	43.00	0.00	6.10	29.00			56.34	
MT Cr Sil/Nt Rlge	9.50	29.00	0.00	6.10				56.34	
Alfalfa Seed-NT	84.50	54.30	0.00					72.00	
Alfalfa Maint	58.00	21.75	0.00					45.50	
Hay/Pasture	5.00	4.00	0.00					38.20	
Pasture[4]	0.00	4.00	0.00					12.70	
100-Cow Dairy									
NT Cr Sil/Mt Rlge	16.00	43.00	12.00	6.10	29.00			54.66	0.00
MT Cr Sil/Nt Rlge	16.00	29.00	12.00	6.10				54.66	0.00
NT Cr Sil/MT Rye	16.00	43.00	12.00	6.10	29.00	9.50		38.26	0.00
MT Cr Sil/NT Rye	16.00	29.00	12.00	6.10		9.50		38.26	0.00
Alfalfa Seed-NT	84.50	54.30	0.00					72.00	
Alfalfa Maint	58.00	21.75	0.00					45.50	
Hay/Pasture	5.00	4.00	18.00				13.50	45.12	0.00
Pasture	0.00	4.00	6.00				9.00	24.12	0.00
150-Cow Dairy									
NT Cr Sil/MT Rlge	16.00	43.00	12.00	6.10	29.00			57.20	
MT Cr Sil/NT Rlge	16.00	29.00	12.00	6.10				57.20	0.00
NT Cr Sil/MT Rye	16.00	43.00	12.00	6.10	29.00	13.92		45.32	0.00
MT Cr Sil/NT Rye	16.00	29.00	12.00	6.10		11.58		45.32	0.00
NT Corn Silage	16.00	43.00	12.00	12.20[5]	29.00	9.50	10.50	38.96	0.00
MT Corn Silage	16.00	29.00	12.00	6.10		9.50	9.00	34.54	0.00
Alfalfa Seed-NT	84.50	54.30	0.00					72.00	
Alfalfa Maint	58.00	21.75	0.00					45.50	
Grass Hay	10.00	4.00	18.00				12.00	54.42	0.00
Hay/Pasture	5.00	4.00	9.00					34.73	0.00
Pasture	0.00	4.00	4.50				6.00	18.46	0.00

1. Abbreviations for crops: MT=minimum till, NT=no-till, Cr Sil=corn silage, Rlge=ryelage, and Maint=maintenance.
2. Tillage costs derived from Virginia Cooperative Extension crop budgets and include one off-set and one tandem disk operation. Costs represent variable operating costs without additional labor.
3. Fertilizer costs are averaged over the five-year simulation period. Nitrogen applications increase each year when replacing litter as plant available nitrogen from residual organic nitrogen decreases.
4. Amounts listed for pasture are actual amounts applied per acre but only on 50% of the pasture acreage.
5. Tillage cost under incorporation includes extra tillage in spring and fall only for the 150-cow farm.

Table 3.16. Crop Production Costs Under Alternative Nutrient Management Policies.

Farm Model & Input	BASE ($/year)	INCORP ($/year)	NLIMIT ($/year)	PLIMIT ($/year)
	Nutrient Management Policy			
60-Cow Dairy				
Seeds	2155	2155	2155	2155
Fertilizer & Lime[1]	1868	1868	1868	4751
Chemical	2518	2168	2518	2518
Planter	561	561	561	561
Tillage	0	305	0	0
Spreading	314	314	277	0
Acquisition[2]	837	837	725	0
Total	8253	8208	8104	9985
100-Cow Dairy				
Seeds	3778	3778	3778	3778
Fertilizer & Lime	3441	3441	3116	8281
Chemical	4577	3877	4577	4577
Litter	2160	2160	1920	0
Planter	1084	1084	1084	1084
Tillage	0	610	0	0
Spreading	383	483	362	0
Total	15,423	15,333	14,837	17,720
150-Cow Dairy				
Seeds	5240	5240	5240	5240
Fertilizer & Lime	5385	5385	4995	12982
Chemical	7096	6046	7096	7096
Litter	3015	3015	2723	0
Planter	1326	1326	1326	1326
Tillage	0	1006	0	0
Labor[3]	0	284	0	0
Spreading	557	557	530	0
Total	22,619	22,859	21,910	26,644

1. Fertilizer costs for the base model include the cost of trace minerals and lime applied every few years. Costs are average annual costs over the five-year simulation period. Nitrogen costs for the NLIMIT and PLIMIT policies are averaged over the five-year simulation period.

2. Acquisition cost only pertains to the 60-cow dairy farm because labor and equipment use are traded for litter. The acquisition costs include variable equipment operations costs.

3. Labor costs under the manure incorporation policy apply only to the 150-cow farm. The cost is determined from Virginia Cooperative Extension farm budgets and includes 0.45 hours per acre at $7.00 per hour, or $3.15 per acre. The 150-cow farm has 90 acres requiring additional fall tillage labor under manure incorporation.

estimated at $6.10 per acre. The costs included fuel, oil, and repairs. The cost for incorporation of the 150-cow dairy farm is set at $6.10 per acre plus $3.15 per acre for labor in the fall (0.45 hours at $7.00/hour per acre). Performing tillage on all corn acreage in the spring reduces the need for pesticides because no-till planting has been eliminated, reducing chemical costs $14.00 per acre. When summing across all corn acres, chemical costs are reduced on half of the acres and tillage costs increase $6.10 per acre for the total corn acreage (additional incorporation is performed on half of the corn acreage in the spring and half of the corn acreage in the fall). The net effect of the change in expenses decreases crop production costs by $45 and $90 for the 60 and 100-cow dairy farms. The 150-cow dairy farm incurs slightly higher crop production expenses of $240 because of higher labor costs.

NLIMIT restrictions reduces the amount of litter and fertilizer applied by the dairy farms. Cost changes for the 60-cow dairy farm includes $37 lower spreading costs and $112 for acquisition costs. Costs are lower because it is assumed the farmer assists in cleaning the poultry house only until his litter needs are met. Acquisition costs are estimated at $3.72 per ton. The 100-cow dairy farm realizes a savings of $586 from reduced litter applications and reduced nitrogen fertilizer purchases. The 150-cow dairy farm realizes $710 in reduced cost of fertilizer, litter, and spreading.

Meeting PLIMIT requirements eliminates acquiring and spreading poultry litter. The farm replaces these activities with the additional purchase of nitrogen and potash. The farmer saves cash from lower machinery operating costs for applying manure. However, the cost of additional commercial fertilizer increases total cash costs. The 60-cow dairy farm's crop production costs increase by $1732 with the purchase of nitrogen and potassium fertilizer offsetting savings from acquiring litter. The 100-cow dairy farm realizes a net crop production cost increase of $2,297. The 150-cow dairy farm realizes an increase of $4,023 in crop production costs.

The 60, 100, and 150-cow BASE dairy/poultry farms have higher operational costs and returns than the dairy-only farms (Table 3.7). Additional costs need to be entered into the model for the dairy/poultry farms for adjustments under the INCORP, NLIMIT, and PLIMIT alternative manure policies. Under INCORP, all manure is incorporated on fields without any growing crops. As with the dairy-only farms, INCORP eliminates no-till planting for corn and rye. The changes in costs are the same as for the dairy-only farms; variable costs for equipment operation and repairs increase while expenses for pesticides decrease. The 150-cow dairy/poultry farm incurs a higher cost for additional labor.

NLIMIT reduces litter applications on the 60-cow dairy/poultry farm while total litter applications remain the same for the 100 and 150-cow dairy/poultry farms. The 60-cow dairy/poultry farm applies 103 fewer tons of poultry litter for a savings of $52. This is the only savings because it is assumed the farm still has to incur the cost of cleaning out the poultry buildings. No cost or revenue is assumed for removal of the excess poultry litter from the farm. The 100-cow dairy/poultry redistributes its poultry litter under NLIMIT and eliminates $650 in nitrogen fertilizer purchases for corn silage/ryelage. The 150-cow dairy farm does not change any nutrient applications with the addition of the poultry operation because litter needs are greater than the litter produced on the farm. The 150-cow dairy/poultry farm incurs a cash saving under NLIMIT by reducing additional litter purchases by 49 tons or a total of $294.

The dairy/poultry farms are subject to the same PLIMIT restrictions as the dairy-only farms and do not apply any poultry litter. Each dairy/poultry farm replaces litter nutrients with commercial fertilizer. The 60-cow dairy/poultry farm increases expenses by $2,569 on the BASE dairy/poultry farm under PLIMIT because of increased fertilizer costs. The 100-cow dairy/poultry farm incurs higher costs of $4,433. The 150-cow dairy/poultry farm has increased costs of $6,468 under PLIMIT. Under PLIMIT the dairy/poultry farms must find another use for their poultry litter. The above changes in production costs are based on the assumption that the dairy/poultry farm does not incur any cost or generate revenue for removing litter from their farms. Additional analyses examines the impact of litter disposal costs of $0 to $40 per ton on the dairy/poultry farms.

3.6 Summary

This chapter describes the three models used to address the research objectives. First, the formulation of representative farms describe the current financial and physical characteristics of farms in Rockingham County. EPIC is used to estimate field level nutrient losses and crop yields for current practices and for selected manure management practices. FLIPSIM is used to estimate the long-term farm level financial performance. The process is repeated for each alternative policy.

Chapter IV

EPIC and FLIPSIM Simulation Results

This chapter presents the EPIC and FLIPSIM simulation results for each farm model. The EPIC results provide the estimated nitrogen and phosphorus field losses and crop yields currently resulting from practices on Rockingham County dairy and dairy/poultry farms (BASE). The alternative manure policies evaluated are manure incorporation (INCORP), nitrogen nutrient restriction (NLIMIT), and phosphorus nutrient restrictions (PLIMIT). The FLIPSIM results provide the corresponding financial performance for current practices and alternative policies on the representative dairy and dairy/poultry farms. Sensitivity analysis presents the impacts of variation of several key financial variables and possible litter disposal costs.

4.1 EPIC Results for Dairy and Dairy/Poultry Farms

The cropping practices of the representative dairy and dairy/poultry farms are modeled with EPIC to estimate field level nitrogen and phosphorus losses and crop yields under the farmer panel-stipulated production practices and timing. Separate models are created for each tillage and fertilization combination for corn silage, alfalfa, hay/pasture, and pasture. All nutrient applications per crop and farm are listed for each policy in Tables 3.11, 3.12, and 3.13.

Each policy is simulated for 100 five-year periods, randomly drawing a continuous five-year sequence of weather data from the 1949-1992. Reported output for each model includes crop yields, soil erosion, nitrogen volatilized (NH_4), surface nitrogen losses which include nitrate (NO_3) contained in the surface runoff and organic nitrogen contained with eroding soil particles, subsurface nitrogen losses which includes nitrogen lost beyond the field edge by subsurface lateral flow and nitrogen contained with water escaping the root zone (percolate), and phosphorus losses which includes phosphorus contained in the surface runoff and organic phosphorus attached to eroding soil particles. Crop yields are reported in tons per acre (corn silage at 65 percent moisture, ryelage at 50 percent moisture, and hay at 10 percent moisture). Soil erosion is reported in tons per acre and all nutrient losses are listed in pounds of nitrogen and phosphorus per acre. Farm level and per acre totals are given for each policy. All reported losses and yields are means from the 100 five-year simulations. Detailed results are reported in Appendix D.

4.1.1 60-Cow Dairy Farm

Base Policy. The 60-cow dairy farm is modeled with no-till corn silage/minimum till ryelage, minimum till corn/no-till ryelage, alfalfa no-till seeding, established alfalfa, hay/pasture, and pasture. The basic changes enacted for each alternative management policy on each crop are shown in Table 4.1. The EPIC simulation results are shown in Table 4.2. BASE surface and subsurface nitrogen losses average 4.1 and 22.1 pounds per farm acre, or 521 and 2,426 pounds for the farm, respectively. The largest losses occur on hay/pasture and pasture fields, followed by corn silage/ryelage and alfalfa. Nitrogen losses on corn silage are evenly split between surface and subsurface losses. There is very little difference

Table 4.1. Summary of Management Changes From BASE for the 60-Cow Dairy Farm

	Alternative Manure Management Policy		
Crop	INCORP[1]	NLIMIT[1]	PLIMIT[1]
Corn Sil/Ryelage	All Dairy Manure Incorporated	No Changes	Less 3.0 ton Litter, Add N&K Fert
Alfalfa	No Changes	No Changes	No P Fertilizer
Hay/Pasture	No Changes	Less 0.75 ton Litter	Less 2.5 ton litter, Add N,P,&K Fert
Pasture	No Changes	Less 1.5 ton Litter	Less 2.5 ton litter, Add N Fert

[1] INCORP refers to manure incorporation within two days, NLIMIT limits plant available nitrogen applications to VALUES recommendations, and PLIMIT limits phosphorus applications to crop phosphorus removals.

in total nitrogen losses between the different corn silage/ryelage tillage regimes. The difference in the two tillage methods is that while half of the acreage undergoes no-till planting in the spring and minimum tillage in the fall, the remaining acreage undergoes minimum tillage in the spring and no-till planting in the fall. All corn silage/ryelage receives equal amounts of dairy manure in the spring and fall. The results indicate that nitrogen losses differ very little between the seasonal variation in tillage. Subsurface nitrogen losses on the alfalfa increase in years two and three but decrease in year four. The EPIC output indicates that alfalfa plants are taking up mineralized nitrogen in year one until the plants develop nitrogen fixing capability. In years two and three, mineralized nitrogen is taken up by the plants but some leaching of excess nitrogen occurs during periods of plant inactivity in the late fall and early spring.

The largest nitrogen losses are on hay/pasture and pasture, which receive 138 and 137 pounds of available nitrogen, 38 percent and 126 percent above recommended agronomic applications. Surface nitrogen losses are very low despite high slopes and no

Table 4.2. Average Annual Yields and Field Nutrient Losses for the 60-Cow Dairy Farm.

Crop	Acres	Crop Yield (tons/acre)	Soil Erosion (tons/acre)	Nitrogen Volatilized (lbs/acre)	Surface Nit Losses (lbs/acre)	Subsurface Nit Losses (lbs/acre)	Phosphorus Losses (lbs/acre)
BASE 60-Cow Dairy							
NT Crn Sil/MT Rlge[1]	25	13.7/3.2	2.83	66.4	9.7	9.2	7.3
MT Crn Sil/NT Rlge[1]	25	13.7/3.1	2.89	64.7	9.6	9.3	6.8
Alfalfa, Seeding	5	3.3	1.19	0.0	0.9	4.3	3.9
Alfalfa, Year 2 & 3	10	4.1	0.33	0.0	0.3	8.1	1.7
Alfalfa, Year 4	5	3.9	0.29	15.4	0.3	3.7	1.6
Hay/Pasture	20	2.8	0.10	49.2	1.0	55.3	3.8
Pasture	10	1.8	0.08	51.9	0.5	69.5	4.1
Unimproved Pasture	10	1.1	0.30	7.0	0.7	4.1	0.3
Total	110		159.5	4927.7	520.5	2426.2	516.5
Mean (per acre)			1.45	44.8	4.7	22.1	4.7
INCORP[2]							
MT Crn Sil/MT Rlge	50	13.7/3.2	3.03	59.3	9.5	10.0	6.4
Alfalfa, Seeding	5	3.3	1.19	0.0	0.9	4.3	3.9
Alfalfa, Year 2 & 3	10	4.1	0.33	0.0	0.3	8.1	1.7
Alfalfa, Year 4	5	3.9	0.29	15.4	0.3	3.7	1.6
Hay/Pasture	20	2.8	0.10	49.2	1.0	55.3	3.8
Pasture	10	1.8	0.08	51.9	0.5	69.5	4.1
Total	110		168.0	4615.0	516.4	2463.3	484.5
Mean (per acre)			1.53	42.0	4.7	22.4	4.4
NLIMIT[2]							
NT Crn Sil/MT Rlge	25	13.7/3.2	2.83	66.4	9.7	9.2	7.3
MT Crn Sil/NT Rlge	25	13.7/3.1	2.89	64.7	9.6	9.3	6.8
Alfalfa, Seeding	5	3.3	1.19	0.0	0.9	4.3	3.9
Alfalfa, Year 2 & 3	10	4.1	0.33	0.0	0.3	8.1	1.7
Alfalfa, Year 4	5	3.9	0.29	15.4	0.3	3.7	1.6
Hay/Pasture	20	2.8	0.11	39.9	0.9	31.3	3.0
Pasture	10	1.8	0.09	32.6	0.4	28.6	2.4
Total	110		159.8	4548.5	519.2	1536.4	484.0
Mean (per acre)			1.45	41.4	4.7	14.0	4.4
PLIMIT[2]							
NT Crn Sil/MT Rlge	25	13.6/3.5	2.96	35.8	9.3	9.7	5.3
MT Crn Sil/NT Rlge	25	13.6/3.4	2.74	34.2	8.5	9.9	4.9
Alfalfa, Seeding	5	3.3	1.20	0.0	0.9	4.3	3.6
Alfalfa, Year 2 & 3	10	4.1	0.33	0.0	0.3	8.1	1.1
Alfalfa, Year 4	5	3.9	0.29	15.4	1.0	3.7	1.2
Hay/Pasture	20	2.8	0.12	18.4	0.4	31.1	1.2
Pasture	10	1.8	0.10	19.6	0.7	22.9	1.2
Total	110		159.7	2461.0	484.9	1503.8	330.5
Mean (per acre)			1.45	22.4	4.4	13.7	3.0

1. Crop abbreviations: NT = No-till, MT = Minimum Till, Crn Sil = Corn Silage, and Rlge = Ryelage.

2. INCORP refers to manure incorporation within two days, NLIMIT limits plant available nitrogen applications to VALUES recommendations, and PLIMIT limits phosphorus applications to crop phosphorus removals.

manure incorporation. This can be attributed to volatilization and organic nitrogen availability. Almost all of the mineral nitrogen is in ammonia form and over 83 percent volatilizes because of no incorporation. Organic nitrogen losses are limited because grass sod holds manure in place, limiting the loss of eroding soil material. Erosion for pasture and hay averages less than 0.1 ton per acre. Subsurface nitrogen losses are higher, with most of the losses attributed to leaching through the root zone in the shallow soil profile.

The 60-cow dairy farm lost 517 pounds of phosphorus, or 4.7 pounds per acre. Phosphorus losses are highest for corn, which has the highest beginning phosphorus levels and highest applications. The lowest phosphorus losses occur on established alfalfa. Most of the losses on corn results from organic phosphorus attached to sediment while most of the phosphorus losses occurring on pasture and hay are soluble phosphorus contained in the surface runoff. These estimates suggest that phosphorus losses on corn acreage can be reduced by preventing surface runoff of soil and organic manure particles. Reducing phosphorus losses on hay and pastures depends on reducing surface runoff. One problem with pasture and hay crops is that while soil tests indicate the phosphorus level in the plow layer, phosphorus levels at the surface are expected to be much greater because of constant surface manure applications. Organic phosphorus concentrates on the soil surface, leading to a greater concentration of water soluble phosphorus that can be carried off with surface runoff. From a crop management perspective, eroding sediment can be visually observed by the farmer. However, soluble nutrients contained in surface runoff are not visible, so farmers cannot determine nutrient runoff by observation and must rely on chemical analysis of runoff samples.

INCORP Policy. INCORP requires that both the spring and fall 3,500 gallon dairy manure applications to corn silage/ryelage are incorporated into soil within two days. The EPIC simulations indicate that INCORP reduces nitrogen volatilization losses by 5 to 7 pounds per acre or 313 pounds for the farm. Close examination of the EPIC simulations reveal that incorporation two days after application reduces volatilization losses by one third. Surface nitrogen losses decrease slightly but subsurface nitrogen losses increase by 0.7 to 0.8 pounds per acre. Overall farm level nitrogen losses increase by 32 pounds, less than the decrease in volatilization losses. The difference indicates that more nitrogen is retained in the soil as organic nitrogen. INCORP also reduces phosphorus losses on corn silage and for the farm by 7 percent. Soil erosion losses increase approximately five percent and crop yields increase slightly for only no-till ryelage. Phosphorus losses decrease but soil phosphorus content increases, increasing the potential for phosphorus losses or soluble phosphorus runoff in the future. These results suggest that INCORP increases potential nitrogen losses to subsurface and surface waters. INCORP is a significant tool when the goal is to reduce nitrogen volatilization, but there is little attention to atmospheric nitrogen losses at this time. The increase in organic nitrogen and phosphorus retention in the soil presents the potential of trading lower current nutrient losses for potential future nutrient losses that are not captured by the five-year simulation period.

NLIMIT Policy. NLIMIT restrictions for the 60-cow farm reduce nutrient applications to hay and pasture, significantly reducing farm level nitrogen losses from 26.8 to 18.7 pounds (30 percent) per acre. Plant available nitrogen applications decline from 138 to 100 pounds per acre for hay/pasture and from 137 to 60 pounds per acre for pasture. The nitrogen reductions are achieved by reducing litter applications by 0.75 and 0.5 tons per acre and result in decreasing nitrogen losses by 43 percent and 58 percent for hay/pasture and pasture crops, respectively. Phosphorus losses decrease on hay/pasture from 3.8 to 3.0 pounds per acre and from 4.1 to 2.4 pounds per acre for pasture, reducing farm losses by 32.5 pounds.

NLIMIT reduces nitrogen and phosphorus losses while not affecting the mean, median, or maximum crop yields. This raises the question of why farmers are over-applying nitrogen to pasture and grass hay. The farmer panels were not specifically asked why farmers applied nitrogen in excess of agronomic recommendations. However, the EPIC simulations indicate the farmers gain very little benefit from the extra nitrogen applications.

PLIMIT Policy. The phosphorus nutrient limitation eliminates litter application as plant phosphorus uptake requirements are met with dairy manure. Commercial phosphorus fertilizer applications are also suspended on alfalfa. Farm level phosphorus losses are reduced by 186 pounds (36.0 percent), from 4.7 to 3.0 pounds per acre. The greatest decrease in phosphorus losses occurs on pasture, declining 69.3 percent. Farm level nitrogen losses are 67 pounds lower than with NLIMIT. Erosions levels are practically identical to BASE and NLIMIT.

Crop yields remain the same for all crops except for rye forage which increases by 10 percent. Even though total nitrogen applications on corn silage/ryelage do not change, the application of commercial nitrogen fertilizer increases rye yields. Examination of the EPIC output reveals a greater quantity of plant available nitrate in the soil profile after commercial fertilizer application than after litter application. Organic nitrogen in the litter and the soil profile are dependent on soil temperature and moisture to induce nitrogen cycling for nitrogen availability to plants. Apparently the early season applications of litter are not providing the amount of nitrogen required by rye as compared to commercial nitrogen fertilizer that is generally in plant available nitrate form.

4.1.2 100-Cow Dairy Farm

BASE Policy. The 100-cow dairy farm has an additional 50 acres of corn silage/rye cover, 5 acres of alfalfa, 25 acres of hay/pasture, and 5 acres of pasture acreage as compared to the 60-cow farm. A general description of management changes for each alternative policy is shown in Table 4.3 and the EPIC simulation results are shown in Table 4.4. Nitrogen and phosphorus losses are 30.5 and 5.0 pounds per acre, 13.8 and 6.4 percent greater than the 60-cow dairy farm, respectively. Subsurface nitrogen losses are smaller for corn silage/ryelage and pasture and larger for grass hay than the losses on the 60-cow farm. In each case, the larger loss on the 100-cow dairy farm is associated with higher crop nitrogen applications. Pasture on the 100-cow farm receives only 2 tons of litter per acre as compared to 2.5 tons and 2500 gallons of dairy manure on the 60-cow farm, a decrease of 45 pounds per acre of plant available nitrogen per year. The result is a decrease in subsurface nitrogen losses of 39 pounds per acre and 1.3 pounds of phosphorus losses per acre.

On the 100-cow dairy farm, both surface and subsurface nitrogen losses on corn silage/rye cover are greater than on corn silage/ryelage. Total nitrogen and phosphorus losses are over 11.0 and 0.9 pounds per acre greater for corn silage/rye cover than for corn silage/ryelage. The higher losses occur because the same level of nutrients are applied to

Table 4.3. Summary of Management Changes From BASE for 100-Cow Dairy Farm.

	Alternative Manure Management Policy		
Crop	INCORP[1]	NLIMIT[1]	PLIMIT[1]
Corn Silage/Ryelage	All Dairy Manure Incorporated	No Changes	Less 2.0 ton Litter, Add N&K Fertilizer
Corn Silage/Rye Cover	All Dairy Manure Incorporated	No N Fertilizer	Less 2.0 ton Litter, Add N&K Fertilizer
Alfalfa	No Changes	No Changes	No P Fertilizer
Hay/Pasture	No Changes	Less 0.75 ton Litter	Less 3.0 ton Litter, Add N,P,&K Fertilizer
Pasture	No Changes	Less 0.5 ton Litter	Less 2.0 ton Litter, Add N,P,&K Fertilizer

[1] INCORP refers to manure incorporation within two days, NLIMIT limits plant available nitrogen applications to VALUES recommendations, and PLIMIT limits phosphorus applications to crop removal.

corn silage/rye cover as are applied to corn silage/ryelage even though agronomic nitrogen recommendations for corn silage/rye cover are 70 pounds per acre less than the recommendation for corn silage/ryelage. Erosion is higher for the 100-cow farm than the 60-cow farm, primarily due to the additional 50 acres of corn silage/rye cover and the larger per acre erosion occurring on these acres. Corn silage yields are essentially unchanged. Ryelage yields for the 100-cow farm are 0.2 to 0.3 ton per acre lower than for the 60-cow farm. The lower yields can be attributed to 32 pounds less plant available nitrogen applied by the 100-cow farm.

Phosphorus losses per acre are greater for the 100-cow dairy farm than for the 60-cow dairy farm. Phosphorus losses are larger for hay/pasture but smaller for corn silage/ryelage and pasture. The higher phosphorus losses on hay/pasture are attributed to an extra 0.5 ton of litter application. The highest phosphorus losses on the 100-cow dairy farm occur on corn silage/rye cover and are 0.6 to 1.2 pounds greater than phosphorus losses on

Table 4.4. Average Annual Yields and Field Nutrient Losses for the 100-Cow Dairy Farm.

Crop	Acres	Crop Yield (tons/acre)	Soil Erosion (tons/acre)	Nitrogen Volatilized (lbs/acre)	Surface Nit Losses (lbs/acre)	Subsurface Nit Losses (lbs/acre)	Phosphorus Losses (lbs/acre)
BASE 100-Cow Dairy							
NT Crn Sil/MT Rlge[1]	25	13.6/2.9	2.93	51.7	9.5	5.6	6.6
MT Crn Sil/NT Rlge[1]	25	13.7/2.8	2.95	50.3	9.3	5.5	6.2
NT Crn Sil/MT Rye[1]	25	13.8	3.26	49.5	11.2	13.4	7.8
MT Crn Sil/NT Rye[1]	25	13.7	3.29	41.4	10.9	15.5	6.8
Alfalfa, Seeding	6.25	3.3	1.19	0.0	0.9	4.3	3.9
Alfalfa, Year 2 & 3	12.5	4.1	0.33	0.0	0.3	8.1	1.7
Alfalfa, Year 4	6.25	3.9	0.29	0.0	0.1	3.3	1.5
Hay/Pasture	45	2.8	0.10	55.2	1.0	72.7	4.4
Pasture	12.5	1.8	0.10	25.9	0.5	30.3	2.8
Unimproved Pasture	12.5	1.1	0.30	7.0	0.7	4.1	0.3
Total	195		333.6	7717.8	1091.7	4848.5	977.4
Mean (per acre)			1.7	39.6	5.6	24.9	5.0
INCORP[2]							
MT Crn Sil/MT Rlge	50	13.7/2.9	3.12	45.3	9.5	5.9	6.0
MT Crn Sil/MT Rye	50	13.7	3.34	38.8	10.6	16.3	6.4
Alfalfa, Seeding	6.25	3.3	1.19	0.0	0.9	4.3	3.9
Alfalfa, Year 2 & 3	12.5	4.1	0.33	0.0	0.3	8.1	1.7
Alfalfa, Year 4	6.25	3.9	0.29	0.0	0.1	3.3	1.5
Hay/Pasture	45	2.8	0.10	55.2	1.0	72.7	4.4
Pasture	12.5	1.8	0.10	25.9	0.5	30.3	2.8
Unimproved Pasture	12.5	1.1	0.30	7.0	0.7	4.1	0.3
Total	195		345.7	7100.3	1073.2	4960.5	911.8
Mean (per acre)			1.8	36.4	5.5	25.4	4.7

1. Crop abbreviations: NT = No-till, MT = Minimum Till, Crn Sil = Corn Silage, and Rlge = Ryelage.
2. INCORP refers to manure incorporation within two days, NLIMIT limits plant available nitrogen applications to VALUES recommendations, and PLIMIT limits phosphorus applications to crop phosphorus removals.

Table 4.4 (continued). Average Annual Yields and Field Nutrient Losses for the 100-Cow Dairy Farm.

Crop	Acres	Crop Yield (tons/acre)	Soil Erosion (tons/acre)	Nitrogen Volatilized (lbs/acre)	Surface Nit Losses (lbs/acre)	Subsurface Nit Losses (lbs/acre)	Phosphorus Losses (lbs/acre)
NLIMIT[2]							
NT Crn Sil/MT Rlge[1]	25	13.6/2.9	2.93	51.7	9.5	5.6	6.6
MT Crn Sil/NT Rlge[1]	25	13.7/2.8	2.95	50.3	9.3	5.5	6.2
NT Crn Sil/MT Rye[1]	25	13.7	3.27	49.7	11.2	8.7	7.7
MT Crn Sil/NT Rye[1]	25	13.7	3.30	41.5	10.8	10.7	6.8
Alfalfa, Seeding	6.25	3.3	1.19	0.0	0.9	4.3	3.9
Alfalfa, Year 2 & 3	12.5	4.1	0.33	0.0	0.3	8.1	1.7
Alfalfa, Year 4	6.25	3.9	0.29	0.0	0.1	3.3	1.5
Hay/Pasture	45	2.8	0.11	40.1	1.0	39.5	3.1
Pasture	12.5	1.8	0.11	19.5	0.5	19.8	2.2
Unimproved Pasture	12.5	1.1	0.30	7.0	0.7	4.1	0.3
Total	195		334.7	6965.8	1087.1	2983.8	913.0
Mean (per acre)			1.7	35.7	5.6	15.3	4.7
PLIMIT[2]							
NT Crn Sil/MT Rlge	25	13.5/3.4	3.01	30.7	9.2	6.1	5.2
MT Crn Sil/NT Rlge	25	13.6/3.3	2.78	29.4	8.4	6.0	4.8
NT Crn Sil/MT Rye	25	13.7	3.29	30.1	10.4	8.7	6.0
MT Crn Sil/NT Rye	25	13.7	3.12	29.2	9.7	9.6	5.5
Alfalfa, Seeding	6.25	3.3	1.20	0.0	0.9	4.3	3.6
Alfalfa, Year 2 & 3	12.5	4.1	0.33	0.0	0.3	8.1	1.3
Alfalfa, Year 4	6.25	3.9	0.29	0.0	0.1	3.3	0.9
Hay/Pasture	45	2.8	0.12	18.4	1.0	38.1	1.3
Pasture	12.5	1.8	0.13	0.0	0.4	17.7	0.3
Unimproved Pasture	12.5	1.1	0.30	7.0	0.7	4.1	0.3
Total	195		329.2	3901.8	1014.3	2897.4	647.9
Mean (per acre)			1.7	20.0	5.2	14.9	3.3

1. Crop abbreviations: NT = No-till, MT = Minimum Till, Crn Sil = Corn Silage, and Rlge = Ryelage.
2. INCORP refers to manure incorporation within two days, NLIMIT limits plant available nitrogen applications to VALUES recommendations, and PLIMIT limits phosphorus applications to crop phosphorus removals.

corn silage/ryelage. The higher losses on corn silage/rye cover and hay/pasture increases phosphorus losses per acre above the per acre phosphorus losses for the 60-cow dairy farm.

INCORP Policy. INCORP results for the 100-cow dairy farm are similar to those of the 60-cow dairy farm. Farm level nitrogen losses increase 92 pounds, or 0.4 pounds per acre. Total volatilization losses drop 617 pounds, or 3.2 pounds per acre, and phosphorus losses decrease 0.3 pound per acre. Mean corn silage yields and ryelage yields increase slightly by eliminating no-till corn silage and no-till ryelage. The greatest reduction in phosphorus losses occur on the no-till corn silage/rye cover. INCORP is not a very effective policy because overall nitrogen losses increase by 2 percent and phosphorus losses decrease by only 6 percent.

NLIMIT Policy. NLIMIT reduces farm level nitrogen losses 31 percent, from 30.5 to 20.9 pounds per acre. The biggest changes are a 45 percent decrease (33.2 pounds) for hay/pasture and a 34 percent (10.5 pounds) decrease for pasture. Corn silage/rye cover nitrogen losses decline an average of 4.75 pounds per acre with elimination of commercial fertilizer application. Almost all of the decrease consists of subsurface nitrogen losses. Phosphorus losses decrease for hay/pasture and pasture, the only crops subject to lower manure applications. Crop yields and erosion are unchanged from the base yields.

PLIMIT Policy. Farm level phosphorus losses decrease 327 pounds (33.4 percent), from 5.0 to 3.3 pounds per acre from BASE losses. The largest reductions in phosphorus losses are on hay/pasture and pasture with no manure or litter applications. Volatilization losses decrease by 48 percent from BASE losses without poultry litter applications. Nitrogen losses remain fairly constant as nitrogen fertilizer substitutes for the poultry litter. A slight shift from surface to subsurface losses is apparent for corn silage as compared to losses under NLIMIT. The substitution of surface applied manure with commercial fertilizer reduces surface losses.

Pasture and hay yields remain the same, corn silage yields decrease slightly, and ryelage yields increase. The presence of abundant nitrate appears important to early rye growth. Nitrate fertilizer is applied to replace nitrogen supplied by poultry litter. The fertilizer is split into two applications, with 55 pounds applied in early March to rye (VALUES recommends up to 70 pounds of nitrogen applied to ryelage in the early spring.). The remaining fertilizer is applied at corn planting. The fertilizer produces mean ryelage yields of 3.3 to 3.4 tons per acre while the application of 3 tons of litter produces mean yields of only 3.1 to 3.2 tons per acre. The difference on 50 acres of ryelage is 5 tons of dry matter.

4.1.3 150-Cow Dairy Farm.

BASE Policy. The additional crops on the 150-cow farm include 10 acres of grass hay and 30 acres of silage corn without any cover crop. A general description of management changes for each alternative policy is shown in Table 4.5 and the EPIC simulation results are shown in Table 4.6. The BASE nitrogen and phosphorus losses are 20.5 and 4.0 pounds per acre, less than for the 60 and 100-cow dairy farms. The largest nitrogen losses occur on grass hay, similar to the results from the 60 and 100-cow dairy farms. The next largest loss occurs on corn silage/no rye cover crops. Nitrogen applications are well in excess of agronomic recommendations for both grass hay and corn silage/no rye cover. Nitrogen losses for hay/pasture and pasture are not as high as the other two dairy farms because nitrogen applications are more in line with agronomic nutrient recommendations.

Table 4.5. Summary of Management Changes From BASE for the 150-Cow Dairy Farm.

	Alternative Manure Management Policy		
Crop	INCORP[1]	NLIMIT[1]	PLIMIT[1]
Corn Sil/Ryelage	All Dairy Manure Incorp	No Changes	Less 2.0 ton Litter, Add N&K Fert
Corn Sil/Rye Cover	All Dairy Manure Incorp	Reduced N Fertilizer	Less 2.0 ton Litter, Add N&K Fert
Corn Sil/No Cover	All Dairy Manure Incorp	Less 0.5 ton Litter, No N Fert	Less 2.0 ton Litter, Add N&K Fert
Alfalfa	No Changes	No Changes	No P Fertilizer
Grass Hay	No Changes	Less 1.0 ton Litter	Less 3.0 ton litter, Add N,P,&K Fert
Hay/Pasture	No Changes	No Change	Less 1.5 ton litter, Add N,P,&K Fert
Pasture	No Changes	Less 0.5 ton litter	Less 1.5 ton litter, Add N,P,&K Fert

[1]. INCORP refers to manure incorporation within two days, NLIMIT limits plant available nitrogen applications to VALUES recommendations, and PLIMIT limits phosphorus applications to crop removal.

Phosphorus losses are higher for no-till corn silage than any other crop/tillage combination for any farm. These losses indicate the potential of surface phosphorus losses when large amounts of manure are applied to soils without a cover crop and incorporation. Erosion and crop yields are very similar to those reported for the other farms except for lower ryelage yields. The lower ryelage yields are attributed to lower poultry litter applications for the 150-cow dairy/poultry farm.

INCORP Policy. INCORP increases farm level surface and subsurface nitrogen losses by 216 pounds (0.6 pounds per acre) while reducing nitrogen volatilization losses by 118 pounds (2.5 pounds per acre). Farm level phosphorus losses decrease by 0.3 pound per acre. The changes in nutrient losses are nearly identical to those incurred on the 60 and 100-cow dairy farms. Nitrogen losses remain about the same for corn silage/ryelage and increase slightly for corn silage/rye cover. The largest increase occurs on no-till corn silage/no rye cover where manure incorporation increases nitrogen losses by 6.7 pounds (16 percent). Phosphorus losses on the no-till corn silage/no rye cover drop from 9.6 to 7.3 pounds per acre (24 percent). Ryelage yields increase slightly with incorporation. The EPIC output reveals that minimum till ryelage produces greater plant biomass in the fall than no-till planting. This appears to caused by the greater amount of nitrogen in the soil because of manure incorporation.

Examination of the no-till corn silage/no rye cover reveals problems that can occur with incorporation of surface applied manure. Volatilization decreases by 33.2 percent, placing 18.7 pounds of ammonia nitrogen per acre in the soil profile. Surface losses decrease by one pound per acre but subsurface nitrogen losses increase by 7.7 pounds, for a

Table 4.6. Average Annual Yields and Field Nutrient Losses for the 150-Cow Dairy Farm.

Crop	Acres	Crop Yield (tons/acre)	Soil Erosion (tons/acre)	Nitrogen Volatilized (lbs/acre)	Surface Nit Losses (lbs/acre)	Subsurface Nit Losses (lbs/acre)	Phosphorus Losses (lbs/acre)
150-Cow BASE Farm							
NT Crn Sil/MT Rlge[1]	30	13.6/2.7	2.99	46.8	9.6	4.8	6.6
MT Crn Sil/NT Rlge[1]	30	13.7/2.6	2.97	45.5	9.3	4.7	6.1
NT Crn Sil/MT Rye[1]	30	13.8	3.41	45.5	11.4	11.8	7.8
MT Crn Sil/NT Rye[1]	30	13.7	3.40	36.7	11.0	14.1	6.9
NT Corn Sil[1]	15	13.7	2.92	56.3	13.1	28.7	9.6
MT Corn Sil[1]	15	13.7	3.58	39.3	11.2	37.5	7.2
Alfalfa, Seeding	10	3.3	1.19	0.0	0.9	4.3	3.9
Alfalfa, Year 2 & 3	20	4.1	0.33	0.0	0.3	8.1	1.8
Alfalfa, Year 4	10	3.9	0.29	15.4	0.1	3.3	1.7
Grass Hay	10	2.9	0.03	59.2	0.4	64.4	0.9
Hay/Pasture	60	2.8	0.12	29.7	0.8	20.3	2.4
Pasture	55	1.8	0.09	31.2	0.4	26.8	2.6
Pasture Base	55	1.1	0.30	7.0	0.7	4.1	0.3
Total	370		531.0	11144.0	1733.1	5858.4	1474.7
Mean (per acre)			1.44	30.1	4.7	15.8	4.0
INCORP[2]							
MT Crn Sil/MT Rlge	60	13.6/2.8	3.16	41.4	9.5	5.0	6.0
MT Crn Sil/MT Rye	60	13.7	3.46	32.3	10.7	15.1	6.5
MT Corn Sil	30	13.7	4.03	37.6	12.1	36.4	7.3
Alfalfa, Seeding	10	3.3	1.19	0.0	0.9	4.3	3.9
Alfalfa, Year 2 & 3	20	4.1	0.33	0.0	0.3	8.1	1.7
Alfalfa, Year 4	10	3.9	0.29	15.4	0.1	3.3	1.6
Grass Hay	10	2.9	0.03	59.2	0.4	64.4	0.9
Hay/Pasture	60	2.8	0.12	29.7	0.8	20.3	2.4
Pasture	55	1.8	0.09	31.2	0.4	26.8	2.6
Pasture Base	55	1.1	0.30	7.0	0.7	4.1	0.3
Total	370		568.5	10,025.0	1707.7	6098.8	1369.7
Mean (per acre)			1.54	27.1	4.6	16.5	3.7

1. Crop abbreviations: NT = No-till, MT = Minimum Till, Crn Sil = Corn Silage, and Rlge = Ryelage.
2. INCORP refers to manure incorporation within two days, NLIMIT limits plant available nitrogen applications to VALUES recommendations, and PLIMIT limits phosphorus applications to crop phosphorus removals.

Table 4.6. (continued). Average Annual Yields and Field Nutrient Losses for 150-Cow Dairy Farm.

Crop	Acres	Crop Yield (tons/acre)	Soil Erosion (tons/acre)	Nitrogen Volatilized (lbs/acre)	Surface Nit Losses (lbs/acre)	Subsurface Nit Losses (lbs/acre)	Phosphorus Losses (lbs/acre)
<u>NLIMIT</u>[2]							
NT Cm Sil/MT Rlge[1]	30	13.6/2.7	2.99	46.8	9.6	4.8	6.6
MT Cm Sil/NT Rlge[1]	30	13.7/2.6	2.97	45.5	9.3	4.7	6.1
NT Corn Sil/MT Rye[1]	30	13.8	3.41	45.5	11.4	10.1	7.8
MT Corn Sil/NT Rye[1]	30	13.7	3.41	36.8	11.0	10.8	6.9
NT Corn Sil[1]	15	13.7	2.95	54.6	13.0	20.7	9.4
MT Corn Sil[1]	15	13.7	3.70	30.4	11.3	25.0	6.9
Alfalfa, Seeding	10	3.3	1.19	0.0	0.9	4.3	3.9
Alfalfa, Year 2 & 3	20	4.1	0.33	0.0	0.3	8.1	1.7
Alfalfa, Year 4	10	3.9	0.29	15.4	0.1	3.3	1.6
Grass Hay	10	2.9	0.03	44.5	0.4	39.5	0.8
Hay/Pasture	60	2.8	0.12	29.7	0.8	20.3	2.4
Pasture	55	1.8	0.10	24.8	0.4	15.1	2.0
Pasture Base	55	1.1	0.30	7.0	0.7	4.1	0.3
Total	370		534.1	10,489.0	1728.8	4504.6	1433.0
Mean (per acre)			1.44	28.3	4.7	12.2	3.9
<u>PLIMIT</u>[2]							
NT Cm Sil/MT Rlge	30	13.3/3.3	3.06	25.7	9.2	4.0	5.1
MT Cm Sil/NT Rlge	30	13.5/3.2	3.05	24.6	9.1	4.9	5.1
NT Corn Sil/MT Rye	30	13.7	3.29	30.2	10.5	10.3	6.0
MT Corn Sil/NT Rye	30	13.7	3.53	24.8	10.8	10.0	6.1
NT Corn Sil	15	13.7	2.99	35.3	11.4	20.6	6.8
MT Corn Sil	15	13.7	3.84	19.8	11.2	22.1	6.2
Alfalfa, Seeding	10	3.3	1.20	0.0	0.9	4.3	3.6
Alfalfa, Year 2 & 3	20	4.1	0.33	0.0	0.3	8.1	1.3
Alfalfa, Year 4	10	3.9	0.29	15.4	0.1	3.3	1.0
Grass Hay	10	2.9	0.03	21.3	0.4	37.1	0.5
Hay/Pasture	60	2.5	0.14	11.0	0.9	22.1	1.0
Pasture	55	1.8	0.11	11.8	0.4	11.2	0.8
Pasture Base	55	1.1	0.30	7.0	0.7	4.1	0.3
Total	370		543.1	5892.5	1657.6	4299.1	1060.5
Mean (per acre)			1.47	15.9	4.5	11.6	2.9

1. Crop abbreviations: NT = No-till, MT = Minimum Till, Cm Sil = Corn Silage, and Rlge = Ryelage.
2. INCORP refers to manure incorporation within two days, NLIMIT limits plant available nitrogen applications to VALUES recommendations, and PLIMIT limits phosphorus applications to crop phosphorus removals.

net potential nitrogen loss to water sources of 6.7 pounds per acre (16 percent). Although volatilization losses are substantially reduced, atmospheric nitrogen losses become potential water quality problems.

NLIMIT Policy. NLIMIT reduces farm level nitrogen losses by 1357 pounds (17.9 percent and 3.6 pounds per farm acre) as compared to 891.1 pounds (30.2 percent and 8.1 pounds per acre) and 1869.3 pounds (31.5 percent and 9.6 pounds per acre) for the 60 and 100-cow dairy farms. Nitrogen loss reductions are not as great for the 150-cow dairy farm because overall nitrogen applications are more in line with agronomic recommendations than for the other two dairy farms. NLIMIT reduces nitrogen applications for corn silage/rye cover, corn silage/no rye cover, grass hay, and pastures. The largest reduction in nitrogen losses occurs on grass hay where losses drop by 25.3 pounds per acre (39 percent). This is because plant available nitrogen applications decline from 169 to 118 pounds per acre. The lower nitrogen applications are not accompanied with an detectable change in crop yield as the mean, maximum, and median yields remain unchanged. Nitrogen losses for pastures decrease by 11.7 pounds per acre (43 percent). Nitrogen losses also decline by 8.1 and 12.4 pounds per acre (19.3 and 15.5 percent) for no-till and minimum till corn silage/no rye cover crops. The lower nitrogen losses for pastures and corn silage/no rye cover result from lower nitrogen applications. However, crop yields for both crops remain about the same. Erosion remains about the same level and farm level phosphorus losses decrease by 41 pounds or 0.1 pounds per acre.

PLIMIT Policy. PLIMIT reduces farm level phosphorus losses by 414 pounds (28.0 percent and 1.1 pounds per acre). Nitrogen losses decline by 1634 pounds per acre (21.5 percent), 277 pounds and 3.6 percentage points greater than the reduction attained under NLIMIT. All crops show a decrease in nitrogen losses from NLIMIT except for hay/pasture, which has a 1.9 pound per acre increase. This can be attributed to the switch from litter to commercial nitrogen fertilizer which places a greater amount of water soluble nitrogen on the soil at one time. Nitrogen losses for the other crops are 1 to 2.5 pounds per acre lower than the reductions reported for NLIMIT. Phosphorus losses decline by 0.3 to 2.8 pounds per acre for all crops, including alfalfa. The largest reduction in phosphorus losses occurs on no-till corn silage/no rye cover (2.8 pounds per acre and 29.1 percent). Phosphorus losses are much greater for no-till corn silage than for minimum tillage because the surface applied dairy manure and litter is more subject to erosion and surface runoff. Phosphorus losses for minimum till corn silage are 1.0 to 1.8 pounds less than for no-till corn silage receiving the same level of nutrients. Ryelage yields jump from 2.6 to 3.3 tons per acre, following the same pattern as the 60 and 100-cow dairy farms. Substituting commercial nitrogen fertilizer for poultry litter provides more plant available nitrate for rye in March and early April.

Effect of Cover Crops. The farmer panel indicated that in most years the 150-cow dairy farms cannot plant all corn acreage to rye because of weather and time constraints. The EPIC simulations for NLIMIT on the 150-cow dairy farm reveal that nutrient losses are significantly lower with cover crops. Nitrogen applications are limited to agronomic recommendations for both the corn silage/rye cover (160 pounds per acre) and corn silage/no rye cover (130 pounds per acre). Without rye cover crops, nitrogen losses average 35 pounds of nitrogen per acre with applications of 130 pounds of plant available nitrogen. When a cover crop is added, average nitrogen losses decrease to 21.7 pounds of nitrogen per acre on fields receiving 160 pounds of plant available nitrogen. Rye cover crops reduce nitrogen losses by 38.0 percent even when receiving 23.1 percent more plant available nitrogen fertilizer. Requiring farmers to plant cover crops can provide major reductions in nitrogen losses, However, only the 150-cow dairy farmers do not plant rye cover crops on all of their corn acreage and the reason is one of management constraints, not poor conservation practices.

4.1.4 60-Cow Dairy/Poultry Farm

Nitrogen and phosphorus losses are also estimated for each dairy farm under the assumption that the farm has added a poultry operation that produces 408 tons of litter. The costs, quantity of poultry litter, and the litter's nutrient content is 57.5 percent turkey and 42.5 percent broiler, proportional to the manure quantity produced in the county (1992 Census of Agriculture). The 60-cow dairy/poultry farm produces more litter than can be utilized on the farm, applying 318 tons and exporting 90 tons. The 100-cow dairy/poultry farm utilizes all the litter it produces. Overall nutrient applications remaining the same under all policies for the 150-cow dairy farm because it utilizes all farm produced litter and still needs to acquires additional poultry litter.

EPIC simulations for the dairy/poultry farm are completed for the BASE, INCORP, and NLIMIT for the 60 and 100-cow dairy/poultry farms. No additional EPIC simulation is required for PLIMIT because no litter is applied and nutrient applications are assumed to equal applications on the 60 and 100-cow dairy farms under PLIMIT. No EPIC simulations are required for the 150-cow dairy/poultry farm.

BASE Policy. A general description of management changes for each alternative policy is shown in Table 4.7 and the EPIC simulation results are shown in Table 4.8. Adding a poultry operation to the BASE 60-cow dairy farm increases farm level nitrogen losses by 1557 pounds (52.8 percent). Almost all of the increase is subsurface losses. Farm level volatilization and phosphorus losses increase by 899 pounds (18.2 percent) and 64 pounds (12.4 percent), respectively, for the dairy/poultry farm. The increase in phosphorus losses is substantially lower than the increase in nitrogen losses. Erosion losses actually decrease slightly, from 1.45 to 1.43 tons per acre for the dairy/poultry farm.

Table 4.7. Summary of Management Changes from BASE for the 60-Cow Dairy/Poultry Farm.

	Alternative Manure Management Policy	
Crop	INCORP[1]	NLIMIT[1]
Corn Silage/Ryelage	All Dairy Manure Incorporated	Less 1.15 ton Litter
Alfalfa	No Changes	No Changes
Hay/Pasture	No Changes	Less 1.25 ton Litter
Pasture	No Changes	Less 2.0 ton Litter

[1.] INCORP refers to manure incorporation within two days and NLIMIT limits plant available nitrogen applications to VALUES recommendations.

Table 4.8. Average Annual Yields and Field Nutrient Losses for the 60-Cow Dairy/Poultry Farm.

Crop	Acres	Crop Yield (tons/acre)	Soil Erosion (tons/acre)	Nitrogen Volatilized (tons/acre)	Surface Nit Losses (lbs/acre)	Subsurface Nit Losses (lbs/acre)	Phosphorus Losses (tons/acre)
BASE 60-Cow Dairy/Poultry Farm							
NT Crn Sil/MT Rlge[1]	25	13.7/3.6	2.78	81.0	10.2	30.8	8.4
MT Crn Sil/NT Rlge[1]	25	13.7/3.6	2.83	78.8	9.9	31.0	7.5
Alfalfa, Seeding	5	3.3	1.19	0.0	0.9	4.3	3.9
Alfalfa, Year 2 & 3	10	4.1	0.33	0.0	0.3	8.1	1.7
Alfalfa, Year 4	5	3.9	0.29	15.4	0.3	3.7	1.6
Hay/Pasture	20	2.8	0.10	55.2	1.0	70.7	4.4
Pasture	10	1.8	0.08	58.0	0.5	84.0	4.7
Unimproved Past	10	1.1	0.30	7.0	0.7	4.1	0.3
Total	110		156.8	5826.0	542.0	3961.6	579.7
Mean (per acre)			1.43	53.0	4.9	36.0	5.3
INCORP[2]							
MT Crn Sil/MT Rlge	50	13.7/3.6	2.93	74.2	9.7	32.4	6.9
Alfalfa, Seeding	5	3.3	1.19	0.0	0.9	4.3	3.9
Alfalfa, Year 2 & 3	10	4.1	0.33	0.0	0.3	8.1	1.7
Alfalfa, Year 4	5	3.9	0.29	15.4	0.3	3.7	1.6
Hay/Pasture	20	2.8	0.10	55.2	1.0	70.7	4.4
Pasture	10	1.8	0.08	58.0	0.5	84.0	4.7
Unimproved Past	10	1.1	0.30	7.0	0.7	4.1	0.3
Total	110		163.0	5541.0	523.0	4035.3	528.4
Mean (per acre)			1.48	50.4	4.8	36.7	4.8
NLIMIT[2]							
NT Crn Sil/MT Rlge	25	13.7/3.3	2.80	70.3	9.8	13.2	7.6
NT Crn Sil/MT Rlge	25	13.7/3.3	2.89	68.4	9.7	13.5	7.0
Alfalfa, Seeding	5	3.3	1.19	0.0	0.9	4.3	3.9
Alfalfa, Year 2 & 3	10	4.1	0.33	0.0	0.3	8.1	1.7
Alfalfa, Year 4	5	3.9	0.29	15.4	0.3	3.7	1.6
Hay/Pasture	20	2.8	0.11	39.9	0.9	31.3	3.0
Pasture	10	1.8	0.09	32.6	0.4	28.6	2.4
Unimproved Past	10	1.1	0.30	7.0	0.7	4.1	0.3
Total	110		159.1	4738.5	526.6	1741.5	496.6
Mean (per acre)			1.45	43.1	4.8	15.8	4.5

[1] Crop abbreviations: NT = No-till, MT = Minimum Till, Crn Sil = Corn Silage, and Rlge = Ryelage.
[2] INCORP refers to manure incorporation within two days, NLIMIT limits plant available nitrogen applications to VALUES recommendations, and PLIMIT limits phosphorus applications to crop phosphorus removals.

The highest nitrogen losses on the 60-cow dairy/poultry farm occur on hay/pasture and pasture because nitrogen applications exceed agronomic recommendations. These losses are 15.4 and 14.5 pounds per acre greater than on the 60-cow dairy farm hay/pasture and pasture. Nitrogen losses on the dairy/poultry farm corn more than double from 18.9 pounds to 41 pounds per acre. A 70 pound increase in plant available nitrogen applications on the dairy/poultry farm corn silage/ryelage increases ammonia volatilization losses up to 14.6 pounds and surface and subsurface nitrogen losses by 22 pounds. More than half of the additional nitrogen applications are lost to the environment. Phosphorus losses on the 60-cow dairy/poultry farm are highest on corn silage/ryelage, at 8.4 pounds for no-till and 7.5 pounds for minimum till corn silage. An additional 43 pounds of phosphorus per acre applied to corn silage/ryelage result in one pound of additional phosphorus loss. However, the soil phosphorus levels are being pushed higher on the dairy/poultry farm, presenting future environmental problems that are not indicated with the five-year period examined in this study.

Mean, maximum, and median corn silage, grass hay, and pasture yields for the 60-cow dairy/poultry farm are nearly identical to the BASE 60-cow dairy farm. Ryelage yields increase by 12.5 percent, from 3.1 and 3.2 tons per acre to 3.6 tons per acre. Examination of the EPIC output reveals the higher poultry litter applications produce higher levels of nitrate available for uptake by rye after the spring litter application. This result is similar to the higher rye yields that are estimated when commercial nitrogen fertilizer replaces poultry litter.

INCORP Policy. INCORP produces the same general results as occur on the representative dairy farms. Incorporating dairy manure on corn silage/ryelage reduces ammonia volatilization and surface nitrogen losses while increasing subsurface nitrogen losses. Volatilization losses on the 60-cow dairy/poultry farm corn silage/ryelage decline by 6.8 pounds per acre (8.4 percent). Total nitrogen losses on corn silage/ryelage increase 0.2 to 1.1 pounds per acre and phosphorus losses decrease 0.6 to 1.5 pounds per acre. Farm level nitrogen losses decrease 0.6 pounds (1.5 percent) and phosphorus losses decrease by 0.5 pound per acre (9.4 percent) for the 60-cow dairy/poultry farm. Farm level erosion increases by 0.05 tons per acre, less than the 0.07 ton erosion increase experienced with manure incorporation on the 60-cow dairy farm. Farm level volatilization decreases 287 pounds, 1.5 percent less than the 315 pound decrease experienced with incorporation on the 60-cow dairy farm. Corn silage and ryelage yields remain approximately unchanged.

NLIMIT Policy. Total farm level nitrogen losses decrease 2235 pounds (49.6 percent), from 40.9 pounds per acre to 20.6 pounds per acre for the 60-cow dairy/poultry farm. These nitrogen losses are 214 pounds (1.9 pounds per acre) greater than nitrogen losses on the dairy farm under NLIMIT. Surface losses for corn silage remain about the same as NLIMIT on the 60-cow dairy while subsurface losses are 3.5 pounds per acre larger. The greatest reduction in nitrogen losses on the dairy/poultry farm occur on hay/pasture and pasture. Nitrogen losses decrease by 39.5 pounds (55.1 percent) on hay/pasture and by 55.5 pounds (65.7 percent) on pasture. These losses are achieved by reducing plant available nitrogen applications on hay/pasture by 57 pounds and by 100 pounds on pasture. NLIMIT reduces nitrogen losses on corn silage/ryelage by 17.7 to 18.0 pounds (43.3 and 43.9 per cent) per acre by reducing plant available nitrogen applications 52 pounds (18.4 percent) per acre.

Phosphorus losses for the 60-cow dairy/poultry farm decrease by 83.1 pounds (14.3 percent, 0.8 pounds per acre). Losses decrease 1.4 and 2.3 pounds per acre on hay/pasture and pasture, resulting from 36 and 56 pounds per acre lower phosphorus applications. Phosphorus applications corn/silage ryelage decline by 33 pounds per acre, resulting in decreased losses of 0.8 to 1.5 pounds per acre. Crop yields remain approximately the same except for ryelage, which decreases from 3.6 to 3.3 tons per acre.

4.1.5. 100-Cow Dairy/Poultry Farm.

BASE Policy. A general description of management changes for each alternative policy is shown in Table 4.9 and the EPIC simulation results are shown in Table 4.10. The 100-cow dairy/poultry farm applies 408 tons of poultry litter as compared to 360 ton for the BASE 100-cow dairy farm. The additional 48 ton of litter, containing 2300 pounds of plant available nitrogen, is applied to corn silage/ryelage. Farm level nitrogen losses for the dairy/poultry farm are 6,274 pounds, 331 pounds greater than for the BASE 100-cow dairy farm. Surface losses remain about the same for both the dairy and dairy/poultry farms while subsurface losses double on corn silage/ryelage on the 100-cow dairy/poultry farm. Total nitrogen losses on corn silage/ryelage for the 100-cow dairy/poultry farm are 6.6 to 6.8 pounds per acre greater than on corn silage/ryelage for the 100-cow dairy farm. Farm level phosphorus losses increase by 30 pounds (3.7 percent) for the dairy/poultry farm. Ryelage yields for the dairy/poultry farm increase by 0.3 to 0.4 tons per acre because of the higher litter applications.

Table 4.9. Summary of Management Changes From BASE for 100-Cow Dairy/Poultry Farm

	Alternative Manure Management Policy	
Crop	INCORP[1]	NLIMIT[1]
Corn Silage/Ryelage	All Dairy Manure Incorporated	Add 0.8 ton Litter, No N Fertilizer
Corn Silage/Rye Cover	All Dairy Manure Incorporated	No N Fertilizer
Alfalfa	No Changes	No Changes
Hay/Pasture	No Changes	Less 0.75 ton Litter
Pasture	No Changes	Less 0.5 ton litter

[1] INCORP refers to manure incorporation within two days and NLIMIT limits plant available nitrogen applications to VALUES recommendations.

INCORP Policy. Farm level nitrogen losses increase by 106 pounds, phosphorus losses decrease by 85 pounds, erosion losses increase by 10 tons, and volatilization losses decrease by 603 pounds with manure incorporation. All changes in nutrient losses occur on corn silage/ryelage and rye cover. Nitrogen losses for all corn silage crops increase 0.5 to 2.3 pounds per acre while volatilization losses decrease by 2.6 to 11.7 pounds per acre. Phosphorus losses decrease by 0.4 to 1.5 pounds per acre. Crop yields remain at the same levels for corn silage and ryelage.

NLIMIT Policy. The 100-cow dairy/poultry farm meets nitrogen nutrient restrictions by eliminating nitrogen fertilizer for all corn silage (25 pounds per acre) and redistributing the poultry litter. The farm level litter application remains the same but litter applications to corn silage/ryelage increase from 3.0 to 3.8 tons per acre and litter applications to hay/pasture and pasture decrease from 3.0 to 2.25 and 2.0 to 1.5 tons per acre, respectively. The balanced nitrogen applications reduce farm level nitrogen losses by 1702 pounds and

Table 4.10. Average Annual Yields and Field Nutrient Losses for the 100-Cow Dairy/Poultry Farm.

Crop	Acres	Crop Yield (tons/acre)	Soil Erosion (tons/acre)	Nitrogen Volatilized (lbs/acre)	Surface Nit Losses (lbs/acre)	Subsurface Nit Losses (lbs/acre)	Phosphorus Losses (lbs/acre)
Base 100-Cow D/Poultry							
NT Crn Sil/MT Rlge[1]	25	13.7/3.2	2.86	61.6	9.7	11.8	7.3
MT Crn Sil/NT Rlge[1]	25	13.7/3.2	2.91	60.0	9.6	12.0	6.7
NT Crn Sil/MT Rye[1]	25	13.8	3.26	49.5	11.2	13.4	7.8
MT Crn Sil/NT Rye[1]	25	13.7	3.29	41.4	10.9	15.5	6.8
Alfalfa, Seeding	6.25	3.3	1.19	0.0	0.9	4.3	3.9
Alfalfa, Year 2 & 3	12.5	4.1	0.33	0.0	0.3	8.1	1.7
Alfalfa, Year 4	6.25	3.9	0.29	0.0	0.1	3.3	1.5
Hay/Pasture	45	2.8	0.10	55.2	1.0	72.7	4.4
Pasture	12.5	1.8	0.10	25.9	0.5	30.3	2.8
Unimproved Pasture	12.5	1.1	0.30	7.0	0.7	4.1	0.3
Total	195		330.9	8207.8	1105.0	5167.8	1006.8
Mean (per acre)			1.7	42.1	5.7	26.5	5.2
INCORP[2]							
MT Crn Sil/MT Rlge	50	13.7/3.2	3.02	55.4	9.5	12.8	6.3
MT Crn Sil/MT Rye	50	13.7	3.34	38.8	10.6	16.3	6.3
Alfalfa, Seeding	6.25	3.3	1.19	0.0	0.9	4.3	3.9
Alfalfa, Year 2 & 3	12.5	4.1	0.33	0.0	0.3	8.1	1.7
Alfalfa, Year 4	6.25	3.9	0.29	0.0	0.1	3.3	1.5
Hay/Pasture	45	2.8	0.10	55.2	1.0	72.7	4.4
Pasture	12.5	1.8	0.10	25.9	0.5	30.3	2.8
Unimproved Pasture	12.5	1.1	0.30	7.0	0.7	4.1	0.3
Total	195		340.9	7605.3	1073.2	5305.3	921.8
Mean (per acre)			1.7	39.0	5.5	27.2	4.7
NLIMIT[2]							
NT Crn Sil/MT Rlge	25	13.7/3.3	2.82	69.2	9.9	14.8	7.8
MT Crn Sil/NT Rlge	25	13.7/3.3	2.90	67.4	9.7	15.3	7.1
NT Crn Sil/MT Rye	25	13.7	3.27	49.7	11.2	8.7	7.8
MT Crn Sil/MT Rye	25	13.7	3.30	41.5	10.8	10.7	6.8
Alfalfa Seeding	6.25	3.3	1.19	0.0	0.9	4.3	3.9
Alfalfa, Year 2 & 3	12.5	4.1	0.33	0.0	0.3	8.1	1.7
Alfalfa, Year 4	6.25	3.9	0.29	0.0	0.1	3.3	1.5
Hay/Pasture	45	2.8	0.11	40.1	1.0	39.5	3.2
Pasture	12.5	1.8	0.11	19.5	0.5	19.8	2.2
Unimproved Pasture	12.5	1.1	0.30	7.0	0.7	4.1	0.3
Total	195		330.7	7830.8	1110.0	3462.8	963.3
Mean (per acre)			1.7	40.2	5.7	17.8	4.9

[1] Crop abbreviations: NT = No-till, MT = Minimum Till, Crn Sil = Corn Silage, and Rlge = Ryelage.

[2] INCORP refers to manure incorporation within two days, NLIMIT limits plant available nitrogen applications to VALUES recommendations, and PLIMIT limits phosphorus applications to crop phosphorus removals.

volatilization losses by 379 pounds. The reduction is not as great as reported for the 100-cow dairy farm under NLIMIT. Farm-level phosphorus losses decrease by 43 pounds with the same total litter and dairy manure applications.

Nitrogen losses increase 3.0 to 3.4 pounds per acre for corn silage/ryelage but decrease 4.7 to 4.9 pounds for corn silage/rye cover. Phosphorus losses increase by 0.4 to 0.5 pounds per acre for corn silage/ryelage and remain the same for corn silage/rye cover. The corn silage/ryelage receives additional litter, increasing nitrogen and phosphorus applications, while the fertilizer application to the corn silage/rye cover is eliminated. Nitrogen losses for hay/pasture and pasture decrease by 43.2 and 10.5 pounds (58.6 and 34.1 percent) per acre. Phosphorus losses on hay/pasture and pasture decrease by 1.2 and 0.6 pounds (27.3 and 21.4 percent) per acre. The lower nutrient losses on hay/pasture and pasture result from 0.75 and 0.5 tons per acre lower litter applications. Crop yields remain essentially the same except for a small increase in ryelage because of higher nitrogen applications.

4.1.6 Variation in EPIC Estimates

The estimated crop yields and nutrient losses reported above are annual means of 100 five-year EPIC simulations from 44 years of historical weather (1949-92). Detailed results of each EPIC model are reported in Appendix D. The results are reported according to crop/tillage method and the alternative manure management policy for each dairy and dairy/poultry farm. The mean, maximum, minimum, standard deviation, and coefficient of variation are reported for crop yields, erosion, volatilization, surface nitrogen losses, subsurface nitrogen losses, and phosphorus losses.

The estimation of the impacts of the INCORP, NLIMIT, and PLIMIT alternative manure management policies focuses on the mean values. However, there is considerable variation in the EPIC estimated crop yields and nutrient losses between years because varying rainfall and temperatures from the 44 years of historical weather. The annual rainfall averages 34.06 inches, with a maximum of 45.93 inches, minimum of 22.10 inches, standard deviation of 5.36 inches, and coefficient of variation of 15.75. Rainfall affects the crop yields and nutrient losses by limiting moisture for plant development and the amount of nitrogen and phosphorus contained in surface runoff and water moving through the soil profile.

Examination of Appendix D indicates that the alternative policies produce the same general results with maximum crop yields and nutrient losses as with the average yields and nutrient losses. For example, mean and maximum volatilization, surface loss, and phosphorus loss estimates all decrease under INCORP while mean and maximum subsurface estimates both decline. There appears to be less variation in minimum estimated nutrient losses because these coincide with low rainfall and nutrient losses are expected to decrease because there is less water to carry nutrients off the surface and through the soil profile. With lower rainfall, the impact of individual policies on nutrient losses can be expected to be much less pronounced. The maximum, minimum, and average yields for all crops yields move in the same direction under each policy. There is very little difference between the annual high, low, and average yields between each policy. Ryelage yields, however, show more variation between the mean, maximum, and minimum yields under alternative policies because of nitrogen availability. These observations are supported by the coefficient of variation which generally remains fairly constant across policies for the yields, erosion, and nutrient losses for each crop/tillage model. The coefficient of variation for ryelage, however, shows somewhat more variation than corn silage, erosion, and nutrient losses.

The crop yields, erosion, and nutrient losses reported in Appendix D suggest that the policies examined in this study are effective at reducing nutrient losses in years of high estimated nutrient losses as well as for years with average nutrient losses. There is much less change in nutrient losses between policies in years with minimum nutrient losses. Therefore, the study suggests that the policies are effective in reducing nutrient losses over a range of possible weather conditions.

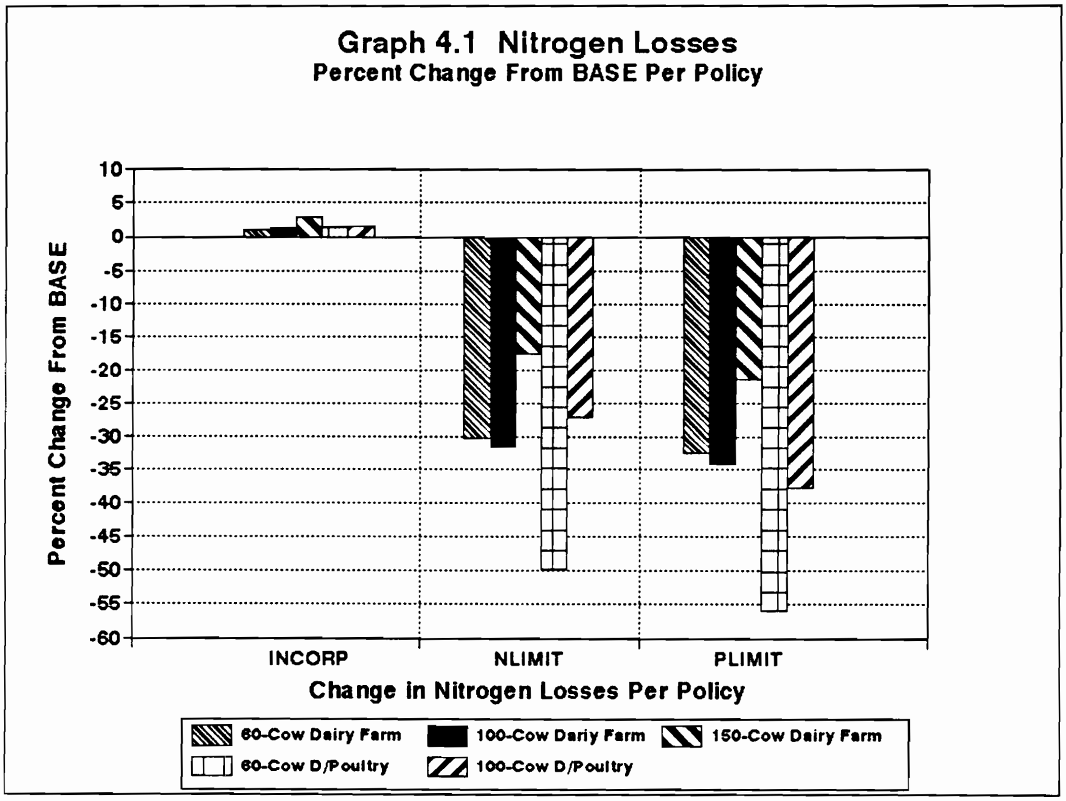
4.1.7 Summary of EPIC Results

The EPIC simulations produce estimates of field level nitrogen and phosphorus losses and crop yields for each crop and tillage combination for each representative farm. Summaries of the field level nutrient losses and the percentage change in nutrient losses between policies are shown on Table 4.11 and Graphs 4.1 and 4.2. Summaries of farm level nutrient losses per farm are found on Table 4.12. The EPIC simulations indicate the effectiveness of each policy toward reducing nutrient losses and the crop yields that result from each policy's adoption.

The highest simulated per acre nitrogen and phosphorus losses under BASE practices occur on the 60-cow dairy/poultry farm. The lowest nitrogen and phosphorus losses occur on the 150-cow dairy farm. The highest losses per crop occur on grass hay and pasture on the 60 and 100-cow dairy and dairy/poultry farms. The highest losses for corn silage occur on corn silage/no rye cover on the 150-cow dairy farm.

Table 4.11. Percentage Change of Mean Field Level Nutrient Losses Per Farm Between Policies.

Farm and Policy	Farm Acres	Nitrogen Losses (lbs./acre)	Percentage Change From BASE	Phosphorus Losses (lbs./acre)	Percentage Change From BASE
60-Cow Dairy					
BASE	110	26.8		4.7	
INCORP	110	27.1	1.1%	4.4	-6.4%
NLIMIT	110	18.7	-30.2%	4.4	-6.4%
PLIMIT	110	18.1	-32.5%	3.0	-36.2%
100-Cow Dairy					
BASE	195	30.5		5.0	
INCORP	195	30.9	1.3%	4.7	-6.0%
NLIMIT	195	20.9	-31.5%	4.7	-6.0%
PLIMIT	195	20.1	-34.1%	3.3	-34.0%
150-Cow Dairy					
BASE	370	20.5		4.0	
INCORP	370	21.1	2.9%	3.7	-7.5%
NLIMIT	370	16.9	-17.6%	3.9	-2.5%
PLIMIT	370	16.1	-21.5%	2.9	-27.5%
60-Cow D/P					
BASE	110	40.9		5.3	
INCORP	110	41.5	1.5%	4.8	-9.4%
NLIMIT	110	20.6	-49.6%	4.5	-15.1%
PLIMIT	110	18.1	-55.7%	3.0	-43.4%
100-Cow D/P					
BASE	195	32.2		5.2	
INCORP	195	32.7	1.6%	4.7	-9.6%
NLIMIT	195	23.5	-27.0%	4.9	-5.8%
PLIMIT	195	20.1	-37.6%	3.3	-36.5%


Graph 4.1 Nitrogen Losses
Percent Change From BASE Per Policy
Percent Change From BASE
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
INCORP
NLIMIT
PLIMIT
Change in Nitrogen Losses Per Policy
60-Cow Dairy Farm
100-Cow Dariy Farm
150-Cow Dairy Farm
60-Cow D/Poultry
100-Cow D/Poultry

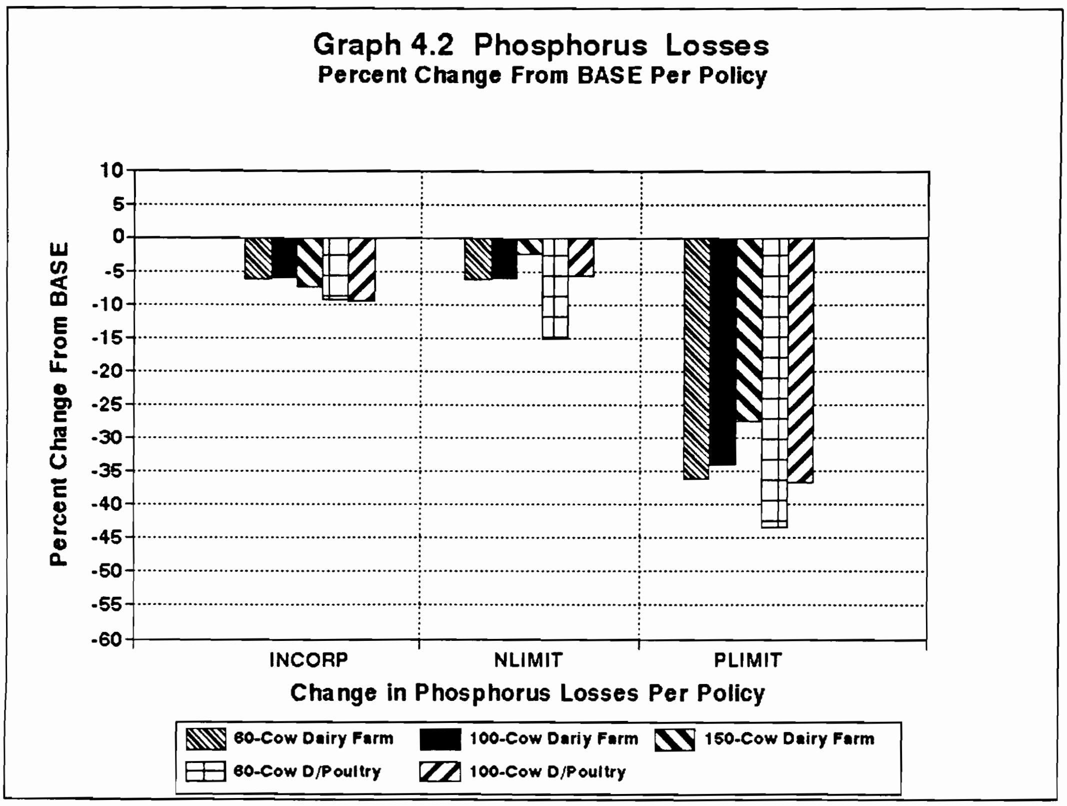

Graph 4.2 Phosphorus Losses
Percent Change From BASE Per Policy
Percent Change From BASE
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
INCORP
NLIMIT
PLIMIT
Change in Phosphorus Losses Per Policy
60-Cow Dairy Farm
100-Cow Dariy Farm
150-Cow Dairy Farm
60-Cow D/Poultry
100-Cow D/Poultry

Table 4.12. Summary of Mean Field Level Nutrient Losses Per Farm.

Farm and Policy	Farm Acres	Soil Erosion (tons/acre)	Nitrogen Volatilized (lbs./acre)	Surface Nitrogen (lbs./acre)	Subsurface N Losses (lbs./acre)	Total N Losses (lbs./acre)	Phosphorus Losses (lbs./acre)
<u>60-Cow Dairy</u>							
BASE	110	159.5	4928	517	2431	2948	517
INCORP	110	168.3	4620	517	2464	2981	484
NLIMIT	110	159.5	4554	517	1540	2057	484
PLIMIT	110	159.5	2464	484	1507	1991	330
<u>100-Cow Dairy</u>							
BASE	195	337.4	7722	1092	4856	5948	975
INCORP	195	345.2	7098	1073	4953	6026	917
NLIMIT	195	335.4	6952	1092	2984	4075	917
PLIMIT	195	329.6	3900	1014	2906	3920	644
<u>150-Cow Dairy</u>							
BASE	370	532.8	11,137	1739	5846	7585	1480
INCORP	370	569.8	10,027	1702	6105	7807	1369
NLIMIT	370	532.8	10,471	1739	4514	6253	1443
PLIMIT	370	543.9	5883	1665	4292	5957	1073
<u>60-Cow D/P</u>							
BASE	110	157.3	5830	539	3960	4499	583
INCORP	110	162.8	5544	528	4037	4565	528
NLIMIT	110	159.5	4741	528	1738	2266	495
PLIMIT	110	159.5	2464	484	1507	1991	330
<u>100-Cow D/P</u>							
BASE	195	331.5	8210	1112	5168	6279	1014
INCORP	195	341.3	7605	1073	5304	6377	917
NLIMIT	195	331.5	7839	1112	3471	4583	956
PLIMIT	195	329.6	3900	1014	2906	3920	644

Incorporation of dairy manure applied to bare ground (INCORP) proves to be an ineffective policy to reduce field level nutrient losses. The INCORP policy does little to reduce potential environmental threats, lowering volatilization losses by 6.3 to 10.0 percent from BASE but increasing total surface and subsurface nitrogen losses by 1.1 to 1.6 percent. INCORP reduces phosphorus losses by 6.0 to 9.4 percent from BASE across dairy and dairy/poultry farms. INCORP produces the highest increase in nitrogen losses for the 150-cow dairy farm and the largest reduction in phosphorus losses for the 100-cow dairy/poultry farm. The reduction in phosphorus losses can be detrimental over an extended time period. INCORP increases the threat of increased phosphorus losses in the future by raising current soil phosphorus levels, lowering current phosphorus losses for potentially higher future phosphorus losses.

NLIMIT effectively reduces per acre nitrogen losses from BASE but proves ineffective at substantially reducing phosphorus losses. Nitrogen loses decline by 17.6 to 49.6 percent under NLIMIT while phosphorus losses are lowered by 2.5 to 15.1 percent from BASE. The largest reduction in nitrogen losses occurs on the 60-cow dairy/poultry farm. Lower nitrogen losses are primarily achieved by lower litter applications to hay/pasture and pasture. Some reduction in nitrogen losses also occurs on corn silage with rye cover and no rye cover. The 100-cow dairy/poultry farm has the smallest reduction in nitrogen loss because litter applications are redistributed instead of reduced. NLIMIT lowers phosphorus losses more than 6.4 percent for only the 60-cow dairy/poultry farm. The lower phosphorus losses are attributed to lower litter applications for most farms. The EPIC simulations indicate that NLIMIT is an effective policy under a nitrogen goal but does little to reduce phosphorus from county fields.

PLIMIT lowers nitrogen losses by 21.5 to 55.7 percent and phosphorus losses by 27.5 to 43.3 percent as compared to BASE. The largest reduction in nitrogen and phosphorus losses occurs on the 60-cow dairy/poultry farm and the smallest reduction occurs on the 150-cow dairy farm. The reductions are made by replacing all litter applications with commercial fertilizers that are balanced for crop agronomic recommendations. PLIMIT is the only policy that substantially reduces nitrogen and phosphorus losses.

Other key findings of the EPIC simulations include the lack of variation of crop yields and the importance of cover crops. Corn silage, hay, and pasture crop yields show very little variation with changes in nutrient applications. The highest excess applications occur on hay/pasture and pasture. Balancing nitrogen applications with agronomic recommendations on these crops did little to crop yields. Corn silage yields are also unchanged under the different policies. However, ryelage yields fluctuate between alternative policies. The lack of variation in average crop yields under different nitrogen applications raises a question of what should be the actual nitrogen applications. Examination of different stress parameters in the EPIC simulation output that affect crop yields indicate that soil moisture, not nitrogen, is the primary factor limiting crop yields for each crop. The output indicates that in years of adequate moisture current and past manure applications provide enough nitrogen for crop needs. The highest excess nitrogen applications occur on hay/pasture and pasture but the farmer panel was not asked for reasons why farmers apply excess to these crops. The EPIC simulations indicate that farmers are incurring costs of applying excess nutrients that are not producing greater yields. Possibly one of the best management tools for water quality management is a better understanding of how farmers determine crop nutrient requirements.

Ryelage yields increase under PLIMIT for all but the 60-cow dairy/poultry farm BASE which applies nitrogen well in excess of crop recommendations. Under PLIMIT, litter is replaced with commercial nitrate based fertilizer which places higher quantities of plant available nitrogen in the soil. The same effect is produced by the high litter applications on the 60-cow dairy/poultry farm. The amount of plant available nitrogen in the soil from organic nitrogen depends upon soil temperatures, moisture, carbon:nitrogen ratio, and other factors. The conditions in early spring may not be conducive to providing adequate amounts of plant available nitrogen to early growing rye plants. The EPIC simulation results indicate that farmers may harvest larger ryelage crops by applying commercial nitrogen fertilizer instead of poultry litter.

Nitrogen losses on corn silage/no rye cover on the 150-cow dairy farm are 38.0 percent greater than nitrogen losses for corn silage/rye cover under NLIMIT. Lower losses occur on corn silage/rye cover despite receiving 23.1 percent more plant-available nitrogen then applied to the corn silage/no rye cover. This supports the recommendation of planting rye cover crops, a practice believed to be commonly followed by Rockingham County dairy farmers.

4.2 FLIPSIM Financial Simulations Results

Each dairy and dairy/poultry farm is modeled with FLIPSIM to estimate the farm's economic performance under alternative policies. Each farm is simulated for 100 five-year periods with the defined financial parameters and incorporating crop yields from the EPIC simulations. This assures the financial period is consistent with the randomly drawn weather used to generate crop yields for the EPIC simulations. The BASE milk production levels for the 60 and 100-cow herds are 18,000 pounds per cow and 18,400 pounds for the 150-cow farm. BASE farm debt is $3,000 per cow for the dairy farms and $3,000 per cow plus $273,458 for the poultry buildings and equipment for the dairy/poultry farms. Minimum family living expenses are $16,000 (based on a Mennonite family) for the 60-cow farms, $49,000 for two families that includes 18,000 in off-farm income for the 100-cow farms, and $52,000 for two families without any off-farm income for the 150-cow farms. The variables examined for sensitivity analysis on each farm are an increase and decrease of 2,000 pounds of milk per cow, farm debt levels of $2000 and $4500 per cow, and a five percent decrease in milk price.

The financial parameters reported each dairy and dairy/poultry farm include the probability of success, which is the chance of the farm surviving all 100 five-year simulation periods without its debt/asset ratio exceeding 0.75. The probability of success is the chance the farm earns a return on equity of 5.3 percent (return on 30-year government bond less the tax rate). Beginning and average ending debt/asset ratio (D/A ratio) and discounted ending net worth indicate the farm's change in financial position over the five-year simulated period. Average net cash income is defined as total farm cash receipts less total cash farm expenses. Total cash expenses does not includes family living expenses, principal payments, federal and state income taxes, and capital asset replacement cash costs. All of these expenses must be paid from net cash income. Net cash available is defined as the average total cash available for family living expenses after paying principal payments, taxes, and machinery replacements. This is what remains to pay for family living expenses after all other cash expenses are paid. Any off-farm income is included. If net cash available does not meet minimum family living expenses, the farm must borrow to make up any cash deficiency. The financial simulation results for the dairy farms are shown in Table 4.13.

4.2.1. Financial Impacts of BASE and Alternative Policies on Dairy Farms.

60-Cow Dairy Farm. None of the alternative manure management policies affect the 60-cow dairy farm's overall viability or probability of economic success. The farm has a 100 percent probability of survival and of making a minimum return on initial equity. These conditions do not change with the adoption of any of the three policies. The farm reduces its initial debt during the simulation period, lowering the D/A ratio from 0.293 to 0.198. The 60-cow dairy farm has adequate cash for principal payments and family living expenses because of low family living expenses. INCORP and NLIMIT policies produce little change in the farm financial analysis. Both net cash income and cash available for family living both increase slightly under NLIMIT and INCORP. the adoption of INCORP lowers farm level chemical costs by a greater amount than the additional tillage costs so the farm increases net revenue. Farm operating expenses decline under NLIMIT because the farm is acquiring and spreading less litter. PLIMIT has a much greater impact on farm finances than NLIMIT or INCORP because of increased commercial fertilizer purchases. The farm's ending net worth and net cash income are lower than estimated for BASE. The ending D/A ratio declines slightly from 0.198 to 0.203 but this is still substantially below the beginning D/A ratio indicating the farm is steadily reducing debt. The cash available for family living expenses by declines by 16.9 percent as compared to BASE, but ending cash remains above minimum family living expenses. The farm's overall economic viability and outlook is not significantly affected by PLIMIT.

Table 4.13 Mean Financial Results From 100 Five-Year FLIPSIM Simulations for Dairy Farms.

Financial Parameters	Alternative Manure Management Policies BASE	INCORP	NLIMIT	PLIMIT
60-Cow Dairy Farm[1]				
Probability of Survival[4]	100	100	100	100
Probability of Success[5]	100	100	100	100
Beginning Debt/Asset Ratio	0.293	0.293	0.293	0.293
Ending Debt/Asset Ratio	0.198	0.198	0.197	0.203
Ending Net Worth ($000)[6]	449.56	450.34	451.17	443.92
Avg Net Cash Income ($000)[7]	27.62	27.70	27.80	25.63
Avg Net Cash Available ($000)[8]	24.35	24.57	24.73	20.23
100-Cow Dairy Farm[2]				
Probability of Survival[4]	100	100	100	100
Probability of Success[5]	100	100	100	100
Beginning Debt/Asset Ratio	0.333	0.333	0.333	0.333
Ending Debt/Asset Ratio	0.247	0.247	0.246	0.253
Ending Net Worth ($000)[6]	601.58	602.22	603.33	596.62
Avg Net Cash Income ($000)[7]	60.71	60.92	61.35	58.19
Avg Net Cash Available ($000)[8]	48.14	48.52	49.42	42.85
150-Cow Dairy Farm[3]				
Probability of Survival[4]	100	100	100	100
Probability of Success[5]	100	100	100	100
Beginning Debt/Asset Ratio	0.331	0.331	0.331	0.331
Ending Debt/Asset Ratio	0.278	0.278	0.276	0.290
Ending Net Worth ($000)[6]	870.45	870.28	872.49	856.22
Avg Net Cash Income ($000)[7]	84.74	84.66	85.54	80.38
Avg Net Cash Available ($000)[8]	52.72	52.60	53.70	46.93

1. Initial parameters are 18,000 pounds of milk per cow, debt of $3000 per cow, and $16,000 annual family living costs.
2. Initial parameters are 18,000 pounds of milk per cow, debt of $3000 per cow, $49,000 total annual family living costs for two families, and $18,000 in off-farm income.
3. Initial parameters are 18,400 pounds of milk per cow, debt of $3000 per cow, and $52,000 total annual family living costs for two families.
4. Probability of Survival - Chance that the farm will not be declared insolvent, i.e., debt to asset ratio does not exceed the maximum of 0.75.
5. Probability of Economic Success - Chance that the farm earns a return on initial equity greater than 0.0540.
6. Ending Net Worth - Discounted value of net worth in the last year simulated.
7. Average Net Cash Income - Total cash receipts minus total cash expenses; excludes family living expenses, principal payments, and costs to replace capital assets.
8. Net Cash Available - Average total cash available after paying principal payments, machinery replacements, and taxes.

The 60-cow farm has a sound financial structure but would find itself in financial trouble if the family cash living expenses were similar to those for the 100 and 150-cow dairy farms. This supports the conclusion of the farmer panels that most 60-cow dairy farms in the county are either owned by members of the Mennonite religion or have off-farm income. Other observations of the farmer panel are supported by the financial analysis. The 60-cow dairy farm would likely experience financial difficulties if it considers some type of future expansion to provide additional income for a family member. Many of the 60-cow dairy farms are located on a small number of acres and have smaller and older equipment lines. Therefore, if these farmers expanded their dairy herds, they would be hard pressed to provide adequate forage and or to purchase additional machinery if they attempted to farm additional acreage. Another aspect that could threaten the future survival of the 60-cow dairy farms is their battle between continually increasing production expenses and steady or declining revenues. With family living expenses at very minimum levels, these farms have less flexibility in adjusting farm income to meet family living requirements, meet all production expenses, and replace aging machinery.

100-Cow Dairy Farm. The FLIPSIM financial analysis indicates the 100-cow dairy farm's probability of survival and probability of success are not affected by the alternative manure management policies. INCORP and NLIMIT both improve the farm's financial position as indicated by slightly higher ending net worth and net cash income as compared to BASE. Herbicide costs decline by a greater amount than the increase in variable operating costs required for additional tillage under INCORP. NLIMIT lowers farm costs by reducing litter acquisition and spreading. The cash available for family living expenses increases slightly for INCORP and NLIMIT. Overall, the 100-cow dairy farm is as well off or slightly better off under NLIMIT and INCORP as under BASE.

The 100-cow dairy farm's ending financial position declines with the adoption of PLIMIT. Litter acquisition and spreading costs are eliminated under PLIMIT and replaced by higher cash costs for commercial fertilizer. Average annual cash expenses increase by $2,480 over BASE, less per acre than for the 60-cow dairy farm which trades non-cash cost labor for litter. Ending net worth declines by $5,640 (1.3 percent) from BASE ending net worth. The most significant change in farm financial performance with PLIMIT is its effect on cash available for family living expenses which declines by an average of $5,290. This amount is below total minimum family living expenses of $49,000 for two families. Cash flow deficits in FLIPSIM are covered by debt refinancing. For example, refinancing short term debt for 10 years instead of 7 years can increase farm cash flow by more than $5000 per year. Therefore PLIMIT causes the 100-cow farm to refinance its existing debt to provide the additional cash for needed family living expenses.

The 100-cow dairy farm can be expected to examine other methods of increasing cash flow and farm income. Under BASE, average cash available for family living expenses is just under the required minimum. The 100-cow dairy farm can be expected to examine other viable methods of increasing farm income and cash flow. Off-farm income is currently providing necessary cash flow for the farm to support two families. Other options include expanding the current farm operation or adding another enterprise.

150-Cow Dairy Farm. The 150-cow dairy farm has a 100 percent probability of survival and economic success under all policy alternatives. INCORP produces slightly different results than for the 60 and 100-cow dairy farms. Ending net worth, average net cash income, and cash available for family living expenses decline slightly because the 150-cow dairy farm incurs additional labor costs for incorporating all dairy manure in the fall. The additional charge is small but enough to reduce the financial measures below BASE measures. NLIMIT increases ending net worth, net cash income, and cash available for family income. Litter acquisition and spreading costs decline by $2,040, increasing the average cash available for family living expenses by $980.

PLIMIT results for the 150-cow dairy farm are similar to those of the 100-cow dairy farm. Substituting commercial fertilizer for poultry litter eliminates litter acquisition and spreading costs under PLIMIT but increases total farm cash expenses by $4,360 as compared to BASE. Ending net worth decreases by $14,230 and the ending D/A ratio increases from 0.278 under BASE to 0.290 under PLIMIT. The change in cash flow reduces the average cash available for family living expenses by $5,790, below the minimum family living expenses of $52,000. The cash flow deficits force farm debt refinancing to provide adequate cash flow for family living expenses.

The 150-cow dairy farm has more flexibility in meeting cash flow deficits. Its larger cash flow allows for greater cash surpluses in good years to carry over in years of cash flow deficits. The 150-cow dairy farm does not utilize off-farm income so the option of a spouse working off the farm can bring in added cash flow. Off-farm employment can also aid farm cash flow by providing non-cash fringe benefits such as health insurance. This can easily reduce family living expenses by several thousand dollars per year. BASE, INCORP, and

NLIMIT on average just meet family living expenses. Therefore, 150-cow dairy farm would be expected to also examine other options of increasing farm profitability and cash flow from other farm enterprises or production adjustments.

4.2.2 Financial Impacts of BASE and Alternative Policies on Dairy/Poultry Farms

Dairy farms add poultry operations to increase farm income and reduce risk associated with fluctuating income and expenses. Adding a poultry operation increases farm debt but income provided by poultry contracts historically has been very stable in the Rockingham County area. The financial analyses for the dairy/poultry farms assume no additional cash labor expenses, 100 percent financing with current equity covering required down payments, and zero net cash cost for litter disposal under the phosphorus nutrient limitations. The BASE dairy/poultry farms used for the analysis are assumed to have initial debt levels of $3000 per cow plus the added debt for the poultry structures. Added poultry debt is financed for 15 years at 9% interest. Each farm is budgeted to increase cash income by more than $66,000, which covers increased production expenses, property taxes, insurance, and mortgage and interest payments. The farm's net cash flow increases by $10,893. The farm also accrues additional cash flow benefits by deducting depreciation and interest payments from current income for federal and state income taxes. The extent of the tax benefits depends upon the profitability of the farm's dairy operation. Specific sensitivity analysis for the poultry operations includes a 5 percent reduction in revenue. The FLIPSIM results for the dairy/poultry farms are shown in Table 4.14. The BASE dairy farm results are also shown for reference.

Table 4.14. Mean Financial Results From 100 Five-Year FLIPSIM Simulations for Dairy/Poultry Farms

Financial Parameters	Dairy Base	Alternative Manure Management Policies BASE	INCORP	NLIMIT	PLIMIT
60-Cow Dairy/Poultry Farm[1]					
Probability of Survival[4]	100	100	100	100	100
Probability of Success[5]	100	100	100	100	100
Beginning Debt/Asset Ratio	0.293	0.536	0.536	0.536	0.536
Ending Debt/Asset Ratio	0.198	0.346	0.345	0.346	0.350
Ending Net Worth ($1000)[6]	449.56	491.41	491.87	492.60	485.56
Avg Net Cash Income ($1000)[7]	27.62	51.09	51.17	51.12	48.05
Avg Net Cash Available ($1000)[8]	24.35	34.47	34.52	34.62	26.67
100-Cow Dairy/Poultry Farm[2]					
Probability of Survival[4]	100	100	100	100	100
Probability of Success[5]	100	100	100	100	100
Beginning Debt/Asset Ratio	0.333	0.507	0.507	0.507	0.507
Ending Debt/Asset Ratio	0.247	0.343	0.343	0.343	0.346
Ending Net Worth ($1000)[6]	601.58	669.81	670.28	671.32	660.97
Avg Net Cash Income ($1000)[7]	60.71	85.31	85.50	85.96	80.59
Avg Net Cash Available ($1000)[8]	48.14	62.76	63.10	64.11	53.33
150-Cow Dairy/Poultry[3]					
Probability of Survival[4]	100	100	100	100	100
Probability of Success[5]	100	100	100	100	100
Beginning Debt/Asset Ratio	0.331	0.454	0.454	0.454	0.454
Ending Debt/Asset Ratio	0.278	0.338	0.338	0.337	0.350
Ending Net Worth ($1000)[6]	870.45	939.24	939.02	941.18	919.99
Avg Net Cash Income ($1000)[7]	84.74	109.45	109.36	110.32	102.41
Avg Net Cash Available ($1000)[8]	52.72	60.05	59.92	61.18	51.37

1. Initial parameters are 18,000 pounds of milk per cow, farm debt of $3000 per cow plus $273,000 for poultry building, and $16,000 annual family living costs.
2. Initial parameters are 18,000 pounds of milk per cow, debt of $3000 per cow plus $273,000 for poultry building, $18,000 in off-farm income, and $49,000 total annual family living costs for 2 families.
3. Initial parameters are 18,400 pounds of milk per cow, debt of $3000 per cow plus $273,000 for poultry building, and $52,000 total annual family living costs for two families.
4. Probability of Survival - Chance that the farm will not be declared insolvent, i.e., debt to asset ratio does not exceed the maximum of 0.75.
5. Probability of Economic Success - Chance that the farm earns a return on initial equity greater than 0.0540.
6. Ending Net Worth - Discounted value of net worth in the last year simulated.
7. Average Net Cash Income - Total cash receipts minus total cash expenses; excludes family living expenses, principal payments, and costs to replace capital assets.
8. Net Cash Available - Average total cash available after paying principal payments, machinery replacements, and taxes.

60-Cow Dairy/Poultry Farm. The farm probability of survival and economic success for the 60-cow dairy/poultry farm are 100 per cent for the BASE and all policy alternatives. The addition of the higher debt improves the farm's cash flow, ending net worth, and cash available for family living expenses. Net cash farm income increases by $20,000 to $24,000 for each policy but this amount must cover the additional principal payments for the poultry buildings and equipment. The dairy/poultry farm's debt is reduced by an average of 19 percentage points over the five-year study period for BASE, INCORP, and NLIMIT. Ending net worth for BASE, INCORP, and NLIMIT increases approximately $42,000 over that of the BASE 60-cow dairy farm. The cash available for family living increases by $10,000 over that of the BASE dairy farm. The additional cash from the poultry operation provides enough income to support another family at $16,000 of annual family living expenses.

The impact of the PLIMIT policy on the dairy/poultry farms is the same as the dairy-only farms in that no litter is applied to the farm's cropland. PLIMIT is also modeled without farm level cost or income from litter removal from the farm. For the 60-cow dairy/poultry farm, PLIMIT reduces the farm's ending net worth, average net cash income, and cash available for family living expenses from the levels generated by BASE, INCORP, and NLIMIT. However, the dairy/poultry farm is in a stronger financial position than the BASE 60-cow dairy farm. Ending net worth is $36,000 higher and average cash available for family living expenses increases by $2,320 over the BASE dairy farm.. The dairy/poultry farm is better off financially under the PLIMIT restrictions than under current conditions of the 60-cow dairy farm. These results indicate the financial advantages of adding a poultry operation.

100-Cow Dairy/Poultry Farm. Adding a poultry operation significantly improves the financial performance of the 100-cow dairy/poultry farm. The results are similar to those of the 60-cow dairy/poultry farm. The BASE, INCORP, and NLIMIT policies increase ending net worth by approximately $68,000 over that of the 100-cow dairy farm. The cash available for family living expenses increases by $14,000 to $16,000 over that of the 100-cow dairy farm. The increased cash available for family living expenses makes the off-farm income less crucial but still an important segment of the farm's cash flow. The addition of the poultry operation would not compensate the loss of the off-farm income. The farm makes steady progress on debt reduction by reducing the debt/asset ratio by 16 percentage points. Principal is reduced on the 7-year equipment loan, 15-year poultry loan, and the 20-year farm mortgage.

The PLIMIT policy reduces average net cash farm income by $4,720, cash available for family living expenses by $9,430, and ending net worth by $8,884 as compared to the BASE 100-cow dairy/poultry farm. With PLIMIT, the cash available for family living expenses remains $5,140 higher than the same value for the BASE 100-cow dairy farm. Under PLIMIT the 100-cow dairy/poultry farm is financially better off than the 100-cow dairy farm which had to refinance debt to provide enough cash for family living expenses. This situation is not as likely to occur with the dairy/poultry farm. Under the assumptions of the study dairy/poultry farms have substantial financial benefits from adding poultry operations to existing dairy enterprises.

150-Cow Dairy/Poultry Farm. The addition of the poultry operation improves the ending financial position of the 150-cow dairy/poultry farm as it does for the 60 and 100-cow dairy/poultry farms. The financial measures for BASE, INCORP, and NLIMIT are substantially higher for the 150-cow dairy/poultry than for the BASE 150-cow dairy farm. Ending net worth increases by $68,000 to $70,000 and cash available for family living expenses increases by $7000 to $9,000. The debt/asset ratio declines over the five-year study period by more than 11 percentage points. The increase in cash available for family provides more than the minimum family expenses for the 150-cow dairy/poultry farm. This reduces the need for a family member to seek off-farm employment. INCORP produces slightly lower cash available for family living expenses than the BASE 150-cow dairy/poultry farm. The cash available for family living expenses under NLIMIT is $1,180 greater than for the BASE 150-cow dairy/poultry farm.

As compared to the BASE 150-cow dairy/poultry farm, PLIMIT reduces ending net worth by $20,000, net cash income by $7,040, and net cash income by $8,680. Unlike the 60 and 100-cow dairy/poultry farms, the 150-cow dairy/poultry farm under PLIMIT has less cash available for family living expenses than the BASE 100-cow dairy farm. However, the 150-cow dairy/poultry farm's ending net worth is $49,000 greater than the ending net worth for the BASE 150-cow dairy farm. PLIMIT reduces the farm's average cash available for family living expenses slightly below the minimum of $52,000, but the 150-cow dairy/poultry farm still has a higher ending net worth than it would have had if it did not add the poultry enterprise.

4.2.3 Sensitivity Analysis of Financial Impacts.

Financial results for the modeled farms are dependent upon the ex post accuracy of key endogenous and exogenous parameters. For these farms, milk production, milk price, and beginning debt level are crucial determinants of economic success. Examining a decrease in milk production and a higher debt level focuses on other county farms that may be more susceptible to the manure policies than the representative farms. The $4500/cow debt level represents the higher end of the general debt range of county dairy farms as indicated by county agricultural lenders. The 16,000 milk production level represents an approximate 5 percent and one standard deviation below mean milk production for county DHIA herds. Since PLIMIT is the most financially restrictive policy, only PLIMIT sensitivity analysis is reported. All sensitivity analysis results are fully described and reported in Appendix E.

Milk Production Reduced by 2000 Pounds Per Cow. Each dairy and dairy/poultry farm is modeled with a 2000 pound decrease in milk production per cow. A 2000 pound reduction in milk production lowers gross income by $260 per cow (at a milk price of $13.00 per cwt.). All dairy and dairy/poultry farms have a 100 percent probability of economic success under each alternative policy. The probability of economic success under PLIMIT drops to zero for the 60-cow dairy, from 94.0 to 80.0 for the 100-cow dairy, and from 80.0 to 66.0 for the 150-cow dairy farm. The lower milk production substantially reduces the cash available for family living expenses for each dairy and dairy/poultry farm. The 60-cow dairy farm experiences a 80 percent reduction under PLIMIT. The cash available for family living expenses declines by 50 and 57 percent for the 100 and 150-cow dairy farms. The financial position of each farm remains about constant as the ending debt/asset ratio is approximately the same as beginning debt asset ratio.

The probability of economic success for the dairy/poultry farms declines from 100 to 94 percent for both the 60 and 150-cow dairy/poultry farms under PLIMIT with a 2000 pound decrease in milk production. Contrary to the dairy-only farms, the dairy/poultry farms are improving their financial position under PLIMIT. Ending D/A ratios decline by 13, 11, and 6 percentage points, respectively, for the 60, 100, 150-cow dairy farms. The ending net worth for each dairy/poultry farm under PLIMIT and lower milk production per cow is $3,000 to $7,000 lower the ending net worth under PLIMIT and the initial milk production levels. Dairy farms with lower milk production can improve their ending net worth and cash availability for family living expenses with the addition of a poultry operation. However, cash flow is variable and requires occasional debt refinancing to meet family living expenses.

Debt Level Increased to $4,500 Per Cow. Increasing debt levels lowers the probability of economic success from 2.0 to zero, 85.0 to 7.0, and 66.0 to 50.0, respectively, for the 60, 100, and 150-cow dairy farms. The 60-cow dairy farm suffers the most, with no cash available for family living expenses. The 100 and 150-cow farms also experience a shortfall in cash availability for family living expenses because of greater debt loads. Each farm's ending D/A ratio is slightly higher than the beginning D/A ratio. The dairy/poultry farms' average cash available for family living expenses are approximately $3,000 to $7,000 higher than for the corresponding dairy farms. Each dairy/poultry farm reduces their debt under PLIMIT but not without refinancing their farm debt. This provides needed cash for family living expenses but can jeopardize future viability if the loan for the poultry building is longer than the building's useful life. The cash flow problems on dairy farms that exist because of high debt levels cannot be eliminated with adding a poultry building and the resulting debt. However, the farm can make improve its net worth over the short-run by adding a poultry operation.

Five Percent Lower Milk Price. Reducing anticipated milk prices by five percent lowers the probability of economic success from 66.0 to 4.0, 100 to 95.0, and 95.0 to 83.0 under PLIMIT, respectively, for the 60, 100, and 150-cow dairy farms. The financial position of each dairy farm declines with lower milk prices but not to the degree found with lower milk production and higher debt. The ending D/A ratio for each dairy farm is within 2 percentage points of beginning D/A, indicating the farms are making very little improvement in their financial position. The average cash available for family living expenses is less than half of minimum amounts for each farm. The farms have to borrow against farm equity to provide adequate cash for family living expenses.

The dairy/poultry farms also incur cash flow deficits with lower milk prices. The 60-cow farm has about a 19 percent deficit while the 100 and 150-cow farms have a 39 and 34 percent cash deficits. The dairy/poultry farms are making economic progress as their ending net worth increase by 10, 12, and 7 percentage points, respectively. The ending net worth for each farm is above that of the ending net worth for the corresponding BASE dairy farm under expected milk prices. Lower milk prices reduces the financial performance of the dairy/poultry farms but these farms are better off than farms with just a dairy operation. Lower milk prices will likely cause more farms to consider adding a poultry operation.

Change in Poultry Revenue Reducing net revenue by five percent does not affect any of the dairy/poultry farms' probability of survival or economic success. Under PLIMIT, each farm's ending net worth is reduced by $8,000 to $9,000. Net cash income decreases by approximately $4,000 for each farm and cash available for family living expenses declines by $4,000 to $7,000. The reduced revenue projections do not change the overall impact of manure management policies on dairy/poultry farms. This would be expected to change if lower revenue occurred in conjunction with farm-incurred litter disposal costs.

Varying Litter Disposal Costs The analysis for the dairy/poultry farms under PLIMIT eliminates the application of poultry litter and assumes no cash cost or revenue for removal of the litter from the farm. If all of the farms in Rockingham County are under a phosphorus nutrient restriction, an immense amount of manure will need to be removed from farms and likely transferred to sites outside of the county. This section analysis examines the impact on the financial returns of the dairy/poultry farms under the assumption that farmers incur cash costs to dispose of their litter in a legally acceptable manner. The costs examined are $10, $20, $30, and $40 per ton. Annual costs for removing 408 tons of litter are $4080, $8160, $12,240, and $16,320. The ending net worth projected in the analysis does not reflect a lower market value for poultry facilities that could result from disposal costs.

The poultry budgets for the dairy/poultry farms indicate cash flow returns of $10,893 for two poultry buildings. This figure indicates that the farm could pay up to $26.69 per ton for litter disposal to break-even on a cash basis for the poultry operation, yielding zero returns for labor and investment. The shutdown point for farmers with payments and expenses as defined on Table 3.7 is much greater. With fixed costs of $38,027, poultry operators could pay up to $119.90 per ton of litter before their losses would be greater than fixed costs.[1] This does not include labor and or consider bankruptcy.

The results of the base dairy/poultry farm simulations with disposal costs are shown in Table 4.15. The results are shown for the PLIMIT policy for the BASE dairy, BASE dairy/poultry farms with no litter disposal costs, and for the dairy/poultry farms under the varying disposal costs. The results indicate that the additional disposal costs do not reduce the probability of economic success until costs of $30 per ton are incurred for the 60-cow farms. All farms are continuing to reduce farm debt at disposal costs of $40 per ton because the losses caused by the litter disposal costs are less than the principal payments made by the farm. The ending net worth of the 60-cow dairy/poultry farm is less than that of the same size dairy farm at disposal costs of $30/ton. Cash available for family living expenses is greater than that provided by the dairy farm only up to a cost of $10/ton for the 60-cow dairy/poultry farm and $20/ton for the 100 and 150-cow dairy/poultry farms. The 100 and 150-cow dairy/poultry farms have the advantage of having a higher taxable income that provides additional benefits not experienced by the 60-cow farm.

The impact of the increased cash costs for litter disposal reduces returns to the poultry operation, cash available for family living expenses, ending net worth, and increases ending debt-asset ratios. From a net worth perspective, the 60-cow farmers are worse off if

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[1] Fixed costs are $38,027, receipts are $66,598, variable costs are $17,678, and the amount of litter is 408 tons. Unless total losses are greater than fixed costs, the farm is better off operating at a loss. At a cost of 199.90, the farm pays out ($38,027 + $17,678 + (408*119.90=$48,919) = $104,624 and receives $66,598 in receipts. The net loss is $38,027, the same amount lost by letting the house remain empty. At costs less than 119.90 per ton, the farm incurs a lower loss by operating than letting the house stand empty so the farm will continue poultry production. The shut-down point will decline for farms with small fixed payments.

Table 4.15. Mean Results From 100 Five-Year FLIPSIM Financial Simulation:

Dairy/Poultry Farms With Varying Litter Disposable Costs Under PLIMIT Restriction

	Varying Litter Disposal Costs Under PLIMIT Nutrient Restriction					
Financial Parameters	BASE Dairy	Dairy/Poultry	$10/Ton	$20/Ton	$30/Ton	$40/Ton
60-Cow Dairy/Poultry Farm[1]						
Probability of Survival[2]	100	100	100	100	100	100
Probability of Success[3]	100	100	100	100	94.0	17.0
Beginning Debt/Asset Ratio	0.293	0.536	0.536	0.536	0.536	0.536
Ending Debt/Asset Ratio	0.203	0.401	0.419	0.442	0.473	0.503
Ending Net Worth ($1000)[4]	443.92	485.56	472.32	456.01	432.21	409.65
Avg Net Cash Income ($1000)[5]	25.63	48.05	43.62	38.99	33.93	28.92
Net Cash Available ($1000)[6]	20.23	26.67	18.84	11.63	5.51	0.32
100-Cow Dairy/Poultry Farm[1]						
Probability of Survival[2]	100	100	100	100	100	100
Probability of Success[3]	100	100	100	100	100	100
Beginning Debt/Asset Ratio	0.333	0.507	0507	0.507	0.507	0.507
Ending Debt/Asset Ratio	0.253	0.346	0.352	0.364	0.377	0.392
Ending Net Worth ($1000)[4]	596.62	660.97	649.78	637.46	624.08	608.77
Avg Net Cash Income ($1000)[5]	58.19	80.59	75.97	71.29	66.60	61.80
Net Cash Available ($1000)[6]	42.85	53.33	44.41	36.35	29.57	23.08
150-Cow Dairy/Poultry Farm[1]						
Probability of Survival[2]	100	100	100	100	100	100
Probability of Success[3]	100	100	100	100	100	100
Beginning Debt/Asset Ratio	0.331	0.454	0.454	0.454	0.454	0.454
Ending Debt/Asset Ratio	0.290	0.373	0.380	0.388	0.396	0.405
Ending Net Worth ($1000)[4]	856.22	919.99	909.52	899.08	888.22	876.05
Avg Net Cash Income ($1000)[5]	80.38	102.41	97.77	93.12	88.47	83.80
Net Cash Available ($1000)[6]	46.93	51.37	46.03	41.51	37.66	33.85

1. BASE farm parameters are milk production of 18,000 pounds per cow for the 60 and 100-cow farms and 18,400 pounds per cow for the 150-cow farm, farm debt of $3000 per cow plus $273,000 for poultry building, $26,000 annual family living costs for 2 families for the 100 and 150-cow farms, and 16,000 for the 60-cow farm.
2. Probability of Survival - Chance that the farm will not be declared insolvent, i.e., debt to asset ratio does not exceed the maximum of 0.75.
3. Probability of Economic Success - Chance that the farm earns a return on initial equity greater than 0.0540.
4. Ending Net Worth - Discounted value of net worth in the last year simulated.
5. Average Net Cash Income - Total cash receipts minus total cash expenses; excludes family living expenses, principal payments, and costs to replace capital assets.
6. Net Cash Available - Average total cash available after paying principal payments, machinery replacements, and taxes.

litter disposal costs exceed $20/ton. Under this analysis, the 100 and 150-cow dairy farms continue to improve their ending net worth with the addition of a poultry operation at disposal costs of $40 per ton. Farmers could continue to operate at a cash flow deficit for the short run if the loss caused by litter disposal costs is less than mortgage payments ($119.90 per ton) that must be paid whether the farm is operating or not. Disposal costs can be expected to affect the current poultry operations, new poultry operations, and the county litter market. Poultry operations with low or no debt will be more likely to shut down. Poultry operators with high debt will likely be forced to continue poultry production as long as litter disposal costs plus variable costs are less than fixed costs. Disposal costs will likely reduce new operations as farmers and lenders will be unwilling to invest in an unprofitable enterprise. The county and industry aspects of disposal costs are discussed in the next chapter.

4.2.4 Conclusions of FLIPSIM Simulations

The financial simulation analyses indicate each farm is as well off financially under INCORP and NLIMIT as under the BASE. In several cases, the farm is slightly better off under NLIMIT because of higher income and net worth and lower D/A ratio. PLIMIT produces definite negative impacts on each representative farm, with relatively higher D/A ratios, lower ending net worth, and cash available for family living generally from $2,000 to $6,500 lower than BASE results. Sensitivity analysis indicates that PLIMIT has a much greater effect on individual farm economic success on farms with lower milk production and higher debts. Lower milk prices produce negative financial impacts on each farm that are greater than incurred under PLIMIT. However, PLIMIT produces significant reductions in the farm's probability of success if accompanied with a lower milk price. In conclusion, restricting phosphorus applications to crop uptake leaves the farm worse off financially. Dairy farms without a strong financial and production base could find themselves not making economic returns under PLIMIT.

Adding poultry operations significantly improves the economic viability of each representative farm as compared to the specialized dairy farm. The farms' ending D/A ratio decreases and the ending net worth increases relative to the dairy farm. Each dairy/poultry farm's cash availability for family living expenses improves under BASE and each policy as compared to dairy-only farms. PLIMIT left the dairy/poultry farm with greater cash availability for family living expenses and a higher ending net worth than the dairy farm under BASE. The specific impacts of INCORP, NLIMIT, and PLIMIT manure management policies on dairy/poultry farms are the basically the same as with the dairy farms. Farms are slightly better off or equally as well off under INCORP and NLIMIT. PLIMIT produces negative financial impacts but leaves the farm's in better condition than the BASE dairy farm. Increased interest rates drain more cash for interest payments and reduces ending net worth more than does lower revenue. Lower revenue reduces the viability of the dairy/poultry farm as compared to dairy farms.

The results indicate why Rockingham County farmers add poultry operations to their dairy operations. These results were attained under the assumption that the dairy farm financed 100 percent of the costs of adding the poultry operation and incurred not disposal costs. If the operations can be added with reduced financing, the representative farms will find poultry operations to be more feasible and profitable. However, farms with high debt levels do not necessarily improve their financial position with the addition of poultry operations. Disposal costs greater than $20 per ton reduces the financial viability of poultry operations for the 60-cow farm. The 100 and 150-cow farms increase their ending net worth over that of the BASE dairy farm at disposal costs of $40/ton.

4.3 Summary

This chapter presents the EPIC and FLIPSIM simulation results for the 60, 100, and 150-cow representative dairy and dairy/poultry farms under baseline farming operations (BASE) and three alternative manure management policies - manure incorporation (INCORP), nitrogen limitation (NLIMIT), and phosphorus limitations (PLIMIT). EPIC simulations indicate that the NLIMIT and PLIMIT policies both reduce mean nitrogen losses up to 34 percent while only PLIMIT produces greater than 15 percent reduction in phosphorus losses on dairy farms. INCORP reduces volatilization losses but increases nitrogen losses. Nitrogen and phosphorus nutrient losses are reduced the most when the BASE applications far exceeded recommended applications. Crop yields are generally not affected by nutrient restrictions except for ryelage. Ryelage yields are particularly susceptible to varying soil nitrogen levels in early spring months when plant available nitrogen is heavily influenced by fluctuations in soil temperature and moisture. From a crop production perspective, the farmer is equally as well off under any of the alternative policies as with the farm baseline conditions.

Nutrient losses are greater on farms with poultry operations and particularly when the farm has inadequate acreage for the resulting litter application. A poultry enterprise added to the 60-cow dairy causes nutrient applications far in excess of recommended levels. Nitrogen losses increase over 50 percent and phosphorus losses increase 12 percent as compared to the dairy farm. The 100-cow dairy/poultry farm increases nutrient losses but can apply all litter under NLIMIT. The 150-Cow farm has more than adequate acreage for litter application under NLIMIT and imports additional litter. NLIMIT and PLIMIT reduce nitrogen losses up to 55 percent and PLIMIT reduces phosphorus losses up to 42 percent. Eliminating litter applications under PLIMIT is the most effective policy in reducing nitrogen and phosphorus losses but leaves the dairy/poultry farms with the problem of how to dispose of their litter.

FLIPSIM simulation results indicate that financially, the farms are generally as well off under INCORP and NLIMIT as under BASE. The farms experience financial hardships under PLIMIT. None of the dairy farms face liquidation under the baseline or alternative policies. However, PLIMIT has a more pronounced effect on farms with higher debt or lower milk production.

Adding a poultry operation strengthens a farm's financial position despite the additional debt. Poultry operations increased each farm's ending net worth, lowered ending D/A ratios, and increased cash available for family living expenses even under the assumption of 100 percent financing for the poultry operation. The results indicate that dairy farms can improve their financial situation with added poultry operations, even with higher interest rates or lower revenue.

Poultry operations are unlikely to improve a farm's financial performance when litter disposal costs are added. The 60-cow dairy/poultry farms decline in ending net worth below the corresponding dairy farms (under PLIMIT) at a cost of $20/ton while the 100 and 150-cow farm has a higher ending net worth up to $40/ton. The difference in ending net worth between farms is partially derived from tax benefits of depreciation and interest which are utilized more by the relatively higher income 100 and 150-cow farm. The addition of disposal costs should discourage 60 and 100-cow farms more than the 150-cow farms from adding poultry operations.

The greatest financial pressure is on the 60-cow farms, which have less flexibility in adjusting farming resources. The 60-cow Mennonite farms of this size have less living expenses but are less inclined to have spouses working off the farm. Adding a poultry operation may be their best option to increase farm income but they cannot utilize all the litter on the farm without over applying nitrogen and phosphorus.

From an environmental perspective, PLIMIT achieves the greatest reduction in nitrogen and phosphorus losses. PLIMIT also has the greatest negative impact on farm finances. NLIMIT is very effective at reducing nitrogen losses but has very little effect on phosphorus losses. But for farm survival, NLIMIT leaves the farms as well off or slightly better off financially while providing a beneficial environmental gain. Thus depending on the goal of a manure management policy, NLIMIT reduces nitrogen losses without adversely affecting farm viability. PLIMIT substantially reduces nitrogen and phosphorus losses and puts the farms in a weaker financial position.

Chapter V

Financial and Nutrient Loss Estimates

This chapter examines the farm and county level costs of reducing potential field level nitrogen and phosphorus losses under NLIMIT and PLIMIT policies. County level nutrient losses are compiled and compared to changes in county average net cash income. Changes in litter acquisition and utilization on dairy farms is presented. Alternative uses of litter are discussed and the possible usages of surplus litter are explored.

5.1 Farm Costs of Nutrient Loss Reductions

The direct farm level cost of reducing nitrogen and phosphorus losses is calculated by comparing the change in the farm's average annual net cash income to the change in farm level nutrient losses for NLIMIT and PLIMIT (Tables 5.1 and 5.2). The average annual net cash income is defined as total cash receipts minus total cash expenses, excluding family living expenses, principal payments, and capital replacement costs. These results do not include any costs associated with removing excess litter from the farm. The procedure is not done for INCORP because nitrogen losses and farm income both increased, making results difficult to interpret.

In Table 5.1, the 60-cow dairy farm gains $0.20 for every pound of reduced nitrogen losses. This is calculated by dividing the change in average net cash income between BASE and NLIMIT ($180) by the change in total nitrogen losses (891 pounds). All farms under

Table 5.1. Farm Level Benefits Per Pound of Nutrient Reduction Under NLIMIT.[1]

Farm and Policy	Net Cash Income[2]	Nitrogen Losses[3]	Benefit Per Lbs of Nitrogen Reduced	Phosphorus Losses[3]	Benefit Per Lbs of Phosphorus Reduced
60-Cow Dairy					
BASE	27620	2948		517	
NLIMIT	27800	2057	0.20	484	5.45
100-Cow Dairy					
BASE	60710	5948		975	
NLIMIT	61350	4075	0.34	917	1.21
150-Cow Dairy					
BASE	84740	7585		1480	
NLIMIT	85540	6253	0.60	1443	11.03
60-Cow Dairy/Poultry					
BASE	51090	4499		583	
NLIMIT	51120	2266	0.02	495	0.34
100-Cow Dairy/Poultry					
BASE	85310	6279		1014	
NLIMIT	85960	4583	0.38	956	11.21
150-Cow Dairy/Poultry					
BASE	109450	7585		1480	
NLIMIT	110320	6253	0.65	1443	23.51

[1.] Benefits per pound of nutrient reductions is calculated by dividing the change in farm income by the decrease in nutrient losses per farm (absolute value).
[2.] The average net cash incomes are from Tables 4.13 and 4.14.
[3.] The farm level nitrogen and phosphorus losses are from Table 4.12.

Table 5.2. Farm Level Costs Per Pound of Nutrient Reduction for PLIMIT.[1]

Farm and Policy	Net Cash Income	Nitrogen Losses	Cost Per Lbs of Nitrogen Reduced	Phosphorus Losses	Cost Per Lbs of Phosphorus Reduced
60-Cow Dairy					
BASE	27620	2948		517	
PLIMIT	25630	1991	-2.08	330	-10.64
100-Cow Dairy					
BASE	60710	5948		975	
PLIMIT	58190	3920	-1.24	644	-7.61
150-Cow Dairy					
BASE	84740	7585		1480	
PLIMIT	80380	5957	-2.68	1073	-10.71
60-Cow Dairy/Poultry					
BASE	51090	4499		583	
PLIMIT	48050	1991	-1.21	330	-12.02
100-Cow Dairy/Poultry					
BASE	85310	6279		1014	
PLIMIT	80590	3920	-2.00	644	-12.76
150-Cow Dairy/Poultry					
BASE	109450	7585		1480	
PLIMIT	102410	5957	-4.32	1073	-17.30

[1] Costs per pound of nutrient reductions is calculated by dividing the change in farm income by the decrease in nutrient losses per farm (absolute value). Note that no estimated disposal costs are included.
[2] The average net cash incomes are from Tables 4.13 and 4.14.
[3] The farm level nitrogen and phosphorus losses are from Table 4.12.

NLIMIT gain between $0.02 and $0.65 in farm net cash farm income for every pound of reduced nitrogen losses. The largest beneficiaries per pound from lower nitrogen losses are the 150-cow dairy and dairy/poultry farms. The smallest benefit goes to the 60-cow dairy/poultry farm which experiences a very small change in farm income. The benefits accruing to farms from decreases in phosphorus losses are much higher because the absolute reduction in phosphorus losses is significantly lower than for nitrogen. The 150-cow dairy/poultry farm gains $23.51 per pound of lower phosphorus loss while benefits to the 60-cow dairy/poultry farm is only $0.34.

NLIMIT lowers nitrogen losses up to 49.6 percent and phosphorus losses up to 15.1 percent for the 60-cow dairy/poultry farm, which also has the largest absolute losses. The results indicate that the NLIMIT policy significantly reduces nitrogen and phosphorus losses on the farms with the most intensive use of dairy and poultry manure and the largest per acre nitrogen and phosphorus losses. The NLIMIT policy produces a favorable outcome for environmental policy because potential nutrient loadings to surface and ground water are reduced. Farm economic viability also benefits as the farm enjoys higher net cash income.

The results raise the question of why farmers are not following the nitrogen applications guidelines at this time. Average net income increases with lower nitrogen losses because fertilizer and litter acquisition costs are reduced. It is important to understand how farmers perceive the expense. If the farmers perceive applying litter as a risk reduction action, in that they believe applying litter assures higher yields and is "good" for soil structure, the farmers actions are rational (Young et al.). The highest nitrogen losses occur on pasture and hay which are receiving nitrogen applications up to 50 percent above recommendations. The EPIC simulations do not show any change in average or maximum yields over the simulation period between recommended nitrogen applications and excess nitrogen applications. Instead, higher hay and pasture yields are associated with adequate rainfall. The farmers, however, may be fertilizing for the higher yields that occur in years with adequate rainfall (Young et al.). Getting farmers to voluntarily reduce nitrogen applications to recommended levels will take education efforts. This may be difficult if farmers believe that adding excess nitrogen is cheap insurance and associate the high yields with nitrogen availability instead of with moisture availability.

Under the PLIMIT policy, nitrogen and phosphorus losses decline but farm income decreases for each representative farm (Table 5.2). Reducing nutrient losses under PLIMIT lowers farm income up to $4.32 per pound of nitrogen and up to $17.30 per pound of phosphorus, both for the 150-cow dairy/poultry farm. The largest percentage reduction in nitrogen and phosphorus losses is for the 60-cow dairy/poultry farm, reducing nitrogen losses 55.7 percent and phosphorus by 43.4 percent.

The PLIMIT policy reduces nitrogen losses slightly more than NLIMIT. NLIMIT reduces phosphorus losses up to 15.1 percent while PLIMIT lowers phosphorus between 28.1 to 43 percent. From an environmental perspective, NLIMIT and PLIMIT both lower nitrogen losses while PLIMIT more effectively reduces phosphorus losses. Both policies produce the largest percentage reduction in nutrient losses on the 60-cow dairy/poultry farm, which has the largest nitrogen and phosphorus losses per acre. However, from a farm perspective, the NLIMIT policy is preferred because farm income increases. The PLIMIT policy would not be favored by farmers because of the reduction in net farm income.

5.2 Farm Costs of Nutrient Loss Reduction Under Various Litter Disposal Costs

Earlier analysis indicates that PLIMIT restrictions substantially reduces the net cash income for each dairy/poultry farm under varying disposal costs. Table 5.3 shows the dollar cost of lower net income per pound of reduced nitrogen and phosphorus losses under varying disposal costs. Reducing nitrogen losses under PLIMIT lowers net cash income by $1.21, $2.00, and $4.32 from BASE for the 60, 100, and 150-cow dairy/poultry farm with no litter disposal costs. Net cash income for the 150-cow dairy/poultry farm declines up to $15.76 per pound of lower nitrogen losses with disposal costs of $40 per ton of litter. The costs also rapidly escalate for 60 and 100-cow farms. Net cash income for the 60-cow dairy/poultry farm declines by $87.63 per pound of lower phosphorus losses with disposal costs of $40 per ton of litter.

The initial phosphorus application restrictions reduce farm income and phosphorus losses without litter disposal costs. But if farms must pay to remove litter, the removal costs under PLIMIT will have a greater impact on farm net cash income than the restricted phosphorus applications. Given the large quantity of litter leaving farms under PLIMIT, it is important to examine the overall effect of these policies beyond the farm level.

5.3 County Nutrient Loss Reduction Estimates

Estimated nitrogen and phosphorus losses for the dairy and dairy/poultry farms are aggregated per farm category and totaled to county level (Table 5.4). The farms are aggregated by the three representative dairy and dairy/poultry farm sizes as defined in Chapter II. It is assumed that each county dairy and dairy/poultry farm conforms to one of

Table 5.3. Farm Level Costs Per Pound of Nutrient Reduction for PLIMIT Under Varying Disposal Costs.[1]

Farm and Disposal Cost	Net Cash Income	Nitrogen Losses	Cost Per Lbs. of Nitrogen	Phosphorus Losses	Cost Per Lbs. of Phosphorus
60-Cow Dairy/Poultry[2]					
BASE	51090	4504		583	
PLIMIT - $0	48050	1991	$1.21	330	$12.02
$10	43620	1991	$2.98	330	$29.53
$20	38990	1991	$4.82	330	$47.83
$30	33930	1991	$6.84	330	$67.83
$40	28920	1991	$8.84	330	$87.63
100-Cow Dairy/Poultry[2]					
BASE	85310	6273		1014	
PLIMIT - $0	80590	3920	$2.00	644	$12.76
$10	75970	3920	$3.96	644	$25.24
$20	71290	3920	$5.94	644	$37.89
$30	66600	3920	$7.93	644	$50.57
$40	61800	3920	$9.87	644	$63.54
150-Cow Dairy/Poultry[2]					
BASE	109450	7592		1480	
PLIMIT - $0	102410	5957	$4.32	1073	$17.30
$10	97770	5957	$7.17	1073	$28.70
$20	93120	5957	$10.03	1073	$40.12
$30	88470	5957	$12.89	1073	$51.55
$40	83800	5957	$15.76	1073	$63.02

1. Benefits per pound of nutrient reductions is calculated by dividing the change in farm income by the decrease in nutrient losses per farm (absolute value).
2. Models include BASE dairy/poultry, PLIMIT without any disposal costs, and PLIMIT with disposal costs of $10, $20, $30, and $40 per ton.

Table 5.4. Total County Nutrient Losses Per Policy on Dairy and Dairy/Poultry Farms (tons).[1]

Farm	Number of Farms	BASE Losses N (tons)	BASE Losses P (tons)	INCORP Losses N (tons)	INCORP Losses P (tons)	NLIMIT Losses N (tons)	NLIMIT Losses P (tons)	PLIMIT Losses N (tons)	PLIMIT Losses P (tons)
Dairy									
60-Cow	102	150.3	26.3	152.0	24.7	104.8	24.7	101.4	16.9
100-Cow	64	190.1	31.3	193.1	29.2	130.3	29.2	125.2	20.7
150-Cow	25	94.9	18.4	97.6	17.1	77.9	17.9	74.5	13.3
Sub-Total	191	435.3	76.1	442.6	71.0	313.0	71.8	301.1	50.8
Dairy/Poultry									
60-Cow	44	99.1	12.8	100.3	11.6	49.9	10.9	43.8	7.3
100-Cow	28	87.8	14.1	89.3	12.9	64.0	13.5	54.8	9.1
150-Cow	11	41.8	8.1	42.9	7.5	34.3	7.9	32.8	5.8
Sub-Total	83	228.7	35.0	232.5	32.1	148.2	32.3	131.3	22.2
Total Losses	274	663.9	111.0	675.1	103.1	461.2	104.1	432.3	73.0
Percentage Change From BASE				1.7%	-7.1%	-30.5%	-6.2%	-34.8%	-34.2%

[1] Losses are calculated by multiplying farm level losses by the number of farms per category and summing for total county wide losses.

the representative farm groups and uses the same level of dairy and poultry manure applications on identical cropping systems.

Both the NLIMIT and PLIMIT reduce nitrogen losses by more than 30 percent as compared to BASE. The INCORP policy increases nitrogen losses by 1.7 percent, or 11.2 tons. The PLIMIT policy was the only policy that substantially lowers phosphorus losses, showing a 34 percent reduction. Both the INCORP and NLIMIT policies reduce phosphorus losses by only 6 to 7 percent.

The largest percentage reduction in nitrogen and phosphorus losses are achieved on the 60-cow dairy and dairy/poultry farms. The largest absolute reduction is on the 100-cow dairy farms. Quantity and percentage wise, the smallest nutrient reductions are achieved on the 150-cow dairy and dairy/poultry farms. These results indicate that any policy directed to reducing nutrient losses should include the smaller 60-cow farms. A policy aimed only at farms with a large number of animals will not achieve substantial reductions in nutrient losses.

5.4 County Income Reductions Without Litter Disposal Costs

The net cash income for county dairy and dairy/poultry farms increases slightly under INCORP and NLIMIT, when no costs are incurred for excess poultry litter disposal (Table 5.5). PLIMIT, however, reduces county net cash income by $816,600, or 5.57 percent. Of this amount $336,700 comes from the 60-cow farms, $292,900 from the 100-cow farms, and $187,000 from the 150-cow farms. The financial impacts are greater for the smaller farms than the larger farms. NLIMIT reduces nitrogen losses by 30.5 percent with a 0.74 percent increase in direct county farm income if no litter disposal costs are

Table 5.5. Total County Net Cash Farm Income Per Policy on Dairy and Dairy/Poultry Farms ($000).[1]

Farms	Number of Farms	BASE Income Farm ($000)	BASE Income County ($000)	INCORP Income Farm ($000)	INCORP Income County ($000)	NLIMIT Income Farm ($000)	NLIMIT Income County ($000)	PLIMIT Income Farm ($000)	PLIMIT Income County ($000)
Dairy									
60-Cow	102	27.6	2,817.2	27.7	2,825.4	27.8	2,835.6	25.6	2,614.3
100-Cow	64	60.7	3,885.4	60.9	3,898.9	61.4	3,926.4	58.2	3,724.2
150-Cow	25	84.7	2,118.5	84.7	2,116.5	85.5	2,138.5	80.4	2,009.5
Sub-Total	191		8,821.2		8,840.8		8,900.5		8,347.9
D/Poultry									
60-Cow	44	51.1	2,248.0	51.2	2,251.5	54.1	2,249.3	48.1	2,114.2
100-Cow	28	85.3	2,388.7	85.5	2,394.0	86.0	2,406.9	80.6	2,256.5
150-Cow	11	109.5	1,204.0	109.4	1,203.0	110.3	1,213.5	102.4	1,126.5
Sub-Total	83		5,840.6		5,848.4		5,869.7		5,497.2
Total	274		14,661.8		14,689.2		14,770.2		13,845.2
Percentage Change from BASE					0.19%		0.74%		-5.57%

[1] County net cash income for dairy and dairy/poultry farms is calculated by multiplying farm net cash income by the number of farms per category and summing for total county wide losses.

incurred. PLIMIT reduces nitrogen losses by 34.8 percent and phosphorus losses by 34.2 percent. However, the environmental benefits are offset by 5.57 percent lower direct farm net cash income.

5.5 County Income Reduction With Various Litter Disposal Costs

The impact of the PLIMIT policy becomes more pronounced with the inclusion of additional disposal costs (Table 5.6 and Graph 5.1). With a zero disposal cost net cash income on county dairy and dairy/poultry farms drops 5.6 percent. However, average net cash income drops 8.1 percent with a cost of $10 per ton and up to 16.3 percent with a disposal cost of $40 per ton. Net income of the 60-cow dairy/poultry farm drops up to 43 percent at costs of $40 per ton. Consequently, PLIMIT substantially reduces average net farm income on dairy/poultry farms and reduces county dairy and dairy/poultry farm income by more than 16 percent at disposal costs of $40 per ton of litter.

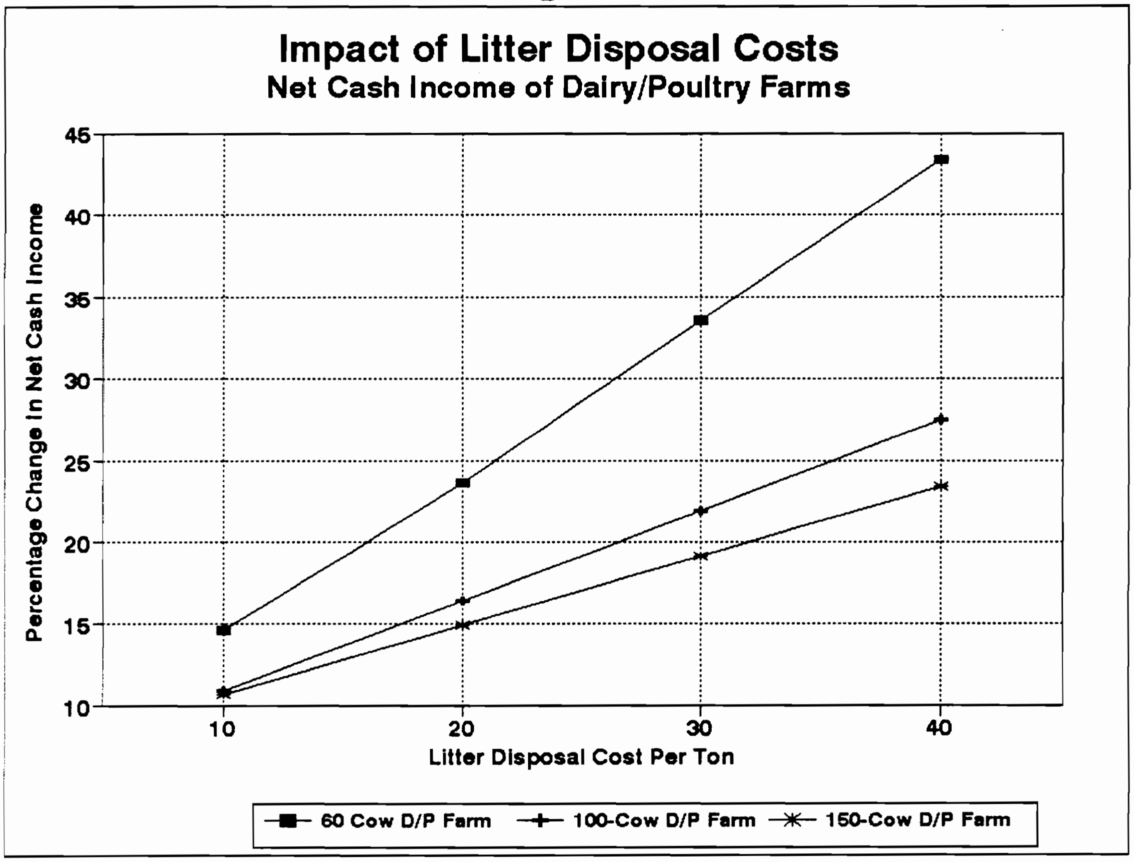
The changes in average net cash income at county level incurred under PLIMIT with varying disposal costs are expressed on a per pound of reduced nutrient, nitrogen, and phosphorus losses in Table 5.7. The direct county dairy and dairy/poultry farm costs of reducing nitrogen and phosphorus nutrients under PLIMIT and with no disposal costs is $1.87 per pound of nitrogen, or $11.37 per pound of phosphorus, or $1.60 per pound of nitrogen and phosphorus. These costs escalate as the disposal cost increases. At a disposal cost of $40 per ton of litter, direct income declines by $2,436,600, which translates into a cost of $5.26 per pound of nitrogen, $32.06 per pound of phosphorus, and $4.52 per pound of nitrogen and phosphorus.

Table 5.6. Total County Net Cash Farm Income Per Policy on Dairy and Dairy/Poultry Farms Under Varying Disposal Costs ($000).[1]

Farm and Disposal Costs	Number of Farms	BASE Income Farm ($000)	BASE Income County ($000)	PLIMIT Income Farm ($000)	PLIMIT Income County ($000)	Percentage Change From BASE
Dairy Farms						
60-Cow	102	27.6	2,817.2	25.6	2,614.3	-7.2%
100-Cow	64	60.7	3,885.4	58.2	3,724.2	-4.2%
150-Cow	25	84.7	2,118.5	80.4	2,009.5	-5.1%
Sub-Total	191		8,821.2		8,347.9	-5.4%
60-Cow BASE D/P	44	51.09	2,248.0	NA	NA	
Costs: $0/ton				48.1	2,114.2	-6.0%
Costs: $10/ton				43.6	1,919.3	-14.6%
Costs: $20/ton				39.0	1,715.6	-23.7%
Costs: $30/ton				33.9	1,492.9	-33.6%
Costs: $40/ton				28.9	1,272.5	-43.4%
100-Cow BASE D/P	28	85.31	2,388.7	NA	NA	
Costs: $0/ton				80.6	2,256.5	-5.5%
Costs: $10/ton				76.0	2,127.2	-10.9%
Costs: $20/ton				71.3	1,961.1	-16.4%
Costs: $30/ton				66.6	1,864.8	-21.9%
Costs: $40/ton				61.8	1,730.4	-27.6%
150-Cow BASE D/P	11	109.45	1,204.0	NA	NA	
Costs: $0/ton				102.4	1,126.5	-6.4%
Costs: $10/ton				97.8	1,075.5	-10.7%
Costs: $20/ton				93.1	1,024.3	-14.9%
Costs: $30/ton				88.5	973.2	-19.2%
Costs: $40/ton				83.8	921.8	-23.4%
Totals Under Disposal Cost:						
Costs: $0/ton			14,661.8		13,845.2	-5.6%
Costs: $10/ton					13,469.8	-8.1%
Costs: $20/ton					13,083.9	-10.8%
Costs: $30/ton					12,678.8	-13.5%
Costs: $40/ton					12,272.6	-16.3%

[1] County net cash income for dairy and dairy/poultry farms is calculated by multiplying farm net cash income by the number of farms per category and summing for total county wide losses.

Graph 5.1.



Impact of Litter Disposal Costs
Net Cash Income of Dairy/Poultry Farms
Percentage Change in Net Cash Income
45
40
35
30
25
20
15
10
10
20
30
40
Litter Disposal Cost Per Ton
60 Cow D/P Farm
100-Cow D/P Farm
150-Cow D/P Farm

Table 5.7. County Per Pound Cost of Per Pound of Reduced Nitrogen and Phosphorus Losses Under PLIMIT Policies with Varying Disposal Costs.[1]

Model and Disposal Costs	County Net Cash Farm Income[2] ($000)	Change in Net Cash Income[3] ($000)	Cost Per Pound of Reduced Nutrient Losses Cost/Pound of Nitrogen[4] ($/pound)	Cost/Pound of Phosphorus[5] ($/pound)	Cost/Pound Total Nutrients[6] ($/pound)
BASE	14,661.6				
Costs: $0/ton	13,845.2	816.6	1.76	10.75	1.51
Costs: $10/ton	13,469.8	1,191.9	2.57	15.68	2.21
Costs: $20/ton	13,083.9	1,577.9	3.41	20.76	2.93
Costs: $30/ton	12,678.8	1,983.0	4.28	26.09	3.68
Costs: $40/ton	12,272.6	2,389.2	5.16	31.44	4.43

1. County net cash income for dairy and dairy/poultry farms is calculated by multiplying farm net cash income by the number of farms per category and summing for total county wide losses.
2. Average net cash income is defined as total cash receipts minus total cash expenses, excluding family living expenses, principal payments, and capital replacement costs.
3. The change in net cash income is calculated by the net cash income under BASE less the net cash income per disposal cost.
4. The cost per pound of reduced nitrogen losses is calculated by dividing the change in net cash income by 463,200 pounds, the reduced nitrogen losses under PLIMIT.
5. The cost per pound of reduced phosphorus losses is calculated by dividing the change in net cash income by 76,000 pounds, the reduced phosphorus losses under PLIMIT.
6. The cost per pound of reduced total nutrient losses is calculated by dividing the change in net cash income 539,200 pounds, the total reduction in nitrogen and phosphorus losses under PLIMIT.

The cost per pound of nitrogen and phosphorus provide an indication of the direct county wide cost, or the marginal cost at the current level of nutrient applications, of reducing nitrogen and phosphorus nutrients on dairy and dairy/poultry farms. The direct costs of adopting PLIMIT are spread over dairy and dairy/poultry farms while additional costs attributed to litter disposal apply only to the dairy/poultry sector. These costs are very expensive when compared to commercial rates of $0.26 for nitrogen and $0.25 for P_2O_5. These levels imply that alternative policies, such as taxing excess nutrients, would have to cost the farmer more than the $5.26 per pound of nitrogen and $32.06 per pound of phosphorus to achieve the same level of reduced nutrient losses at litter disposal costs of $40 per ton. In addition, these are only the direct costs involved with the program. There has been no attempt to estimate the impacts of the indirect costs that result from less spending by the farm sector because of the lower income. The lower farm expenditures affect other business, causing reduced spending by these firms, and so forth. Limiting litter applications produces indirect impacts well beyond the farm gate.

5.6 Litter Distribution Problems

The biggest problem caused by any manure management policy that ultimately reduces litter applications on Rockingham County farms is what to do with the surplus litter. The previous analysis examined the direct impact on farm income if producers had to pay for poultry litter removal. The larger question is what would happen to the litter leaving dairy and dairy/poultry farms. Unless it is used in an environmentally safe manner, the potential nitrogen and phosphorus losses to Virginia waters will not be reduced.

This study assumes that 30 percent of the county's dairy farms have broiler or turkey operations and produce 408 tons of litter per farm (see Chapter II). Litter utilization by the 191 county dairy farms totals 58,565 tons under BASE and 51,720 tons under NLIMIT (Table 5.8). Dairy/poultry farms produce 33,864 tons of litter. The 60-cow dairy/poultry farm exports 3,960 tons under BASE while the 150-cow imports an additional 1045 tons, leaving a net export of 2915 tons under BASE and 7986 tons under NLIMIT (Table 5.9). All county dairy farms import a total of 55,650 tons under BASE and 43,734 tons under NLIMIT from other county poultry farms.[1] On a county wide basis, all dairy and dairy/poultry farms are assumed to use 89,514 tons of litter under the BASE and 77,598 tons of litter under NLIMIT.[2] Adoption of NLIMIT nutrient restrictions reduces total poultry litter used on all county dairy farms by 13.3 percent (11,916 tons). The PLIMIT policy reduces litter applications by the full 89,514 tons.

The Shenandoah Soil and Water Conservation District estimates that county broiler and turkey litter production in 1993 was 224,000 tons, of which 30,000 tons was estimated to have been transferred outside of the county.[3] Litter utilization by all county dairy farms equal 40.0 percent of the estimated county litter production under BASE and 34.6 percent

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[1] Net litter imports under BASE = 58,565 tons (imported by dairy farms) - 3,960 tons (exported by 60-cow dairy/poultry farms) + 1,045 tons (imported by 150 cow dairy/poultry farms) = 55,650 tons. Litter imports under NLIMIT = 51,720 tons (imported by dairy farms) - 8,492 tons (exported by 60-cow dairy/poultry farms) + 506 tons (imported by 150 cow dairy/poultry farms) = 43,734 tons.

[2] Litter use on all county dairy and dairy/poultry farms under BASE = 58,565 tons (dairy farms) + 29,504 tons (produced and used on dairy/poultry farms) + 1,045 tons (imported by 150-cow dairy poultry farms) = 89,514 tons. Litter use on all county dairy and dairy/poultry farms under NLIMIT = 51,720 tons (dairy farms) + 25,372 tons (produced and used on dairy/poultry farms) + 506 tons (imported by 150-cow dairy poultry farms) = 77,598 tons.

[3] Litter estimates on Table 2.1 are from the 1992 U.S. Census of Agriculture. Estimates from the Shenandoah Valley Soil and Water Conservation District are for 1993 and include litter produced by turkey breeding flocks.

Table 5.8. Litter Imported For Use as Fertilizer on Dairy Farms in Rockingham County Under BASE and NLIMIT Policies (tons).[1]

Dairy Farm Size	Number of Farms	Litter Imported - Farm Level		Litter Imported - County Level	
		BASE	NLIMIT	BASE	NLIMIT
60-Cow Farm	102	225	195	22,950	19,890
100-Cow Farm	64	360	320	23,040	20,480
150-Cow Farm	25	503	454	12,575	11,350
Total	191			58,565	51,720

[1] No litter is used on dairy farms under PLIMIT.

Table 5.9. Litter Use on Dairy/Poultry Farms in Rockingham County Under BASE and NLIMIT Management Policies (tons)[1].

Dairy/Poultry Farm Size	Number of Farms	Own Litter Used		County Litter Use		Litter Exported		Litter Imported	
		Base	NLIMIT	Base	NLIMIT	Base	NLIMIT	BASE	NLIMIT
60-Cow	44	318	215	13,992	9460	3960	8492	0	0
100-Cow	28	408	408	11,424	11,424	0	0	0	0
150-Cow	11	408	408	4488	4488	0	0	1045	506
Total	83			29,904	25,372	3960	8492	1045	506

[1] Each farm has two poultry houses and produces 408 tons of litter per year. The 60-cow farm does not use all of its litter under the BASE of NLIMIT. The 100 and 150-cow farm use all of their litter under each alterative. The 150-cow farm imports additional litter. No litter is used dairy/poultry farms under PLIMIT.

under NLIMIT.[4] Excluding the estimated 30,000 tons of litter transferred outside of the county, 194,000 tons remain to be utilized within the county. Current county nutrient management plans indicate that over 45 percent (101,000 tons) of poultry litter produced in the county needs to be transferred from the farm on which it is produced (Zhu). With 30,000 tons being transferred out of the county, current nutrient management plans call for 71,000 tons of poultry litter to be transferred within the county. In this study it is estimated that dairy farms import 55,650 tons of litter under BASE and 43,734 tons under NLIMIT, accounting for much of the within county transfers.

5.6.1 Uses of Surplus Litter

The growth of the poultry industry in Rockingham County has relied on the surrounding farm environment to absorb the litter produced by broilers and turkeys. The litter is commonly used for fertilizer as indicated by farms in this study and as a feed source for cattle. County nutrient management plans, soil test phosphorus levels, and the decline in county fertilizer sales indicate that much of the litter is being applied to county fields.

The economic value of litter for fertilizer and cattle feed depends on two main factors. One is the value of the fertilizer or feed ingredients the litter replaces. The second factor is transportation and handling costs incurred. Bosch and Napit estimated the fertilizer value of a ton of litter applied to cropland ranged from $20.05 per ton for corn grain to $28.50 per ton for grass-clover pasture. At transportation costs of $0.10 per ton per mile, the geographical distance for litter procured at a zero cost would range from 200 miles for

[4] Under BASE and NLIMIT dairy and dairy/poultry farms use 89,514 and 77,598 tons of litter, respectively, which are 40.0 and 34.6 percent of 224,000 tons.

corn grain to 285 miles for grass-clover pasture. Costs for litter within Rockingham County vary from year to year and are influenced by the type and nutrient content of the litter. Within Rockingham County, fertilizer dealers indicate that many farmers began considering replacing litter with fertilizer when litter acquisition and spreading costs approach $14.00 per ton. However, high soil phosphorus and potassium levels reduce the value of litter as fertilizer source because unneeded nutrients have no value to the farmer.

Broiler litter is utilized as a feed supplement for cattle. Turkey litter generally is not used for cattle feed because farmers have found turkey litter to be less palatable and too lumpy to mix evenly with other feeds ingredients. The protein and energy content of broiler litter makes it a viable substitute for other feed stuffs. The value of broiler litter for use as cattle feed depends upon the value of equivalent ration ingredients and transportation costs. Bosch and Napit estimated the maximum price farmers could pay for broiler litter based on optimal feed rations at $58.52 for beef cows, $49.82 for stockers, and $46.46 for finishing steers. At $0.10 per mile per ton and zero acquisition costs, broiler litter could be transported up to 585 miles for beef cows. It is estimated that slightly more than half of the 30,000 tons being exported from Rockingham County in 1993 is being used for cattle feed (Roller). Nutrient management plans indicate that very little of the litter is being used as cattle feed in Rockingham County, Virginia's number one beef cattle county. Rockingham County's dairy farmers are prohibited from feeding litter to dairy cows because of Grade A health regulations. Litter could be used as a feed supplement for dairy heifers but this is not a common practice among Rockingham County dairy farmers (Roller).

5.6.2 Impact of Additional Litter Supplies

Under NLIMIT nutrient application restrictions, dairy farms reduce their litter use by nearly 12,000 tons. There will likely be other county farms that have excess litter under NLIMIT restrictions but those farms are not included in this study. It is difficult to judge how an additional 12,000 tons would affect the overall litter transfer market. Bosch and Napit indicated there is economic potential for much greater exports of litter from Rockingham County beyond the 30,000 tons currently being exported. If this potential materialized, there is a possibility that the extra 12,000 tons of litter could be transferred out of the county without disrupting poultry industry production costs.

Under the PLIMIT nutrient application restriction, nearly 90,000 tons would have to utilized in addition to the 30,000 tons being exported. Under current practices only broiler litter is used for cattle feed, so if all broiler litter (77,000 tons) was exported out of the county for cattle feed, nearly 43,000 tons of turkey litter would need to be exported for fertilizer use. The broiler litter has higher value as a feed source and thus has a greater distance in which it can be economically transferred. The turkey litter has a lower value in use as fertilizer and thus has a smaller distance in which it can be economically transferred.

If producers have to pay to remove litter, the maximum transferable range widens. At a $10 per ton cost of litter removal, the maximum transportation distance for litter buyers would increase by 100 miles. A $10 per ton payment for litter removal creates negative delivery and acquisition costs for farms within 100 miles of shipment points in Rockingham County. Farmers within the 100 miles would be paid to use litter for fertilizer or cattle feed.

Adoption of the PLIMIT policy would impact other sectors within Rockingham County. Disposal costs that decrease profitability would cause some farmers to discontinue poultry production, depending upon the individual farm's fixed costs. The break-even and shutdown points will vary with different levels of fixed costs. At break-even,cash costs equal cash expenses. The shutdown point occurs when cash losses from operations are equal or greater than fixed costs. The poultry budgets in this study show a before tax cash flow break-even cost of removing litter at a cost of $26.69 per ton of litter.[5] The farm would discontinue production at a cost of $119.90 per ton. For farms that are debt free, the cash flow break-even point occurs at a disposal cost of $109.84 per ton of litter. The shutdown point occurs at a disposal cost of $119.90 per ton of litter.[6]

Loans would become harder to acquire and the net worth of current producers would likely decrease because of devalued facilities. The poultry industry thrives on efficiency of the production system, from hatchery to the processing plant. A threatened reduction in poultry producers would affect their entire operations, reducing volume, cash flow, and reducing the economies of scale upon which their operations depend. This situation may force the integrator to take actions that would reduce their potential losses. These actions could range from locating new growers with adequate farm land to absorb litter production to relocating their plants and equipment. Another possible action would be for the integrator to coordinate litter disposal efforts among their growers to help create stronger litter markets.

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[5] Before tax break-even cash flow is based on gross revenue less variable costs less mortgage costs (100 percent financing over 15 years at 9 percent). Fixed costs are $38,027, receipts are $66,598, variable costs are $17,678, and the amount of litter is 408 tons. Cash flow break-even occurs when receipts less total costs equals zero ($66,598 - $38,027 - $17,678 - (408*26.69=$10,893) = $0). Shut down occurs when receipts less total costs is less than fixed costs ($66,598 - $38,027 - $17,678 - (408*119.90=$48,919) = -$38,027).

[6] Costs and returns for the debt free poultry operations include $17,678 in variable costs, $4,102 in fixed costs, and $66,598 in revenue. Cash flow break-even occurs when receipts less variable and fixed costs less litter disposal costs equal zero ($66,598 - $17,678 - $4,102 - (109.85*408=$44,818) = 0). Shut down occurs when receipts less expenses equals the fixed costs ($66,598 - $17,678 - $4,102 - (119.90*408=$48,920) = -$4,102).

Questions of how to dispose of surplus litter raises the question of why crop and cattle farmers outside of Rockingham County are not currently using litter for feed and fertilizer. Several factors mentioned by Bosch and Napit include educational issues, failure of communication between potential producers and users, or institutional barriers such as resistance to the idea of feeding animal waste to other animals. Identification of barriers that limit farmers use of litter would be of great benefit to poultry producers and could assist in creating a market demand for surplus litter. Another question is why beef cattle farmers in Rockingham County do not use more poultry litter as feed. Why more litter is not being transferred is beyond the scope of this study but certainly is one that needs additional research in the future.

5.7 Summary

This study has identified the farm and county costs related to reducing potential nitrogen and phosphorus nutrient losses under different policies. NLIMIT significantly reduces nitrogen losses while slightly increasing farm cash income if no litter disposal costs are incurred. However, NLIMIT reduces phosphorus losses only by 6 percent. PLIMIT reduces nitrogen and phosphorus losses over 34 percent but lowers county net cash income by 5.57 percent with no litter disposal costs. When disposal costs are considered, the county dairy and dairy/poultry farm net cash income drops up to 17 percent. The loss of direct income equates to a cost of up to $5.16 per pound of nitrogen loss reduction or $31.44 per pound of phosphorus loss reduction at disposal costs of $40 per ton. Under NLIMIT an additional 11,916 tons of litter would need to be transferred out of the Rockingham County.

Under PLIMIT, an additional 90,000 tons of litter will need to be transferred. The impact of additional litter on litter disposal costs and litter prices is beyond the scope of this study.

Chapter VI

Summary, Implications, and Conclusions

6.1 Study Summary

The objective of this dissertation is to estimate the environmental and economic tradeoffs between alternative manure management policies on dairy and dairy/poultry farms in Rockingham County, Virginia. The issue of manure management is important to Rockingham County because of its large and growing animal population. In 1992 county dairy and poultry produced 173 pounds of manure nitrogen and 155 pounds of manure phosphorus per county cropland acre. These are more nutrients than are needed under most intensive crop production. A recent trend in the county has been the addition of poultry operations to existing dairy farms. The growth of this sector concentrates a greater amount of manure production on these farms.

Public attention is increasingly focusing on concentrated animal production and the potential water degradation problems that are attributed to manure nitrogen and phosphorus. Possible future manure management policies in Virginia are sure to affect Rockingham County's dairy and poultry producers. Dairy and dairy/poultry farms are particularly susceptible because dairy manure is highly liquid, and is relatively low in value and expensive to transport. Policymakers, however, are often uncertain about the potential impacts of some manure management policies on the environment and farm economic viability. The goal of this study is to provide policymakers with information that will aid them in assessing the potential impacts on water quality of policies that affect manure management practices on dairy and dairy/poultry farms.

The specific objectives of this study are:

1) To estimate potential field and farm level nitrogen and phosphorus losses, and net farm returns occurring under current manure management practices on dairy and dairy/poultry farms in Rockingham County, Virginia.

2) To estimate potential field and farm level nitrogen and phosphorus losses, and net farm returns under three alternative policies. These policies are: 1) all manure is incorporated within two days of application (INCORP), 2) nitrogen applications are limited to crop agronomic recommendations (NLIMIT), and 3) phosphorus nutrient applications are limited to levels removed by the crop (PLIMIT).

3) To determine the farm level economic costs associated with corresponding changes in potential nutrient losses for each manure management policy.

4) To estimate county level nutrient losses and the financial impacts on dairy and dairy/poultry farms.

6.1.1 Current Field Level Nitrogen and Phosphorus Losses

Estimation of potential field and farm level nitrogen and phosphorus losses and net farm returns occurring under current manure management is done by simulating crop production practices and the financial performance of three different size representative dairy and dairy/poultry farms are defined - a 60-cow, a 100-cow, and a 150-cow farm. It is assumed that all 191 county dairy and 83 dairy/poultry farms fit one of the representative farms. The production practices and specific parameters for each farm are defined by a panel of farmers whose personal operations closely fit the size of the respective representative farms. Dairy/poultry farms are assumed to be a dairy farm that added a poultry operation which produces 408 tons of litter per year.

The farmer panels specified that each representative farm applies at least 2 tons of litter in addition to 5000-7000 gallons of dairy manure per acre per year to corn acreage. Nitrogen applications on all dairy farms are below agronomic recommendations for corn silage/ryelage by 20 to 40 pounds per acre. The 100 and 150-cow dairy farms slightly exceed agronomic recommendations for corn silage/rye cover and corn silage/no rye cover. The 60 and 100-cow dairy farms exceed nitrogen recommendations on grass hay and pasture by 40 to 70 pounds per acre. The dairy/poultry farms apply more litter than the dairy farms, with the 60-cow dairy/poultry farm exceeding nitrogen agronomic recommendations for corn silage by 20 pounds per acre, and hay and pasture by 55 to 80 pounds per acre. The 100-cow dairy poultry farm exceeds agronomic recommendations for hay and pasture by 60 and 30 pounds, respectively, per acre. All farms apply phosphorus and potassium well in excess of crop needs on all crops because of the dependence on manure. Due to the high phosphorus presently in the soils, no additional phosphorus is needed during the five year study period.

Each farm's cropping practices are simulated with EPIC for 100 five-year periods. Each crop and cropping system is simulated individually with weather randomly drawn from 44 years of historical Rockingham County weather records. Results include mean surface and sub-surface nitrogen losses, total phosphorus losses, and crop yields. The nutrient losses are measured at the edge of the field and below the root zone so they represent ***potential***

loadings, not actual loadings to surface and ground water. Field level nutrient losses are summed across crops to estimate farm level nitrogen and phosphorus losses.

EPIC simulations indicate that BASE nitrogen losses are 26.8, 30.5, and 20.5 pounds per acre for the 60, 100, and 150-cow dairy farms, respectively. Surface nitrogen losses are highest for corn silage. The subsurface losses nearly doubled on the corn silage without rye cover crops for the 150-cow farm, indicating that the rye cover crop reduces nitrogen losses in the fall and winter by absorbing plant available nitrogen. The largest subsurface nitrogen losses are occurring on grass hay and pastures. Phosphorus losses are highest on corn silage without ryelage and fields being planted no-till. The highest per acre nitrogen and phosphorus losses occur on the 60-cow dairy/poultry farm, and are 52 and 12 percent higher than nutrient losses on the 60-cow dairy farm. Nutrient losses for the 100-cow dairy/poultry farm are slightly higher than the 100-cow dairy farm.

The FLIPSIM model uses the EPIC estimated crop yields to simulate the farm's financial performance over 100 five-year periods. The financial analysis estimates each farm's probability of survival, probability of economic success, ending net worth, net cash income, and cash available for family living expenses. The results indicate that each farm will survive for the five year period, however, PLIMIT and possible litter disposal costs can substantially reduce each farm's financial returns and reduce the cash available for family living expenses below minimum levels. Adding a dairy/poultry operation is beneficial because the ending net-worth and cash available for family living expenses increase for each size farm. Dairy farms with lower milk production and higher debt would increase ending net worth and cash available for family living by adding a poultry operation.

The procedure described above produced the results for Objective One by estimating nutrient losses under current cropping operations and baseline financial values for Rockingham County dairy and dairy/poultry farms. The analysis produces several key findings. Rockingham County dairy and dairy/poultry farms rely primarily on dairy and poultry manure for crop nutrients. Nitrogen applications by the dairy farms are under agronomic recommendations for corn silage/ryelage but excess nitrogen is applied to corn silage with and without rye cover. The highest nitrogen losses occur on hay and pasture crops which are receiving up to 50 percent more nitrogen than needed. The highest farm level nutrient losses occur on the 60 and 100-cow dairy/poultry farms. The highest phosphorus losses occur on corn silage. Phosphorus applications exceed agronomic recommendations because the manures are applied to meet nitrogen needs. The representative farms are estimated to remain economically viable over the next five years, but farms have economic incentives to add poultry operations. Adding poultry improves the farm's financial standing but increases field level nutrient losses.

6.1.2 Nutrient Losses Under Alternative Policies

Each representative farm's cropping regimes are modeled with EPIC to estimate changes in nutrient losses under the INCORP, NLIMIT, and PLIMIT manure management policies. Under INCORP, nutrient applications remain at the same level and all manure applied to soils without a growing crop is incorporated into the soil within two days. INCORP decreases volatilization by five to seven percent and increases surface and subsurface nitrogen losses by one to three percent. Phosphorus losses are lower under INCORP.

NLIMIT reduces all nitrogen applications to agronomic recommendations. Consequently, litter applications are reduced on hay and pasture crops on the 60 and 100-cow dairy farms, and on corn silage, hay, and pasture crops on the dairy/poultry farms. Nitrogen losses are reduced by more than 30 percent on the 60 and 100-cow dairy farms, and up to 49 percent on the 60-cow dairy/poultry farm. Phosphorus losses are reduced by 2.5 to 6.4 percent except for the 60-cow dairy/poultry farm which experiences a 15.1 percent reduction. Crop yields remain about the same except for a small decrease in ryelage. Average and maximum hay and pasture yields remain about the same with the lower nitrogen applications. The EPIC simulations indicate that soil moisture, instead of nitrogen, is the limiting factor on the hay and pasture yields.

PLIMIT restricts phosphorus applications to crop removal to prevent additional buildup in the soil. All poultry litter applications are eliminated because minimum crop phosphorus requirements are met by dairy manure applications. Supplemental nitrogen and potassium fertilizer are added to make up for the amounts of these nutrients previously supplied by the litter. Nitrogen losses are slightly lower under PLIMIT than NLIMIT on most of the farms. The largest reduction is 55.7 percent for the 60-cow dairy/poultry farm. Phosphorus losses are reduced on dairy-only farms by 27.5 to 36.3 percent. Phosphorus losses are reduced by 43.4 and 36.5 percent on the 60 and 100-cow dairy/poultry farms. All crop yields remain approximately the same except for ryelage which increases by 0.3 to 0.5 tons per acre.

For Objective Two, the results indicate that INCORP is an ineffective policy to significantly reduce nitrogen and phosphorus losses. NLIMIT significantly reduces nitrogen losses but phosphorus loss reductions are minimal. PLIMIT produces the greatest reduction in nitrogen and phosphorus losses. The highest reduction in nutrient losses is on the 60-cow dairy/poultry farm. The lowest nitrogen and phosphorus losses are on the 150-cow farms.

6.1.3 Farm Costs of Nutrient Loss Reductions

Each representative farm's financial operations are modeled under the INCORP, NLIMIT, and PLIMIT policies using the same method as for the BASE farm. INCORP produces virtually no change in the financial returns for any of the representative farms because higher tillage costs to incorporate the manure offset reduced herbicide costs. NLIMIT produces slightly higher ending net worth and cash available for family living expenses for each farm than under BASE. The probability of survival and economic success remain the same as under BASE.

Each representative farm is financially worse off under PLIMIT because cash expenses for commercial fertilizer exceed the cost of acquisition and spreading of poultry litter. Each farm has a higher debt/asset ratio, lower ending net worth, and cash available for family living is $2,000 to $6,500 lower than results under BASE. Net cash incomes are reduced for each farm but not enough to significantly affect the farm's economic viability. The 60 and 100-cow dairy/poultry farms have more cash available for family living under PLIMIT than the equivalent BASE dairy farms. PLIMIT affects dairy and dairy/poultry farms that have higher debt and lower milk production than the representative farms. These farms' probability of economic success drops by 15 to 25 percentage points below BASE, INCORP, and NLIMIT. This means that these farms can stay in business by borrowing against farm equity but they are experiencing declining owner equity. Some of these farms can be expected to go out of business.

Each dairy/poultry farm is examined under PLIMIT with the assumption that cash costs are incurred to dispose of their 408 tons of litter. For the 60-cow dairy/poultry farm the ending net worth is less at disposal costs above $30 per ton than for the BASE dairy farm. The 100 and 150-cow dairy/poultry farms can absorb disposal costs of $40 per ton and still maintain a higher ending net worth than the BASE dairy farms. The 60 and 150-cow dairy/poultry farm has less cash available for family living expenses than the BASE 60-cow dairy farm at disposal costs of $10 per ton. The 100-cow dairy/poultry farms have less cash available for family living expenses as compared to BASE dairy farms at a disposal cost of $20 per ton.

The farm level cost of reducing field-level nitrogen and phosphorus losses is expressed in terms of lower net cash income per pound change in nutrient losses. The cost of reducing nitrogen losses ranged from $1.21 to $4.32 per pound and from $9.46 to $17.30 per pound for phosphorus. With variable disposal costs under PLIMIT, the cost of reducing nitrogen more than doubles, from $1.22 per pound at $10 per ton to $8.84 per pound at a cost of $40 per ton. The cost of reducing phosphorus losses for the 60-cow farm escalates from $12.02 per pound to $87.63 per pound. The dairy/poultry farms are losing considerable income per pound of reduced nitrogen and phosphorus losses.

6.1.4 County Level Nutrient Losses and Costs

Estimated county level nutrient losses under current manure management practices on Rockingham County Dairy and dairy/poultry farms are 663.9 tons of nitrogen and 111.0

tons of phosphorus. These are the losses measured at the edge of the field and below the root zone and represent ***potential loadings,*** not actual loadings to ground and surface water. Under NLIMIT nitrogen losses decline by 202.7 tons (30.5 percent) and phosphorus losses by 7.9 tons (6.2 percent). Under PLIMIT nitrogen losses are reduced 231.6 tons (34.8 percent) and phosphorus losses are reduced by 38.0 tons (34.2 percent). The net farm cash income for all county dairy and dairy/poultry farms is lowered by $816,600 under PLIMIT and assuming no litter disposal costs. County net farm cash income declines by $2,389,200 at litter disposal costs of $40 per ton. The county wide cost of reducing nitrogen and phosphorus losses under PLIMIT, in terms of lost direct net cash income per pound, is $1.76 and $10.75 per pound of reduced nitrogen and phosphorus losses under the assumption of no litter disposal costs.

At varying disposal costs, the cost of reducing nitrogen losses per pound in terms of the change in county net farm cash income ranges from $2.57 at a cost of $10, to $5.16 at a cost of $40 per ton of litter. The cost of reducing phosphorus losses reduces county net farm cash income by $15.68 per pound at a disposal cost of $10 and ranges to $31.44 per pound at a disposal cost of $40 per ton of litter.

The cost of litter disposal that may occur under PLIMIT is difficult to estimate and depends on the supply and demand factors of litter. Although these estimates are beyond the scope of this study, estimates are made of surplus litter that may occur under the NLIMIT and PLIMIT policies. This study assumes that each dairy/poultry farm produces 408 tons of litter per year. County dairy and dairy/poultry farms use 89,514 tons of litter under BASE, 77,598 tons under NLIMIT, and zero tons under PLIMIT. County nutrient management plans indicate that 101,000 tons of litter produced in Rockingham County need to be transferred from the farm on which it is produced. With NLIMIT, this amount increases by nearly 12,000 tons. Under PLIMIT the amount needed to be transferred increases by nearly 90,000 tons. Only 30,000 tons (13.4 percent) were transferred out of the county in 1993 for use as fertilizer and cattle feed (Shenandoah Valley Soil and Water Conservation District). Thus the addition of up to 90,000 tons under PLIMIT will have a significant affect on the supply of litter. If increased demand for litter cannot be generated, poultry producers may likely find themselves forced to pay someone to remove the litter from their farms unless they can find other alternatives.

Significant findings under Objective Four include that PLIMIT was the most effective policy to reduce nitrogen losses by 231.6 tons and phosphorus losses by 38.0 tons. The cost per pound of reduced nutrient losses is significantly higher for phosphorus than nitrogen because absolute values are much lower. The cost of reducing nutrient losses increases significantly as disposal costs increase. The county dairy farms utilized nearly 90,000 tons of litter under BASE, 78,000 tons under NLIMIT and zero tons under PLIMIT. NLIMIT and PLIMIT release an additional 12,000 and 90,000 tons of litter, respectively, for use elsewhere.

6.2 Implications

Water quality efforts in Virginia are generally related to efforts to reduce nutrient inflow from point and non-point sources into the Chesapeake Bay. The state is committed to reducing Bay nutrient inflows by 40 percent by the year 2000. Virginia's efforts to reduce nutrient losses in the Potomac River basin have lowered nitrogen loads by 6.5 percent and phosphorus by 25.6 percent. However, monitoring stations along the Southern

Shenandoah Region, which includes Rockingham County, report increasing long term nutrient trends in contrast to other regions of the state. The region is characterized by nutrient concentrations, primarily from intensive agricultural activities, that are among the highest in the Shenandoah River (Virginia's Potomac Basin Tributary Nutrient Reduction Strategy).

This study indicates that substantial reductions in nutrient losses originating from cropland in Rockingham County can be accomplished with the NLIMIT and PLIMIT policies. NLIMIT reduces nitrogen losses by 30 percent and PLIMIT lowers both nitrogen and phosphorus losses by 34 percent. Under nitrogen based objectives, NLIMIT appears to be a very effective program to reduce nitrogen nutrient inflows and presents the advantage of not lowering farm incomes without any litter disposal costs. From a policy perspective, NLIMIT is a win-win situation. Policymakers achieve a more politically acceptable outcome - lower potential nitrogen losses from agricultural regions without adversely affecting farm incomes. This finding suggests that greater education efforts directed toward farmer's nitrogen applications can aid both farmers and the environment.

The results under PLIMIT indicate that its implementation would reduce both nitrogen and phosphorus nutrient losses. However, PLIMIT's gains to society from lower nutrient losses comes at the expense of farmers. PLIMIT suggests that nutrient losses can be substantially reduced but only by requiring lower manure applications by farmers. This study examines only the physical results of the policy, not the legal ramifications of such a policy. The enactment of this type of policy questions the property rights of individual farmers to apply manure as they desire versus society's rights to clean water supplies. The property rights issue is beyond the scope of this study but is an important issue confronting both policymakers and farmers concerned with nutrient management policies.

Current nutrient management efforts in Virginia are primarily aimed at larger farms which are perceived as posing greater environmental problem. However, this research indicates that the greatest nutrient pollution potential exists on the smaller livestock intensive farms in Rockingham County. Nutrient management policies will be much less effective if small farms are ignored. Consequently, successful efforts to reduce nutrient losses will need to be directed at farms with high animal units per acre. A policy that applies to only to farms that have greater than a specified number of animal units per acre could result in overlooking farms with a high number of animals in one location but with large land bases. However, a joint criteria based on animal units per acre and total animal units could direct policies toward small and large intensive animal production sites. Under a joint criteria, policies could be implemented that cover the land intensive 60-cow dairy/poultry farms as well as farms with a large number of animals situated at one location.

The policies examined in this study are regulatory in nature in that all farmers are assumed to comply with the policy's specifications. Education and incentive based programs are used in other parts of the U.S. to address nutrient management issues. The regulatory based policies examined in this study assume 100 per cent compliance. However, policymakers generally do not want to regulate production practices on a large number of geographically dispersed farms when other efforts can produce favorable results.

Incentive based programs are part of Virginia's overall water quality programs. The state provides special tax credits for the purchase of conservation equipment such as no-till planters, soil conservation tillage equipment, and certain manure spreaders. This program has assisted farmers in purchasing 93 litter spreading beds since 1991 (Roller). In addition, Virginia has assisted in the financing of litter storage structures that permit the farmer to store litter until it can be properly applied to fields, or for timely transfer to a broker or another farmer. These programs assist in manure management by providing incentives for more accurate and timely litter application (Roller). This program has been credited with assisting the development of litter brokerage firms in Rockingham County. Another incentive policy (regulatory in nature for individual growers) voluntarily adopted by the poultry industry requires each grower to have a nitrogen based nutrient management program by 1996.

Nutrient management education efforts in Virginia have concentrated on trying to make farmers aware of manure's value as a fertilizer substitute and to improve soil structure. The state (DEQ) provides professional nutrient management specialists who consult with farmers and assist in drawing up nutrient management plans. These programs are primarily nitrogen based and do not have any form of compliance check. All farmers applying for conservation tax credits or any cost share programs must have a DEQ approved nutrient management plan. In addition, farmers receive some protection from civil complaints concerning manure disposal practices if the farm is following a DEQ approved nutrient management plan. The state specialists have assisted many farmers across the state in designing nutrient management plans. Rockingham County has instituted a required nitrogen-based nutrient management for all poultry operations. But, again, there is no form of compliance check. There is also a lack of information determining if the nutrient managements are identifying and reaching farms where large amounts of nutrients are being lost.

The effectiveness of nutrient management plans depends on the degree to which total nutrient losses are being reduced. One problem with education and voluntary incentive programs is how to determine if the programs are effective in changing individual behavior and if the program is reaching individuals who account for a large share of nutrient losses. The incentive programs in Virginia are well directed, but it may be questionable that they are reaching the small acreage dairy/poultry farm. Tax incentives on conservation tools are likely to be more favorable to larger land operators because they can more easily justify the machine purchase. The tax credit is an incentive, but it does not provide for the purchase of the machine without individual cost. The litter storage building program is available to all producers but it could be argued that poultry operators with greater numbers of buildings would be the first to consider storage buildings. Smaller operators, such as the 60-cow dairy/poultry farms without storage would be more likely to apply litter to fields when buildings are cleaned and also will not be able to store for possible litter sales or transfer. If the small dairy/poultry farm or any poultry operator makes use of the tax incentive and/or the litter storage programs, there is the possibility that this does not alter operator behavior - farmers who over-apply manure nutrients can easily continue to do so.

Estimating the effectiveness of nutrient management programs requires accompanying detailed research to determine if programs have actually altered farmer behavior. This requires identifying those participating in the programs, estimating before and after nutrient management practices, and estimating changes in nutrient losses. But additional research also needs to be done to identify the worst offenders and estimate their contribution toward overall water degradation from manure nutrients. It is reasonable to assume that this will be difficult since those individuals are not likely to voluntarily identify themselves . The results from this study contribute toward identifying attributes of farms with the highest nutrient applications, the highest estimated losses, and the highest reductions under several examined policies. Additional research is needed to further segment the groups, but it can be concluded that small farms with high animal units per acre need to be targeted.

Some of the problems with nutrient management practices rests with differences in attitudes between farmers and general society. Virginia's governor signed The Chesapeake Bay Agreement which commits the state to reduce nutrient inflows into the Bay by 40 percent by the year 2000. However, it may be difficult for a dairy/poultry farmer in Rockingham County to perceive eutrophication of the Bay as their problem. Pease and Bosch reported that farmers in the county do not perceive their farming practices as being detrimental to the environment and water quality. It would be expected that farmers may change their attitude toward nutrient management if, for example, their own water source became contaminated with nitrate. Establishing concern within the farm community over phosphorus may be more difficult. What are the costs to farmers who have soil with high phosphorus levels? Field research does not suggest that crop yields decline. There is little documentation or mention in the literature of the dangers to human health or of contamination of public and private drinking water supplies attributed to phosphorus.

Reducing soil phosphorus levels can be accomplished by reducing phosphorus applications. Few crops act as phosphorus sinks, drawing out large amounts of soil phosphorus. However, as shown in this study, significantly reducing soil phosphorus levels is difficult to achieve without causing major changes in farm income and impacting off-farm sectors.

This study estimated that up to 90,000 tons of nutrient rich poultry litter would have to be relocated under PLIMIT on dairy and dairy/poultry farms. This is a conservative estimate because other non-dairy farms would be similarly under the same policy. The impact on the county market was not measured in this study, but would be of major concern to areas similar to Rockingham County. Agriculture in general and poultry in particular are keys to the county's economy. This study estimated the direct change in farm income but did not attempt to measure the economic impact to all county sectors. With a highly developed infrastructure in breeding, hatchery, feed milling, and processing facilities, the poultry industry and the community have a large investment. The enactment of any policy that goes to the extent of PLIMIT can potentially cause very detrimental results to the county economy. However, another view is that the industry may avert more restrictive policies or production constraints in the future by taking a proactive stance on confronting current soil phosphorus levels. But in an industry as competitive as poultry, there is little economic incentive for one firm to voluntarily pursue policies that may make them less competitive in the marketplace.

6.3 Additional Research Needs

There is need for additional research on nutrient management issues in Rockingham County. Excess nutrient applications are occurring on the 60 and 100-cow dairy farms on hay and pasture as well as on the small dairy/poultry farms. There is need to know why farmers who are applying nutrients at less than recommend rates on important crops such as corn silage while over-applying to such an extent on grass hay and pasture. Further information is also needed on the disposal practices of small dairy/poultry farms. These farms over apply nutrients and are the most financially vulnerable to any change in their production cost structure.

Another key area in need of research is to determine what would be required to develop demand for litter in agricultural areas outside of Rockingham County. Research indicates that economically viable alternative uses for poultry litter exist but there is currently small demand. But there must be major reasons preventing wider use of litter in many regions of the state. This may be the most important part of the equation because if market based demand for litter can be established, many of the other problems arising from excess nutrient applications will be substantially reduced.

There are other water quality research issues that need to be addressed. EPIC estimates nutrient losses at the field edge and below the root zone. While these estimates represent potential loadings, there is need for research to directly relate fields losses to actual loadings of surface and ground water sources. There is also a need for research on phosphorus. One of the biggest potential problems in Rockingham County is the growing soil phosphorus levels. Research is needed to determine if high soil phosphorus can percolate into water supplies and at what levels percolation can occur. There is also a need to develop greater knowledge of the potential impact to soils and crops from high phosphorus levels. Some of these topics can be addressed with crop/soil models but there is a distinct need for through field research.

These research needs are important to all of Rockingham County. The county's economy is animal based and has an established infrastructure to maintain that relationship well into the future. Water quality concerns will likely increase if growth of the poultry industry continues along with the presence of other large dairy and cattle industries.

Concern over the potential impact of nutrient management will certainly take greater precedence if there is a greater incidence of nitrate or fecal coliform contamination of private and public water systems. This may not materialize, but the chances become much greater as manure nutrient production continues to increase, and alternative disposal methods and locations are not pursued.

There is also a need for longer term projections of potential nutrient losses. The results of this study are for a five-year period and may understate potential reductions in nutrient losses under the various policies. Lower manure applications can have longer term effects on nutrient losses because of a reduced buildup of organic nitrogen and phosphorus, limiting potential losses beyond the five-year study period. There is also a potential understatement of potential nutrient losses under current nutrient applications. The buildup of organic nitrogen and phosphorus in the soil can cause larger nutrient losses beyond the five-year study period.

6.4 Research Caveats

The results of this study depend on the assumptions for characterizing the representative farms. The specific parameters of the representative farms are specified by a panel of farmers whose own farming operations are of the same herd size. The representative farm validation rests on the agreement among the farmer panel members. It is assumed that each county farm fits one of three specific herd sizes. The estimated 83 poultry dairy/farms are assumed to be distributed in the same proportions as the dairy farms. The poultry operations are proportional to reported turkey and broiler sales as reported by the 1992 Census of Agriculture.

The EPIC simulations estimate nutrient losses and crop yields from parameters defined by the farmer panel. The EPIC simulation results are estimates of nutrient losses at the edge of the field and below the root zone and are not actual loadings to surface and ground water. EPIC produces per acre estimates that are assumed to represent all field acres. EPIC's simulation relations are calibrated from field research results but much additional research is needed to provide a linkage between edge of field and below root zone nutrient losses and nutrient loadings to ground and surface water.

Recent programming changes in FLIPSIM allow the financial simulations to reflect weather variability by inputting EPIC generated crop yields. Inflation and future changes in prices and expense are drawn from FAPRI estimates. The FLIPSIM results rest on the defined parameters and assumptions of the representative farms.

Farm level results are summed across representative farms to estimate county wide impacts, based on the assumption that all county farms fit one of the representative farms. These assumptions are not totally valid. The study acknowledges that many farms have significantly different characteristics but that the aggregation of representative farms provides a valuable insight into the parameters of interest. The results of this study are not assumed to be 100 percent accurate, but are believed to be reasonable representations of actual county wide values.

6.5 Conclusions

The results of this study provide an environmental and a farm level financial view of the issues facing policymakers in determining manure management policies to protect water quality in Virginia. The policies examined in this study are 1) the incorporation of all manure within two days (INCORP), 2) limiting nitrogen applications to agronomic applications (NLIMIT), and 3) limiting phosphorus applications to crop removals (PLIMIT).

This study found that dairy and dairy/poultry farms in Rockingham County are relying on dairy and poultry manure based crop nutrient programs. The highest nutrient applications take place on hay and pasture on 60 and 100-cow dairy and dairy/poultry farms, and corn silage on the 60-cow dairy/poultry farm. The smallest dairy/poultry farm applies the highest amount of excess nutrients and has the highest nutrient losses. Dairy farms can achieve higher economic returns by adding poultry operations.

The NLIMIT policy reduces nitrogen losses with a small increase in farm income. PLIMIT reduces both nitrogen and phosphorus losses by more than 34 percent overall. Income is reduced under PLIMIT, but not to the extent that farm viability is reduced. The highest per acre reductions are achieved on the smallest farms which have the largest per acre nutrient losses. Financial returns indicate dairy farms can achieve higher economic returns by adding poultry operations under PLIMIT.

NLIMIT makes nearly 12,000 tons of litter available for use elsewhere. PLIMIT eliminates the use of nearly 90,000 tons of poultry litter that will have to transferred off the farm on which it is produced. Disposal cost of $10 per ton results in less cash available for family living expenses on dairy/poultry farms than that of corresponding size dairy farms. At higher disposal costs, the impact on the 60-cow farm is greater than that of the 100 and 150-cow dairy/poultry farms. The net farm cash income for all county dairy and dairy/poultry farms is lowered by $816,600 under PLIMIT and assuming no litter disposal costs. County net farm cash income declines by $2,389,200 at litter disposal costs of $40 per ton.

The extra poultry litter released under NLIMIT and PLIMIT can potentially overwhelm the local litter acquisition and disposal sector. The 90,000 additional tons under PLIMIT is three times the amount currently being exported from the county. There will likely have to be organized efforts to reduce the potential impact on the county poultry sector.

The problem of what to do with poultry litter is a concern of the entire county. With continued growth of the poultry sector and presence of large dairy and beef cattle sectors, the management of manure will become a more acute issue. Water quality may not be of major concern to the county at this time, but this can change very quickly if manure nutrients contaminate county drinking water supplies. Rockingham County's agricultural sector currently enjoys economic prosperity that is benefiting the county's economy. However, the future stability of the prosperity will depend greatly on how the county handles the potential environmental problems presented by the poultry litter.

References

Addiscott, T. M., A. P. Whitmore, and D. J. Powlson. *Farming, Fertilizers, and the Nitrate Problem.* University of Arizona Press, Tucson, AR. 1991.

Allen, G., A. Lovell, B. Schwart, R. Lacewell, J. Schmucker, D. Leatham, and J. Richardson. "Economic and Financial Feasibility of Dairy Waste Management: Central Texas Representative Dairies." Department of Agricultural Economics, Texas Agricultural Extension Service, Texas A&M University, College Station, Texas. 1992.

Amdur, M.O., J. Doull, and C.D. Klaassen (eds.). *Casarett and Doull's Toxicology.* Pergamon Press. Fourth Edition. 1991.

Archer, M.C., S.R. Tannenbaum, T-Y Fan, and M. Weisman. "Reaction of Nitrite With Ascorbate and Its Relation to Nitrosamine Formation." *Journal of the National Cancer Institute. 54(1975):1202-1205.*

Babcock, B.A. The Effects of Uncertainty on Optimal Nitrogen Applications. *Review of Agricultural Economics.* 14(1992):271-280.

Bacon. S. C., L. E. Lanyon, and R. M. Schlauder, Jr. "Plant Nutrient Flow in the Managed Pathways of an Intensive Dairy Farm." *Agronomy Journal.* 82(1990):755-761

Baker, J. L. and J. M. Laflen. "Effect of Crop Residue and Fertilizer Management on Soluble Nutrient Runoff Losses." *Transactions of the ASAE.* 25(1982):344-348

Barker, Randolf, and Bernard Stanton. "Estimation and Aggregation of Firm Supply Functions." *Journal of Farm Economics.* 47-3(1965):701-712.

Beegle, Douglas B., and Les E. Lanyon. "Nutrient Management in Pennsylvania." *Journal of Soil and Water Conservation.* Special Supplement to March-April Issue. 1994:84-87.

Benson, V.W., K.N. Potter, H.C. Bogusch, D. Goss, and J.R. Williams. "Nitrogen Leaching Sensitivity to Evapotranspiration and Soil Water Storage Estimators in EPIC." *Journal of Soil and Water Conservation.* 47-4(1992):334-337.

Berentsen, P.B.M., and G.W.J. Giesen. "Economic and Environmental Consequences of Different Government Policies to Reduce N Losses on Dairy Farms." *Netherlands Journal of Agricultural Science.* 42-1(1994):11-19.

Berentsen, P.B.M., G.W.J. Giesen, and S.C. Verduyn. "Manure Legislation Effects on Income and on N, P, and K Losses in Dairy Farming." *Livestock Production Science.* 31(1992):43-56.

Better Crops With Plant Food. "Soil Test Summaries: Phosphorus, Potassium, and pH." Potash and Phosphate Institute. Atlanta, Georgia. 1(1990):16-18.

Bitzer, C.C., and J.T. Sims. Estimating the Availability of Nitrogen in Poultry Manure Through Laboratory and Field Studies. *Journal of Environmental Quality.* 17(1988):47-54.

Boggess, William G., John Holt, and Robert P. Smithwick. "The Economic Impact of the Dairy Rule on Dairies in the Lake Okeechobee Drainage Basin." Food and Resource Economics Department, University of Florida, Gainsville, Florida. SP # 91-39. Nov. 1991.

Bosch, Darrell J. and Krishna B. Napit. "The Economic Potential for More Effective Poultry Litter Use in Virginia." Department of Agricultural Economics, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. SP-91-11. June 1991.

Bosch, Darrell J., James W. Pease, Sandra S. Batie, and Vernon O. Shanholtz. *Crop Selection, Tillage Practices, and Chemical and Nutrient Applications in Two Regions of the Chesapeake Bay Watershed.* Virginia Water Resources Research Center, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. Bulletin 176. (1992).

Bowman, Greg. "Swapping Manure - An Idea That's Spreading." *The New Farm.* 14-1(1992):21-29.

Brady, N.C. *The Nature and Property of Soils*. MacMillan Publishing Co.: New York. 1974.

Bryant, K.J., V.W. Benson, J.R. Kiniry, J.R. Williams, and R.D. Lacewell. "Simulating Corn Yield Response to Irrigation Timings: Validation of the EPIC Model." Journal of Production Agriculture. 5-2(1992):237-242.

Cabelguenne, M. C.A. Jones, J.R. Marty, P.T. Dyke, and J.R. Williams. "Calibration and Validation of EPIC for Crop Rotations in Southern France." *Agricultural Systems.* 33(1990):153-171.

Catus, Brian, Thomas S. Colvin, Carl E. Anderson, J.R. Williams. "An Evaluation of EPIC Using Iowa and Ohio Data." Presented at the 1989 American Society of Agricultural Engineers, Quebec, PQ, Canada. 1989.

Census of Agriculture, 1992. Bureau of Census, United States Department of Commerce, Washington, D.C. 1993.

Chesapeake Bay Citizen Report. "Blueprint for the Future - Governors, Mayor, EPA Endorse New Bay Pact." Winter edition, Page 1. 1988.

Clark, E. H., J. A. Haverkamp, and W. Chapman. "Eroding Soils: The Off-Farm Impacts." The Conservation Foundation, Washington, D.C. 1985.

Collins, E.R.,Jr., J.D. Jordon, and T.A. Dillaha. "Nutrient Values of Dairy Manure and Poultry Litter as Affected by Storage and Handling." In: *Animal Waste and the Land-Water Interface.* K. Steele, ed. pp. 343-353. 1995.

Council on Environmental Quality. "Environmental Quality - 1979." The Tenth Annual Report, U.S. Government Printing Office, Washington, D.C. December 1979.

Crowder, B.M., D.J. Epp, H.B. Pionke, C.E. Young, J.G. Beierlein, and E.J. Partenheimer. *The Effects on Farm Income of Constraining Soil and Plant Nutrient Losses: An Application of the CREAMS Simulation Model.* Bulletin 850. University Park: The Pennsylvania State University. 1984.

Crowder, B.M, and C.E. Young. *Modeling Agricultural Nonpoint Source Pollution for Economic Evaluation of the Conestoga Headwaters RCWP Project.* ERS Staff Report No. AGES850614, Natural Resource Economic Division, Economic Research Service, U.S. Department of Agriculture, Washington, D.C. 1985.

Daniel, T. C., A. N. Sharpley and T. J. Logan. "Research Needs." *National Livestock, Poultry, and Aquaculture Waste Management.* Proceeding of the National Workshop. American Society of Agricultural Engineers, St. Joseph, Michigan. July 29-31, 1991. pp. 155-160.

Darling, W. Arthur. "Status of Florida Regulations of Dairy Farm Waste Management." *National Livestock, Poultry, and Aquaculture Waste Management*. Proceeding of the National Workshop. American Society of Agricultural Engineers, St. Joseph, Michigan. July 29-31, 1991. pp. 67-70.

Day, Richard H. "On Aggregating Linear Programming Models of Production." *Journal of Farm Economics.* 45-4(1963):797-813.

Diebel, Penelope L. *An Economic Analysis of Low-Input Agriculture as a Groundwater Protection Strategy*. Ph.D. Dissertation. Department of Agricultural Economics, Virginia Polytechnic Institute and State University, Blacksburg, VA. 1990.

Donohue, S.J., T.W. Simpson, J.C. Baker, M.M. Monett, and G.W. Hawkins. Development and Implementation of the Virginia Agronomic Land Use Evaluation System (VALUES). *Communications in Soil Science and Plant Analysis*. 25(1994):1108-1108.

Duda, A.M. and D.S. Finan. "Influence of Livestock on Nonpoint Source Nutrient Levels of Streams." *Transactions of American Society of Agricultural Engineers.* 26(1983):1710-1716.

Edwards, D.R., V.W. Benson, J.R. Williams, T.C. Daniel, J. Lemunyon, and R.G. Gilbert. "Use of the EPIC MODEL to Predict Runoff Transport of Surface-Applied Animal Manure Constituents." Presentation: American Society of Agricultural Engineers International Summer Meeting, Spokane, Washington. 1993.

Foth, Henry D. *Fundamentals of Soil Science.* New York: John Wiley and Sons, Inc. 1978.

Fox, R. H. and W. P. Piekielek. "Response of Corn to Nitrogen Fertilizer and the Prediction of Soil Nitrogen Availability with Chemical Tests in Pennsylvania." Pennsylvania Agricultural Experiment Station, University Park, PA. Bulletin 843(1983).

Fraser, P. and C. Chilvers. "Health Aspects of Nitrates in Drinking Water." *Science of the Total Environment.* 18(1981):103-116.

Frink, C. R. 1969. "Water Pollution Potential Estimated from Farm Nutrient Budgets." *Agronomy Journal.* 51(1969):550.

Frye, Jack E. "Review Comments Regarding the Shenandoah Valley Coil and Water Conservation Districts Position Paper Opposing Extension of CZARA into the Shenandoah River Basin." Department of Conservation and Recreation, Division of Soil and Waters, Commonwealth of Virginia. 1994.

Fultz, John C., John G. Lee, and Marshall A. Martin. "Farm-Level Economic and Environmental Impacts of Eastern Corn Belt Cropping Systems." *Journal of Production Agriculture.* 6-2(1993):290-296.

Garsow, James D., Larry J. Connor, and Sherrill B. Nott. "Impact of Michigan Dairy Manure Handling Alternatives." Department of Agricultural Economics, Michigan State University, East Lansing, Michigan. Agricultural Economics Report No. 561. June 1992.

Gochenour, Julie. "Poultry Ordinance a Model for the Nation." *Virginia Farmer.* 1993(May):31.

Hagedorn, Charles. Professor, Department of Crop and Soil Environmental Sciences, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. Personal Communication with Author. 1995.

Hallberg, George R. "From Hoes to Herbicides: Agriculture and Groundwater Quality." *Journal of Soil and Water Conservation.* 41(1986):357-364.

Halstead, John M. *Managing Ground Water Contamination from Agricultural Nitrates.* Ph.D. Dissertation. Department of Agricultural Economics, Virginia Polytechnic Institute and State University, Blacksburg, VA. 1989.

Halstead, John M., Sandra S. Batie, and Randall A. Kramer. "Agricultural Practices and Environmental Attitudes of Rockingham County, Virginia Dairy Farmers: Results of a Survey." Department of Agricultural Economics, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. SP 88-1. January, 1988.

Hamlett, J.M., and D.J. Epp. "Water Quality Impacts of Conservation and Nutrient Management Practices in Pennsylvania." *Journal of Soil and Water Conservation.* 49-1(1994):59-66.

Hanway, J. J. and J. M. Laflen. "Plant Nutrient Losses from Tile Outlet Terraces." *Journal of Environmental Quality.* 7(1974):208-212.

Hazell, Peter, and Roger Norton. *Mathematical Programming For Economic Analysis in Agriculture. Macmillan. New York. 1986.*

Heatwole, C.D., P.L. Diebel, and J.M. Halstead. "Management and Policy Effects on Potential Groundwater Contamination from Dairy Waste." *Water Resources Bulletin.* 26(1990):25-34.

Heatwole, Conrad (ed.). *The International Symposium on Water Quality Modeling: Proceedings of the International Symposium.* American Society of Agricultural Engineers. 1995.

Heimlich, Ralph E. "Economics and Environmental Effects of Manure Handling Systems for Northeastern Dairy Farms." *Journal of the Northeastern Agricultural Economic Council.* 11(1982):45-56.

Henry, G.M., M.A. DeLorenzo, D.K. Bedde, H.H. Van Horn, C.B. Moss, and W.G. Boggess. "Determining Optimal Nutrient Management Strategies for Dairy Farms." *Journal of Dairy Science.* 78(1995):693-703.

Hinkle, K. R. and R. M. Sterett. 1976. *Rockingham County Groundwater.* Commonwealth of Virginia, State Water Control Board.

Jones, C.A., A.N. Sharpley, and J.R. Williams. "A Simplified Soil and Plant Phosphorus Model: III. Testing." *Soil Science Society of America Journal.* 48(1984):810-813.

Jones, C.A., C.V. Cole, and A.N. Sharpley. Simulation of Nitrogen and Phosphorus Fertility in the EPIC model. In: *Soil Erosion and Conservation.* S.A. El-Swaify, C. Moldenhauer, and A. Lo (eds.). Soil Water Conservation Society, Ankeny, IA, pp. 307-315. 1985.

Kamm, J.J., T. Dashman, H. Newmark, and W.J. Mergens. "Inhibition of Amine-Nitrite Hepatotoxity by Alpha-Tocopherol." *Toxicology and Applied Pharmacology. 41(1977):575-583.*

Keeney, D. R. "Transformation and Transport of Nitrogen." In F. W. Schaller and G. W. Bailey (eds.), *Agricultural Management and Water Quality*. Iowa State University Press: Ames, Iowa. 1983.

Kingery, W.L., C.W. Wood, D.P. Delaney, J.C. Williams, and G.L. Mullins. "Impact of long-term application of broiler litter on environmentally related soil properties. *Journal of Environmental Quality.* 22(1993):

Knisel, W.G. *CREAMS, A Field Scale Model for Chemicals, Runoff, and Erosion from Agricultural Management Systems*. USDA Conservation Research Service Report No. 26. (1980).

Kohl, David M. *Weighing the Variables: A Guide to Ag Credit Management.* American Bankers Association. Washington, D.C. 1992.

Kohl, David M. Professor, Department of Agricultural and Applied Economics, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. Personal Communication with Author. 1995.

Konikow, Leonard F., and John D. Bredehoeft. "Ground-Water Models Cannot be Validated." *Advances in Water Resources.* 15(1992):75-83.

Lanyon, Les E. "Implications of Dairy Herd Size for Farm Material Transport, Plant Nutrient Management, and Water Quality." *Journal of Dairy Science.* 75(1992):334-344

Lanyon, Les. "Nutrient Management Legislation Testimony." Testimony presented to the Senate Agriculture and Rural Affairs Committee Hearing. Bloomsburg, PA. Feb 12, 1992.

Lanyon, L.E. and D.B. Beegle. "The Role of On-Farm Nutrient Balance Assessments in an Integrated Approach to Nutrient Management." *Journal of Soil and Water Conservation.* 44-2(1989):164-168.

Law, A.M. and W.D. Kelton. *Simulation Modelling and Analysis.* New York: McGraw-Hill Book Company. (1990).

Leatham, David J., John F. Schmuker, Ronald D. Lacewell, Robert B. Schwart, Ashley L. Lovell, and Greg Allen. "Impact of Texas Water Quality Laws on Dairy Income Nutrient Management, and Water Quality." *Journal of Dairy Science.* 75-10(1992):2846-2856.

Leonard, R.A., W.G. Knisel, and D.A. Still. "GLEAMS: Groundwater Loading Effects of Agricultural Management Systems." *Transactions of the ASAE.* 30(1987):1403-1418.

Little, Charles E. "Rural Clean Water: The Okeechobee Story." *Journal of Soil and Water Conservation.* 43-5(1988):386-390.

Little, Charles E. "Annie-Fanny-Mike and the Dunsmore Proposition." *Journal of Soil and Water Conservation.* 44-1(1989a):16-19.

Little, Charles E. "The Economy of Rain and the Tillamook Imperative." *Journal of Soil and Water Conservation.* 44-3(1989b):199-202.

Logan, T. J., R. Lai, and W. A. Dick. "Tillage Systems and Soil Properties in North America." *Soil Tillage Research.* 20(1991):241-270.

Maiga, Alpha S. *An Economic Analysis of Nitrogen Fertilization Regimes in Virginia.* Ph.D. Dissertation. Department of Agricultural Economics, Virginia Polytechnic Institute and State University, Blacksburg, VA. 1992.

Manale, Andrew P. "European Community Programs To Control Nitrate Emissions From Agriculture." *International Environmental Reporter.* The Bureau of National Affairs, Inc. Washington, D.C. June 19, 1991.

McCollum, R. E. "Buildup and Decline of Soil Phosphorus: 30-Year Trends on a Typic Umprabuult." *Agronomy Journal.* 83(1991):77-85.

McGuire, Richard D. A New Model to Reach Water Quality Goals. *Choices.* The American Agricultural Economics Association. Second Quarter(1994):20-21,24-25.

Meng, Andrew A. III, John F. Harsh, and Thomas K. Kull. *Virginia Ground-Water Resources.* U.S. Geological Survey Water - Supply Paper 2275. 1985.

Mesinger, J.J., W.L. Hargrove, R.L. Mikkelsen, J.R. Williams, and V.W. Benson. "Effects of Cover Crops on Groundwater Quality." *In:* W.L. Hargrove (ed.). *Cover Crops for Clean Water.* Soil Water Conservation Society, Ankeny, IA. 1991:57-68.

MidWest Plan Service. *Livestock Waste Facilities Handbook.* Iowa State University, Ames, Iowa. 1985.

Miller, Sheila. Executive Assistant to State Senator Edward Helfrick. Harrisburg, Pennsylvania. Conversation with the Author. 7/92 and 10/92

Miranowski, J.A. and K.H. Reichelderfer. "Risk Management Research on the Agricultural-Natural Resource Interface: Is Policy Relevant?" In *Risk and Natural Resources: Proceedings of a Regional Workshop*, S.S. Batie and R.A. Kramer, ed. SNREC Publication No. 24. 1987.

Moore, P.A., T.C. Daniel, A. N. Sharpley, and C.W. Wood. "Poultry Manure Management: Environmentally Sound Options." *Journal of Soil and Water Conservation.* 50-3(1995):321-327.

Motschall, R. M. and T. C. Daniel. " A Soil Sampling Method to Identify Critical Manure Management Areas." *Transactions of the ASAE.* 25-6(1982):1641-1645.

Mueller, D., R. Wendt, and T. Daniel. "Phosphorus Losses as Affected by Tillage and Manure Applications." *Soil Science Society of America Journal.* 48(1984):901-905.

New York Times. "Huge Spill of Hog Waste Fuels an Old Debate in North Carolina." Volume CXLIV, Number 50103, Sunday, June 25, 1995. Page A21.

Norris, Patricia E. *A Case Study of Investment in Agricultural Sustainability: Adoption and Policy Issues for Nitrogen Pollution Control in the Chesapeake Bay Drainage.* Ph.D. Dissertation. Department of Agricultural Economics, Virginia Polytechnic Institute and State University, Blacksburg, VA. 1988.

North East Wisconsin Waters for Tomorrow, Inc. (N.E.W.). "Cost Effective Implementation of Water Resources Objectives in the Fox-Wolf Basin." Executive Summary for the Wisconsin Department of Natural Resources. July 6, 1993.

Nutman, P. S. "Symbiotic Nitrogen Fixation." In W.V. Bartholomew and F.E. Clark (eds.), *Soil Nitrogen*. Agronomy Monograph No.10, American Society of Agronomy: Madison, WI. 1965.

Nutrient Control in the Chesapeake Bay. Scientific and Technical Advisory Committee, Chesapeake Bay Program. January 1986.

O'Hare. M., D. Curry, S. Atkinson, S. Lee, and L. Canter. *Contamination of Ground Water in the Contiguous United States from Usage of Agricultural Chemicals.* Environmental and Ground Water Institute. Norman, Oklahoma. 1984.

Oloya, T. O. and T. J. Logan. "Phosphate Desorption From Soils and Sediments With Varying Levels of Extractible Phosphate." *Journal of Environmental Quality.* 9(1980):526-531.

Oreskes, Naomi, Kristin Shrader-Frenchette, and Kenneth Belitz. "Verification, Validation, and Confirmation of Numerical Models in the Earth Sciences." *Science.* 216(Feb. 4,1994):641-646.

Padgitt, Steve. *Farmers' Views on Groundwater Quality: Concerns, Practices, and Policy Preferences.* Staff Report of Office of Technology Assessment. Feb. 17, 1989

Parsons, Robert L., James W. Pease, and David C. Martens. "Simulating Corn Yields over 16 Years on Three Soils Under Inorganic Fertilizer and Hog Manure Fertility Regimes." *Communications in Soil Science and Plant Analysis.* 26:7-8(1995):1133-1150.

Parsons, Robert L., James W. Pease, and Darrell J. Bosch. "Simulating Nitrogen Losses from Agricultural Land: Implications for Water Quality and Protection Policy." *Water Resources Bulletin.* 31-6(1995).

Pease, James, and Darrell Bosch. Relationships Among Water Quality Options, Fertilization Practices, and Cropland Potential to Pollute in Two Regions in Virginia. *Journal of Soil and Water Conservation.*49-5(1994):477-483.

Perkinson, Russ. "Evolution of Nutrient Management in the Chesapeake Bay Region." *Journal of Soil and Water Conservation.* 49-2(Supplement)(1994):88-89.

Putman, J., J. Williams, and D. Sawyer. "Using the Erosion-Productivity Impact Calculator to estimate the impact of soil erosion for the 1985 RCA Appraisal." Journal of Soil and Water Conservation. 43-4(1988):321-326.

Renard K.G. and M.J. Mausbach. "Tools for Conservation." In W.E. Larson, G.R. Foster, R.R. Allmaras, and C.M. Smith (eds.) *Soil Erosion and Productivity Research Issues.* Proceedings Workshop USDA and University of Minnesota, Bloomington, Minnesota. March 13-15, 1989. University of Minnesota, St. Paul, Minnesota. 1990. pp.55-64.

Richardson, James W. Professor, Department of Agricultural Economics, Texas A&M University, College Station, Texas. Personal Communication with Author. 1994-95.

Richardson, James W. and Clair J. Nixon. *Description of FLIPSIM V: A General Firm Level Policy Simulation Model.* Agricultural and Food Policy Center, Department of Agricultural Economics, Texas Agricultural Experiment Station, Texas A & M University, College Station, Texas. B-1528. July 1986.

Richardson, James W., Peter T. Zimmel, David P. Anderson, Chris A. Moehring, and Monico A Moreno. "Technical Description of FLIP: FLIPSIM Operation Environment." Agricultural and Food Policy Center, Department of Agricultural Economics, Texas Agricultural Experiment Station, Texas A & M University, College Station, Texas. AFPC Policy Research Report 93-13. Version 1.00.

Richardson, James. W., Joe L. Outlaw, David P. Anderson, Allan W. Gray, Peter T. Zimmel, John W. Miller, Edward G. Smith, Ronald D. Knutson. "Implications of the 1990 Farm Bill and FAPRI 1993 Baseline on Representative Farms." Agriculture and Food Policy Center, Department of Agricultural Economics, Texas A&M University, College Station, Texas. AFPC Working Paper 94-1. 1994.

Ritter, W.E., and A.E.M. Chirnside. "Ground-Water Quality in Selected Areas of Ken and Sussex counties, Delaware." Delaware Agriculture Experiment Station. Projection Completion Report. 1982.

Roanoke Times and World News. "Montgomery Spill Kills Thousands of Fish." Volume 30, Number 262, September 17, 1991. Page B2.

Rockingham County Tax Assessment Office. Rockingham County Courthouse, Harrisonburg, Virginia. Personal Communication with Author. 1994.

Rockingham and Agusta County Farm Bureau, Harrisburg and Staunton, Virginia. Personal Communication with Author.

Roller, Harold W. " Nutrient Management Plans - Practical Considerations." Proceedings: 1994 National Poultry Waste Management Symposium. National Poultry Waste Management Symposium Committee. 1994. Pages 74-80.

Roller, Harold W. Rockingham County Extension Specialist, Rockingham County, Harrisonburg, Virginia. Personal Communication with Author. 1995.

Romkens, J. M. and D. W. Nelson. "Phosphorus Relationships in Runoff from Fertilized Soils." *Journal of Environmental Quality.* 3(1974):10-13.

Schuurkes, J.A.A.R., M.M.J. Maenen, and J.G.M. Roelofs. Chemical Characteristics of Precipitation in NH_3- Affected Areas. Atmospheric Environment. 22-8(1988):1689-1698.

Sharpley, A. N. Soil Scientist, USDA-Agricultural Research Service, Water Quality and Watershed Research Laboratory, Durant, Oklahoma. Personal Communication with Author. 1994.

Sharpley, A. N., L R. Ahuja, and R. G. Menzel. "The Release of Soil Phosphorus to Runoff in Relation to the Kinetics of Desorption." *Journal of Environmental Quality.* 10(1981):386-389.

Sharpley, A.N. and J.R. Williams (eds.). *EPIC: Erosion Productivity Impact Calculator.* Volume I. Model Documentation. U.S. Department of Agriculture. Technical Bulletin No. 1768. 1990.

Shenandoah Valley Soil and Water Conservation District. "Position Paper: In Opposition - Extension of Coastal Zone Management Act Reauthorization Amendments of 1990 into the Shenandoah River. 1994.

Shiflett, James. Nutrient Management Specialist, Virginia Department of Environmental Quality, Rockingham County, Virginia. Personal Communication with Author. 1995.

Shortle, James S., and James W. Dunn. "The Relative Efficiency of Agricultural Source Water Pollution Control Policies". *American Journal of Agricultural Economics* 68-3(1986):668-677.

Smith, S.J., R.G. Menzel, E.D. Rhoads, Jr., J.R. Williams, and H.V. Eck. "Nutrient and Sediment Discharge from Southern Plains Grasslands." Journal of Range Management. 36(1983):435-439.

Smith, S.J., A.N. Sharpley, and A.J. Nicks, 1990. "Evaluation of EPIC Nutrient Projections Using Soil Profiles for Virgin and Cultivated Lands of the Same Soil Series." In: *EPIC - Erosion Productivity Impact Calculator: 1. Model Documentation.* A.N. Sharpley and J.R. Williams (eds.). U.S. Department of Agriculture, Agricultural Research Service, Temple, TX, Technical Bulletin No. 1768, pp. 217-219. 1990.

Starner, David E. *Field and Laboratory Characterization of Soil Desorption Properties and Comparison of Plant Available Water for Two Virginia Soils.* M.S. Thesis, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. 1985.

State of Maine. Public Law Chapter 838, S.P. 922 - L.D. 2369. Section 20. 38 MRSA §417-A. Manure Spreading. 1992.

State of Washington. "National Pollutant Discharge Elimination System and State waste Discharge General Permit." Department of Ecology, Olympia, Washington. July 10, 1992.

Steiner, J.L., J.R. Williams, and O.R. Jones. "Evaluation of the Simulation Model Using a Dryland Wheat-Sorghum-Fallow Crop Rotation." *Agronomy Journal.* 9(1987):732-738.

Systems Approach to Regional Income and Sustainable Resource Assistance (SARSA). *An Introduction to Geographic Information Systems for Resource Management.* Clark University. November, 1990.

Thomas, Art, and Richard Boisvert. Bioeconomics of Regulating Nitrates in Groundwater: Taxes, Quantity Restrictions, and Pollution Permits. Working Paper, Department of Agricultural, Resource and Managerial Economics, Cornell University. Ithaca, New York. WP 94-07. July 1994.

Thomas, Everett D. "Don't Fertilize Grass with K if it's For Dry Cows." *Hoard's Dairyman.* 38-10(1993):439.

Tietenberg, Tom. *Environmental and Natural Resource Economics.* Harper-Collins Publishers, Inc. New York. 1992.

United States Department of Agriculture. *Soil Survey of Rockingham County, Virginia.* USDA Soil Conservation Service. 1982.

United States Environmental Protection Agency. *Chesapeake Bay: A Framework for Action.* USEPA, Chesapeake Bay Program, Annapolis, MD. 1983.

United States Environmental Protection Agency. *Nitrate-Nitrite Health Advisory.* Office of Water, USEPA. Washington, D.C. 1987.

Valiulus, D. "Nitrogen Transformations." *Agricultural Age.* May: 8-10. 1986.

Van Horn, H.H., R.A. Nordstedt, A.V. Bottcher, E.A. Hanlon, D.A. Graetz, and C.F. Chambliss. "Dairy Manure Management: Strategies for Recycling Nutrients to Recover Fertilizer and Avoid Environmental Pollution." Florida Cooperative Extension Service, University of Florida, Gainsville. Circular 1016. December 1991.

Van Horn, H.H., A.C. Wilkie, W.J. Powers, and R.A. Nordstedt. "Components of Dairy Manure Management Systems" *Journal of Dairy Science.* 77(1994):2008-2030

Virginia Agricultural Statistics. Department of Agriculture and Consumer Services, Commonwealth of Virginia, Richmond, VA. 1993.

Virginia Cooperative Extension. *Virginia Farm Management Crop and Livestock Budgets.* Virginia Polytechnic Institute and State University, Blacksburg, Virginia. 1995.

Virginia Department of Agriculture and Consumer Services. List of Rockingham County Grade A Dairy Producers. Supplied by the Virginia Department of Agriculture and Consumer Services. 1994.

Virginia Department of Conservation and Recreation. *Nutrient Management Handbook.* Commonwealth of Virginia, Division of Soil and Water Conservation, Richmond, Virginia. 2nd Edition. 1993.

Virginia Department of Environmental Quality. Virginia Tributary Strategy Status Report: September. Richmond, Virginia. 1993.

Virginia Groundwater Protection Steering Committee. *A Groundwater Protection Strategy for Virginia.* Richmond, Virginia: State Water Control Board. 1987.

Virginia's Potomac Basin Tributary Nutrient Reduction Strategy. Virginia Departments of Environmental Quality, Conservation and Recreation, and Virginia Chesapeake Bay Local Assistance Department. Richmond, Virginia. Draft-For Public Review and Comment. August, 1995.

Wall Street Journal. Treasury Bonds, Notes, and Bills. Volume 221, Number 1. Page C15, January 4, 1993.

Westphal, P., L. Lanyon, and E. Partenheimer. *Plant Nutrient Management Strategy Implications for Optimal Herd Size and Performance of a Simulated Dairy Farm.* Agricultural Systems. 31(1989):381-394.

Williams, Jimmy. Hydraulic Engineer/Model Developer. USDA/ARS. Temple, Texas. Numerous conversations with Author. 1994-95.

Williams, J.R. "Testing the modified universal soil loss equation." *In: Proceedings of the Workshop on Estimating Erosion and Sediment Yield on Rangelands.* Tucson, Arizona. USDA-ARS. Agricultural Reviews and Manuals. ARM-W-26. 1982:244-252.

Williams, J.R., P.T. Dyke, W.W. Fuchs, V.W. Benson, O.W. Rice, and E.D. Taylor. In Sharpley, A.N. and J.R. Williams (eds.), *EPIC - Erosion/Productivity Impact Calculator.* Volume II. User Manual. U.S. Department of Agriculture. Technical Bulletin No. 1768. 1990.

Williams, J.R., C.A. Jones, J.R. Kiniry, and D.A. Spanel, 1989. "The EPIC crop growth model." *Transactions of the ASAE.* 32(1989):497-511.

Williams, J.R. and D.E. Kissel. "Water percolation: An Indicator of Nitrogen Leaching Potential." In: *Managing Nitrogen for Groundwater Quality and Farm Profitability*. R.F. Follett (ed.). Soil Science Society of America, Madison, WI, pp. 59-83. 1991.

Williams, J.R., A.D. Nicks, and J.G. Arnold. "Simulator for Water Resources in Rural Basins." *Journal of Hydraulic Engineering of the ASAE.* 111(1985):970-986.

Williams, J.R. and K.G. Renard. "Assessment of Soil Erosion and Crop Productivity with Process Model (EPIC)." In Follett, R.F. and B.A. Steward. *Soil Erosion and Crop Productivity.* American Society of Agronomy, Madison, WI. 1985. pp. 68-103.

Wischmeier, W.H., and D.D. Smith. "Predicting Rainfall Erosion Losses: A Guide to Conservation Planning." USDA. Agriculture Handbook Number 537. 1978.

Wolfe, M.L., W.D. Batchelor, T.A. Dillaha, S. Mostaghimi, and C.D. Heatwole. "A Farm Scale Water Quality Planning System for Evaluating Best Management Practices." In: *The International Symposium on Water Quality Modeling: Proceedings of the International Symposium.* American Society of Agricultural Engineers. 1995. pp. 324-332.

Wossink, G.A.A. "Agro-Chemical Reduction Policies in the Netherlands." *Agro-Chemical Reduction Policies in the Netherlands.* 12-6(1995):4-7.

Wu, Jun Jie, D.J. Bernardo, H.P. Mapp, S. Galeta, M.L. Teague, K.B. Watkins, G.J. Sabbaugh, R.L. Elliot, and J.F. Stone. "An Evaluation of Nitrogen Runoff and Leaching Potential in the High Plains." Presented at the American Agricultural Economics Association. San Diego, CA. 1994.

Young, C. and B. Crowder. "Managing Nutrient Losses: Some Empirical Results on the Potential Water Quality Effects." *Northeastern Journal of Agricultural and Resource Economics.* 15-2(1986):130-136.

Young, C. Edwin and James S. Shortle. "Benefits and Costs of Agricultural Nonpoint-Source Pollution Controls: The Case of St. Albans Bay." *Journal of Soil and Water Conservation.* 44-1(1989):64-67.

Young, C. Edwin, Bradley M. Crowder, James S. Shortle, and Jeffrey R. Alwang. "Nutrient Management on Dairy Farms in Southeastern Pennsylvania." *Journal of Soil and Water Conservation.* 40-5(1985):443-445.

Zhu, Minkang. Unpublished Poultry Enterprise Budgets. Department of Agricultural and Applied Economics, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. 1995.

Appendix A:

Simulating Corn Yields Over 16 Years on Three Soils Under Inorganic Fertilizer and Hog Manure Fertility Regimes

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SIMULATING CORN YIELDS OVER 16 YEARS ON THREE SOILS UNDER INORGANIC FERTILIZER AND HOG MANURE FERTILITY REGIMES[1]

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ABSTRACT: Corn yields (*Zea mays L.*) on control treatments with inorganic fertilizer and on copper-enriched hog manure treatments with annual rates up to 168 mt/ha from a 16-year study were modelled with the Erosion Productivity Impact Calculator (EPIC) simulation model. The field research study was conducted on three diverse soils, on a Guernsey silt loam, a Bertie fine sandy loam, and a Starr-Dyke clay loam. Results indicated EPIC simulated manure and fertilizer treatments equally well. EPIC produced simulated yield means that were not different from measured yield means for all treatments ($p \leq 0.05$). Goodness of fit tests indicate simulated yields did not differ from measured yields for all simulation models except the Bertie manure treatment ($p \leq 0.05$). For control and manure treatments, simulated yields explained 78% and 89% of variation in measured yields for the Guernsey soil, 55% and 42% for the Bertie soil, and 76% and 70% for the Starr-Dyke soil. Overall, these are reasonable yields estimates, but site-specific soil and other model parameter respecification is critical. Yield modeling with heavy applications of animal manure or inorganic fertilizer is feasible and useful.

INTRODUCTION

Simulation models offer the opportunity to estimate crop yields and trace the movement of soil nutrients given varying crop species, weather conditions, and management practices. A basic issue that may limit greater acceptance of these models is whether they realistically simulate yields. The ability to reliably simulate crop yields on soils receiving heavy manure applications is needed in regions facing serious concerns over water quality and nutrient management issues.

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This study examines the reliability of the Erosion Productivity Impact Calculator (EPIC) simulation model to replicate corn grain yields under inorganic fertilizer and heavy hog manure applications.[2] The model was developed by a multi-disciplinary USDA research team to replicate yield distributions and nutrient cycling by simulating the intra-year and inter-year interactions of weather, hydrology, erosion, mineral nutrients, plant growth, pesticides, soil tillage and crop management practices (16). EPIC has been validated with varying crops in over 200 applications in Australia, Europe, and the United States (3,14). The model's nitrogen nutrient cycling and percolation estimates have been verified in various studies (7,8,12,15). The model has been used to accurately estimate nutrient/sediment losses under poultry litter applications (5). The objective of this study is to evaluate EPIC's reliability in simulating 16 years of measured corn yields under inorganic fertilizer and heavy hog manure applications on three different soil types in Virginia.[3]

MATERIALS AND METHODS

Measured Yields: This study draws upon results from the control and manure treatments of field experiments from 1978 to 1993 designed to evaluate the response of corn *(Zea mays L.)* to high applications of copper-enriched hog manure on diverse soils. The treatments were replicated four times in a randomized complete block design on each soil. These studies were conducted on a Guernsey silt loam (Ridge and Valley region), a Bertie fine sandy loam (Atlantic Coastal Plain region), and a Starr-Dyke clay loam (Piedmont region).

The control treatment at each location received only inorganic fertilizer applications at levels which assured that corn grain yields were not limited by nutrient deficiencies (Table 1). The manure treatment at each site received large applications of copper-enriched hog manure and inorganic commercial fertilizer. Manure applications for the 16 year period ranged from 44.8 to 168.0 mt/ha (Table 2).[4]

Effects of copper-enriched manure application on corn production on the three soils has been reported elsewhere (1,6,9,11). The study showed that corn grain and stalk yields were not decreased by the application of hog manure.

EPIC Simulations: The EPIC simulations for the two treatments on the three soils required detailed soil, management, and weather input data (13). Soil specifications for each site drew upon reported soil

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[2] EPIC (Erosion Productivity Impact Calculator) DOS Version 3090, July 23, 1993. USDA/ARS, Grassland, Soil, and Water Research Laboratory, Blackland Research Center, 808 East Blackland Road, Temple, TX 76502.

[3] All measured and simulated yields in this study are at the 15.5% moisture level.

[4] The Bertie fine sandy loam soil received manure applications for all 16 years, 1978-1993, however, soybeans were grown in 1978 and corn plantings were begun in 1979.

properties, Soil Conservation Service (SCS) data files incorporated into EPIC, various Virginia County Soil surveys, and the Virginia Agronomic Land Use Evaluation System (4). Type and date of all cropping management operations were entered. Actual weather data from 1978-1993 (daily high and low temperatures and rainfall) collected at the research sites were used for the simulations.

Model Calibration: Mineral nutrients are specified in the EPIC model as dry matter water-soluble nutrients. Organic nutrients are partitioned into nitrogen and phosphorus pools with nutrient release to plant-available nutrient forms modeled as a function of organic carbon, soil temperature, moisture levels, soil particle proportion, and other factors in the nitrogen and phosphorus cycles. Tables 1 and 2 specify inorganic and organic nutrient applications for the two treatments.

Key soil model input parameters such as field capacity, wilting point, soil depth, saturated conductivity, and sand, silt and clay content were obtained from SCS data files and county soil surveys. Site-specific runoff curves, erosion control practices, weathering codes, and slopes were set as in Wischmeier and Smith (1978). The cation exchange capacity, saturated conductivity, and sum of bases parameters were not adjusted due to the lack of site-specific measures.

The soil parameters for fertilizer treatment simulations required slight calibration after initial runs. For manure treatment simulations, it was recognized that regular manure application for an extended period of time would enhance soil tilth, increase water holding capacity, and increase water retention. These properties were modeled by increasing the field capacity (meters of water per meters of soil) and decreasing the bulk density for the manure treatments' top 0.2 meters of soil.

The initial simulations of the fluctuating high water table on the Bertie soil were found to produce dramatic effects on corn yields, probably due to the combination of lateral water flow, critical root aeration levels, plant aeration stress specification, and root depth. Setting the minimum water table depth to 0.5 meters minimized unexpected effects of the high water table on crop yields. The maximum depth was set to the reported level of 2.0 meters to model the deep soil water reserve.

Statistical Analysis: EPIC yields were evaluated by comparing yield scatterplots and statistical evaluations. First, scatterplots of simulated yields vs. measured yields for each treatment were examined visually. Second, the means and standard deviations of corresponding simulated and measured yields for each treatment were compared. The coefficients of variation (CV) were compared to assess specific treatment variation over years. Third, a paired comparison T-test determined if the differences between paired mean yields over years were significantly different from zero.

Finally, simulated yields were regressed on measured yields with the following Ordinary Least Squares (OLS) model: $Y_i = a + b*X_i$, where Y_i = measured yield in year *i*, a = intercept, b = the slope coefficient, and X_i = simulated yield in year *i*. The resulting coefficient of determination, or R^2, expresses the proportion of variation in measured yields explained by simulated yields.

Each simulation model's goodness of fit (the overall ability to replicate corresponding measured yields) was determined by performing a joint test on the regression intercept and slope estimates. If simulated yields perfectly replicate corresponding measured yields, a cross plot would place all the regression observations on a 45 degree ray originating at zero, i.e., an intercept of zero and a slope of one. Failure to reject the joint test indicates the simulated yields do not differ from measured yields. All significance tests were evaluated at the $p \leq 0.05$ level.

RESULTS AND DISCUSSION

Graphic Comparisons: The scatterplots do not indicate any distinct differences between the effectiveness of the site fertilizer and manure simulations, but there was some variation between sites. The Guernsey soil scatterplots indicated that simulated yields closely duplicate measured yields except for 1986 (Figures 1 and 2). The exceptionally low measured yields in 1986 are attributed to high temperatures and droughty conditions during pollination and stalk damage from a wind storm. These weather conditions could not be successfully modelled in the EPIC simulations.

The Bertie simulated yields were similar to observed yields for both treatments but were more variable than those for the Guernsey soil (Figures 3 and 4). Starr-Dyke simulated yields closely matched measured yields for both treatments (Figures 5 and 6). However, EPIC underestimated higher yields for both treatments. The EPIC simulations did not reflect the exceptionally low measured yields for both Starr-Dyke treatments in 1983 but estimated stalk weight less ear was within 5% of measured weight for the manure treatment and 10% for the fertilizer treatment. The low measured grain yields were attributed to droughty conditions and high temperatures that occurred just prior to pollination, which decreased grain yields but barely affected stalk yields.

The effects of certain weather conditions at critical times as in 1983 and 1986 illustrates EPIC's modeling limitations. Air temperatures and water availability are used in EPIC to determine plant growth and biomass. However, pollination is not directly simulated, so the model cannot replicate the combinations of high temperatures and droughty conditions at pollination. EPIC's day-step growth simulator also cannot model localized wind storm damage. The modeler can attempt to replicate these weather impacts with EPIC's stress parameter, which sets the period of the growing season when stress affects grain yields. This adjustment was unsuccessful in producing more realistic yield estimates for the Starr-Dyke soil in 1983 and for the Guernsey soil in 1986. Previous studies have identified similar problems involving weather factors not modeled by EPIC (3,10).

Descriptive Statistics: Measured manure treatment yields averaged 14.2%, 0.6%, and 10.9% above those of measured fertilizer treatments for the Guernsey, Bertie, and Starr-Dyke soils, respectively, while EPIC simulated manure treatment yields averaged 12.5%, 2.7%, and 4.2% above simulated inorganic fertilizer treatment yields. Except for the manure treatment on the Starr-Dyke soil, all mean simulated yields were greater than observed yields. However, simulated yields never exceed measured yields by more than 6.5%.

All mean simulated and measured yields on manure treatments except for the Bertie soil simulated yield were less variable than comparable fertilizer treatment yields. Yields of all simulated fertilizer treatments were less variable than corresponding observed fertilizer treatment yields. For manure treatment yields, the simulated Guernsey and Bertie treatments were more variable than corresponding measured yields.

If 1983 Starr-Dyke observations are excluded because of non-modeled factors, the variability of simulated yields remains constant while that of measured yields decreased for both treatments (Table 5). Simulated yields remain less variable than measured yields. Variability of simulated yields on the Guernsey soil changed little with the 1986 observations excluded. Measured yields are less variable than simulated yields for both treatments (Table 3).

Tests of Central Tendency: For each treatment on all three soils, T-tests indicate that the difference between corresponding simulated and measured mean yields were not significantly different from zero. The results were not affected by the deletion of Guernsey 1986 and Starr-Dyke 1983 observations.

Overall Predictive Ability: EPIC simulations for the Guernsey soil explained 35% of the variance in measured yields on the fertilizer treatment and 53% of the variation in measured yields on the manure treatment (Table 6). The goodness of fit test indicates simulated yields were identical to measured yields for both treatments ($p \leq 0.05$). Influence diagnostics as proposed by Belsley et al. (1980) were calculated to identify observations which may have disproportional leverage on parameter estimates. Results from the diagnostics and inspection of data (Figures 1 and 2 and Table 3) indicate that 1986 Guernsey observations were highly influential for the fertilizer and manure treatments. Dropping the 1986 Guernsey observations significantly raised the R^2 from 35% to 78% for the fertilizer treatment and from 53% to 89% for the manure treatment.

Regression results indicate that EPIC yields explain 55% of the variance in measured yields for the Bertie fertilizer treatment and only 42% of the variance of measured yields for the manure treatment. The goodness of fit test indicated simulated yields did not differ from measured yields for the fertilizer treatment, but manure treatment yields were dissimilar. Examination of influence diagnostics and visual examination of Figures 3 and 4 proved inconclusive. Overall, it can be concluded that EPIC dealt less successfully with the Bertie high water table.

The regressions for the Starr-Dyke treatments explain a considerable portion of variation in measured yields and imply simulation results provide a fairly accurate representation of measured yields. Simulated yields for the Starr-Dyke fertilizer and manure treatments explained 71% and 67%, respectively, of the variability of measured yields. The goodness of fit test indicated simulation models for both treatments were identical to measured yields ($p \leq 0.05$). Influence diagnostics and visual examination suggested removal of the 1987 and 1983 observations (Figures 5 and 6 and Table 5). The 1987 observation was not removed because the observation is a fairly reasonable simulation of an exceptional dry year. The 1983 observation was dropped because EPIC's inability to model pollination problems. Excluding the 1983 observations for the Starr-Dyke soil increased the R^2 for the fertilizer treatment regression from 71% to 76% and the R^2 for the manure treatment regression increased from 67% to 70%.

CONCLUSION

Results from this study indicate that EPIC provided relatively reliable simulated corn grain yields for 16 years of inorganic fertilizer and high manure treatments on Guernsey silt loam and Starr-Dyke clay loam soils. The simulation results from the Bertie fine sandy loam were not as encouraging because of difficulties in modeling the high water table. The 1983 Starr-Dyke and 1986 Guernsey observations indicate EPIC's limitations in modeling drought and heat stress at sensitive growth stages and the impact of factors not considered by the model, such as wind storms.

Overall, EPIC simulations produced estimates representing the central tendency of observed yields on Virginia soils and they successfully modeled heavy manure nitrogen and phosphorus applications well out of the range normally specified in the model. EPIC simulations can be a valuable tool in modeling yields of crops receiving animal manure.

The procedure used in this study is important for achieving reliable simulation results. Input from research surveys, soil survey data, and appraisal from soil scientists were used to specify key parameters. Thus, simulation modeling without site-specific expertise and corroborative data should be attempted only with great caution.

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References

1. Anderson, M.A., J.R. McKenna, D.C. Martens, S.J. Donohue, E.T. Kornegay, and M.D. Lindemann. 1991. Long-term effects of copper rich swine manure applications on continuous corn production. Communications in Soil Science and Plant Analysis. 22:993-1002

2. Belsley, D.A., E. Kuh, and R.E. Welsch. 1980. Regression diagnostics: identifying influential data and sources of collinearity. John Wiley, New York.

3. Bryant, K.J., V.W. Benson, J.R. Kiniry, J.R. Williams, and R.D. Lacewell. 1992. Simulating corn yield response to irrigation timings: validation of the EPIC model. Journal of Production Agriculture. 5(2):237-242.

4. Donohue, S.J., T.W. Simpson, J.C. Baker, M.M. Monett, and G.W. Hawkins. 1994. Development and implementation of the Virginia agronomic land use evaluation system (VALUES). Communications in Soil Science and Plant Analysis. 25:1108-1108.

5. Edwards, D.R., V.W. Benson, J.R. Williams, T.C. Daniel, J. Lemunyon, and R.G. Gilbert. 1993. Use of the EPIC model to predict runoff transport of surface-applied animal manure constituents. *Presentation:* American Society of Agricultural Engineers International Summer Meeting, Spokane, Washington.

6. Gettier, S.W., D.C. Martens, and E.T. Kornegay. 1988. Corn response to six annual Cu-enriched pig manure applications to three soils. Water, Air and Soil Pollution. 40:409-418.

7. Jones, C.A., A.N. Sharpley, and J.R. Williams. 1984. A simplified soil and plant phosphorus model: III. Testing. Soil Science Society of America Journal. 48:810-813.

8. Jones, C.A., C.V. Cole, and A.N. Sharpley. 1985. Simulation of nitrogen and phosphorus fertility in the EPIC model. pp. 307-315. *In:* S.A. El-Swaify, C. Moldenhauer, and A. Lo (eds.), Soil Erosion and Conservation. SWCS, Ankeny, IA.

9. Mullins, G.L., D.C. Martens, W.P. Miller, E.T. Kornegay. and D.L. Hallock. 1982. Copper availability, form, and mobility in soils from three annual copper-enriched hog manure applications. Journal of Environmental Quality. 11:316-320.

10. Musick, J.T., and D.A. Dusek, 1980. Irrigated corn yield response to water. Transactions of the ASAE. 23:92-98.

11. Payne, G.G., D.C. Martens, C. Winarko, and N.F. Perera. 1988. Form and availability of Cu and Zn following long-term $CuSO_4$ and $ZnSO_4$ applications. Journal of Environmental Quality. 17:707-711.

12. Smith, S.J., A.N. Sharpley, and A.J. Nicks, 1990. Evaluation of EPIC nutrient projections using soil profiles for virgin and cultivated lands of the same soil series. pp. 217-219. *In:* A.N. Sharpley and J.R. Williams (eds.). EPIC - Erosion/Productivity Impact Calculator: 1. Model Documentation. U.S. Department of Agriculture, Agricultural Research Service, Temple, TX. Technical Bulletin No. 1768.

13. Williams, J.R., P.T. Dyke, W.W. Fuchs, V.W. Benson, O.W. Rice, and E.D. Taylor, 1990. EPIC-Erosion Productivity Impact Calculator: 2. User Manual. U.S. Department of Agriculture, Agricultural Research Service, Temple, TX. Technical Bulletin Number 1768.

14. Williams, J.R., C.A. Jones, J.R. Kiniry, and D.A. Spanel, 1989. The EPIC crop growth model. Transactions of the ASAE. 32:497-511.

15. Williams, J.R. and D.E. Kissel, 1991. Water percolation: An indicator of nitrogen leaching potential. pp. 59-83. *In:* R.F. Follett (ed.), Managing Nitrogen for Groundwater Quality and Farm Profitability. Soil Science Society of America, Madison, WI.

16. Williams, J.R. and K.G. Renard, 1985. Assessment of soil erosion and crop productivity with process models (EPIC). pp. 67-103. *In:* R.F. Follett and B.A. Steward (eds.), Soil Erosion and Crop Productivity. American Society of Agronomy/Crop Science Society of America, Madison, WI.

17. Wischmeier, W. H., and D.D. Smith. 1978. Predicting rainfall erosion losses - a guide to conservation planning. U.S. Department of Agriculture. Agriculture Handbook No. 537.

TABLE 1. Inorganic nutrients applied for the inorganic fertilizer treatment.

	Guernsey sil		Bertie fsl[1]		Starr-Dyke cl	
	N	P	N	P	N	P
Year	----- kg/ha ----		---- kg/ha ----		---- kg/ha ----	
1978	196	20	-	-	196	49
1979	196	49	196	24	196	49
1980	196	24	224	24	224	49
1981	224	37	224	37	224	73
1982	224	37	224	37	224	73
1983	196	37	196	37	196	73
1984	252	24	252	24	252	24
1985	252	37	252	37	252	37
1986	196	37	196	37	196	37
1987	252	49	252	49	252	49
1988	196	49	196	49	196	49
1989	252	49	250	49	252	49
1990	252	20	254	20	252	39
1991	252	29	252	29	252	29
1992	252	29	252	29	252	29
1993	248	29	248	29	248	30

1. Soybeans were grown on the Bertie soil 1978. Corn was grown from 1979-1993.

TABLE 2. Total inorganic and organic nutrients applied from the hog manure applications.

	Manure[2]	Guernsey sil		Bertie fsl[1]		Starr-Dyke cl	
		N	P	N	P	N	P
Year	mt/ha	--- kg/ha ---		--- kg/ha ---		--- kg/ha ---	
1978	67.2	796	305	-	-	807	305
1979	67.2	639	294	818	331	747	299
1980	67.2	741	271	689	262	738	250
1981	134.4	1357	803	1271	648	1397	820
1982	134.4	1391	433	1679	362	1538	414
1983	168.0	1871	585	1722	492	1792	572
1984	168.0	1686	746	1817	839	1817	874
1985	84.0	793	544	848	449	810	397
1986	84.0	783	466	753	483	892	519
1987	67.2	776	366	776	366	776	366
1988	67.2	688	281	688	281	688	281
1989	56.0	567	343	567	343	567	307
1990	44.8	510	276	510	276	510	276
1991	44.8	474	295	474	295	474	295
1992	44.8	467	244	467	244	467	244
1993	44.8	493	178	493	178	493	178

1. Soybeans were grown on the Bertie soil in 1978. Corn was grown from 1979-1993.

2. Manure applications rates were very heavy in order to get a high copper buildup in the soil in a shorter period of time.

TABLE 3. Measured and simulated corn grain yields on Guernsey silt loam.[1]

	Fertilizer Treatment Yields		Manure Treatment Yields		Annual
	Measured	Simulation	Measured	Simulation	Rainfall
Year	---- kg/ha ----		---- kg/ha ----		cm/yr
1978	9998	7951	10601	10677	106.5
1979	9334	8401	10313	9183	118.5
1980	11241	9800	12469	11893	91.0
1981	8057	7693	8316	9048	91.2
1982	10662	9556	12379	10892	117.1
1983	6482	4443	6547	4559	115.5
1984	10302	11312	11939	12718	102.9
1985	10213	10901	10692	11978	97.3
1986	3105	11456	5241	12247	94.2
1987	3085	2772	4283	3492	101.3
1988	11810	10668	12569	11722	82.9
1989	11231	11836	12300	12979	119.1
1990	8067	8560	8805	9055	102.9
1991	5970	6378	8037	6814	85.7
1992	9344	9909	10992	11138	126.7
1993	5645	7757	8147	8379	102.2
Mean	8409.2	8712.1	9601.9	9798.3	103.4
St Dev	2712.8	2470.0	2569.0	2748.4	12.6
CV[2]	32.3	28.4	26.8	28.1	
T-Test[3]		p=0.63		p=0.71	
Without 1986					
Mean	8762.8	8529.1	9892.6	9635.0	104.1
St Dev	2418.5	2443.8	2384.9	2762.5	12.7
CV	27.6	28.7	24.1	28.7	
T-Test		p=0.46		p=0.32	

1. All yields measured at 15.5% moisture level.

2. CV = the coefficient of variation between years, (standard deviation/mean) * 100.

3. A paired comparison two tail T-Test was used to test the null hypothesis H_o: mean difference (reported yield$_i$ - simulated yield$_i$) = 0 vs. the alternative hypothesis H_a: mean difference (reported yield$_i$ - simulated yield$_i$) $\neq$ 0. The level of significance to reject H_o is $p \leq 0.05$.

TABLE 4. Measured and simulated corn grain yields on Bertie sandy loam.[1]

Year	Fertilizer Treatment Yields Measured	Fertilizer Treatment Yields Simulation	Manure Treatment Yields Measured	Manure Treatment Yields Simulation	Annual Rainfall
	---- kg/ha ----		---- kg/ha ----		cm/yr
1979	6359	10243	6859	11282	159.2
1980	4772	4169	5650	4664	87.2
1981	7837	6376	8845	6424	102.0
1982	13537	9538	11860	9526	137.5
1983	6354	7529	6283	7905	138.7
1984	8936	10814	8695	10972	120.6
1985	9844	11004	9524	12707	133.2
1986	7118	8910	6449	9258	96.4
1987	3933	5006	4403	4583	117.0
1988	8067	9909	8166	10141	102.7
1989	11760	11772	12200	11502	161.2
1990	9235	10003	9424	9265	102.9
1991	7747	7915	7358	8491	108.7
1992	10383	9787	10163	9482	131.6
1993	5005	3135	5689	3308	81.8
Mean	8059.2	8407.3	8104.5	8634.0	118.7
St Dev	2561.6	2555.1	2213.6	2681.3	23.6
CV[2]	31.8	30.4	27.3	31.1	
T-Test[3]		$p=0.49$		$p=0.36$	

[1] All yields measured at 15.5% moisture level.

[2] CV = the coefficient of variation between years, (standard deviation/mean) * 100.

[3] A paired comparison two tail T-Test was used to test the null hypothesis H_o: mean difference (reported $yield_i$ - simulated $yield_i$) = 0 vs. the alternative hypothesis H_a: mean difference (reported $yield_i$ - simulated $yield_i$) $\neq 0$. The level of significance to reject H_o is $p \leq 0.05$.

TABLE 5. Measured and simulated corn grain yields on Dyke-Starr clay loam.[1]

	Fertilizer Treatment Yields		Manure Treatment Yields		Annual
	Measured	Simulated	Measured	Simulated	Rainfall
Year	---- kg/ha ----		---- kg/ha ----		cm/yr
1978	9839	9629	10671	10141	114.4
1979	8845	8542	8556	8608	147.0
1980	6439	6881	7697	7072	79.2
1981	12619	9012	12719	9730	88.3
1982	9574	9358	9864	9530	111.2
1983	723	6077	1690	6424	127.9
1984	11321	10108	12419	10612	119.7
1985	7897	8302	9085	8579	121.2
1986	8416	9093	9165	9503	90.9
1987	1967	1564	3075	1953	128.4
1988	7817	8387	9644	8936	87.9
1989	11740	11039	13368	11340	125.2
1990	8087	9370	7398	9784	120.6
1991	7527	9111	8126	9427	90.0
1992	7877	8592	10313	8494	105.4
1993	2735	5769	3061	6252	110.3
Mean	7713.9	8177.1	8553.1	8524.0	110.5
St Dev	3274.9	2168.6	3318.1	2176.2	18.2
CV[2]	42.5	26.5	38.8	25.5	
T-Test[3]		p=0.35		p=0.96	
Without 1983					
Mean	8180.0	8317.2	9010.6	8664.0	109.3
St Dev	2822.1	2168.5	2897.3	2176.7	18.2
CV	34.5	26.1	32.2	25.1	
T-Test		p=0.72		p=0.43	

1. All yields measured at 15.5% moisture level.

2. CV = the coefficient of variation between years, (standard deviation/mean) * 100.

3. A paired comparison two tail T-Test was used to test the null hypothesis H_o: mean difference (reported yield$_i$ - simulated yield$_i$) = 0 vs. the alternative hypothesis H_a: mean difference (reported yield$_i$ - simulated yield$_i$) $\neq$ 0. The level of significance to reject H_o is $p \leq 0.05$.

TABLE 6. Regression-hypothesis test results (Measured Yield = a + b*EPIC Yield).

Model Results	Regression Variable	Parameter Estimate	Standard Error	Goodness of Fit[1]
Guernsey Fertilizer Treatment				
$R^2 = 0.35$	Intercept	44.51	34.30	$p = 0.32$
Prob > F = 0.0168	Beta	0.64	0.24	
Guernsey Fertilizer Treatment (w/o 1986)				
$R^2 = 0.78$	Intercept	20.56	18.04	$p = 0.49$
Prob > F = 0.0001	Beta	0.88	0.13	
Guernsey Manure Treatment				
$R^2 = 0.53$	Intercept	47.12	27.88	$p = 0.20$
Prob > F = 0.0015	Beta	0.68	0.17	
Guernsey Manure Treatment (w/o 1986)				
$R^2 = 0.89$	Intercept	22.40	12.52	$p = 0.16$
Prob > F = 0.0001	Beta	0.82	0.08	
Bertie Fertilizer Treatment				
$R^2 = 0.55$	Intercept	28.57	26.04	$p = 0.33$
Prob > F = 0.0015	Beta	0.75	0.19	
Bertie Manure Treatment				
$R^2 = 0.42$	Intercept	55.17	25.03	$p = 0.04$
Prob > F = 0.0085	Beta	0.54	0.17	
Starr-Dyke Fertilizer Treatment				
$R^2 = 0.71$	Intercept	-42.65	29.41	$p = 0.32$
Prob > F = 0.0001	Beta	1.27	0.22	
Starr-Dyke Fertilizer Treatment (w/o 1983)				
$R^2 = 0.76$	Intercept	-19.85	24.29	$p = 0.71$
Prob > F = 0.0001	Beta	1.13	0.18	
Starr-Dyke Manure Treatment				
$R^2 = 0.67$	Intercept	-33.50	32.74	$p = 0.58$
Prob > F = 0.0001	Beta	1.25	0.23	
Starr-Dyke Manure Treatment (w/o 1983)				
$R^2 = 0.70$	Intercept	-10.53	28.64	$p = 0.63$
Prob > F = 0.0001	Beta	1.12	0.20	

[1] The goodness of fit test performed on all regressions tested the joint hypothesis H_0: Intercept = 0 and Slope = 1 vs. the alternative hypothesis H_a: Intercept $\neq$ 0 and/or Slope $\neq$ 1. The level of significance to reject H_0 is $p \leq 0.05$.

Figure 1. Guernsey Silt Loam

Fertilizer Treatment Corn Grain Yields

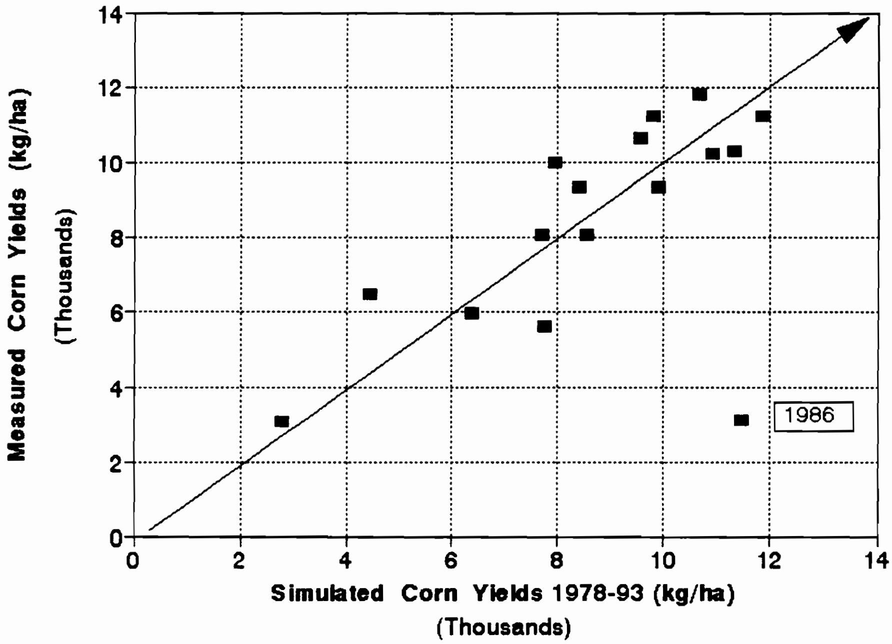


Figure 2. Guernsey Silt Loam

Manure Treatment Corn Grain Yields

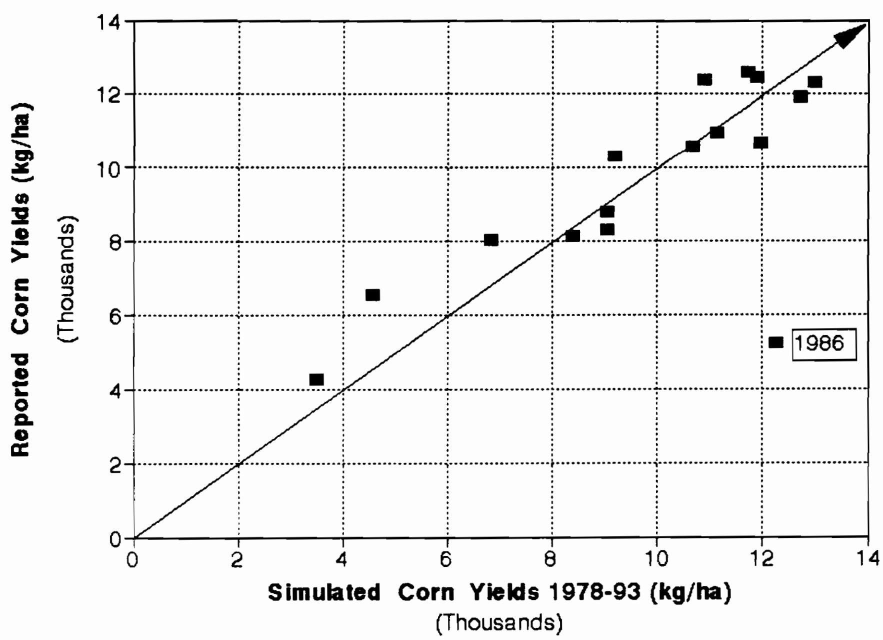


Figure 3. Bertie Fine Sandy Loam

Fertilizer Treatment Corn Grain Yields

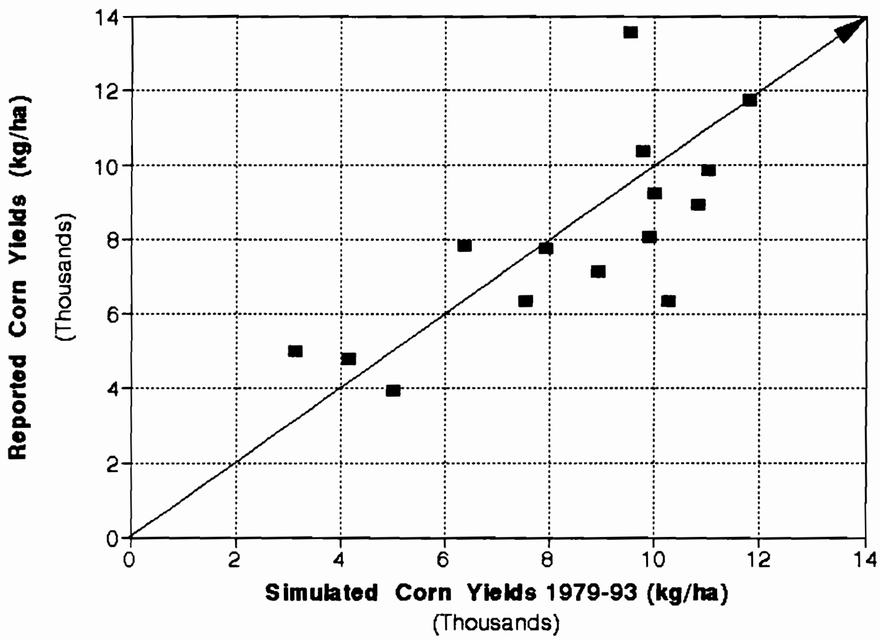


Figure 4. Bertie Fine Sandy Loam

Manure Treatment Corn Grain Yields

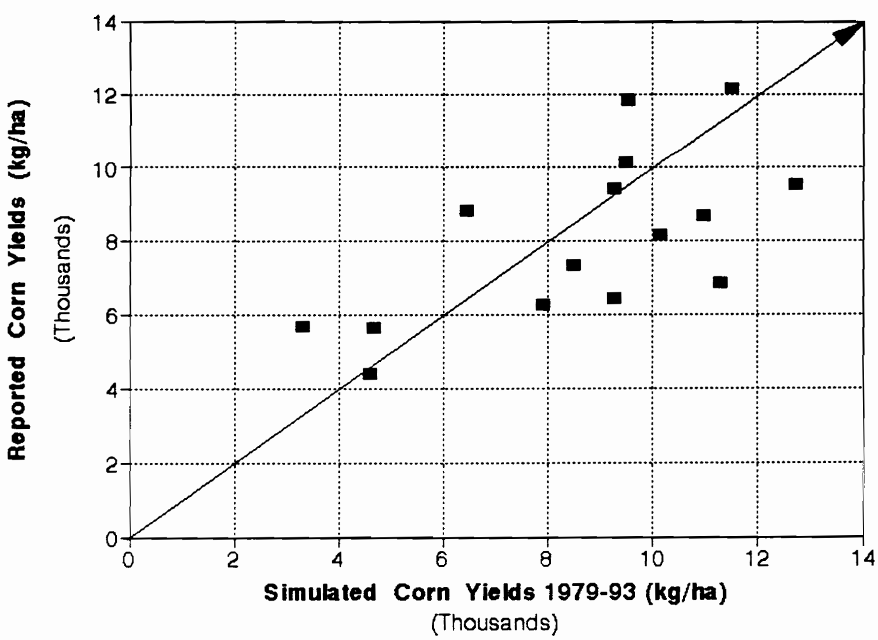


Figure 5. Starr-Dyke Clay Loam

Fertilizer Treatment Corn Grain Yields

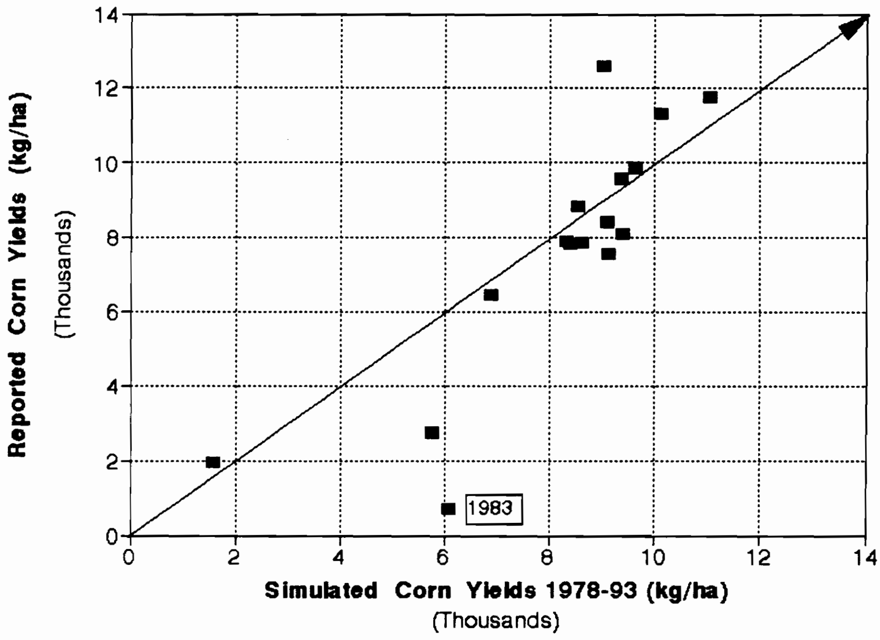
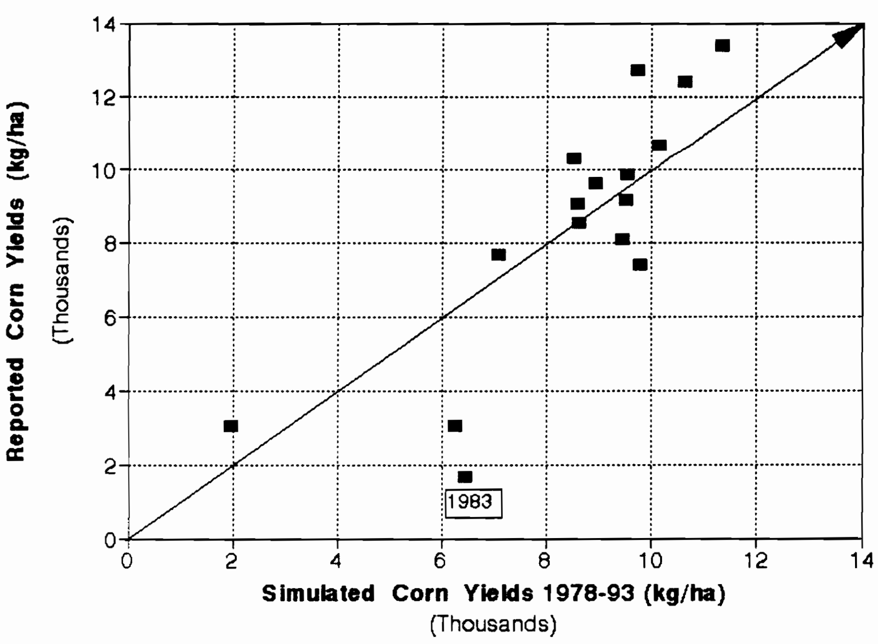


Figure 6. Starr-Dyke Clay Loam

Manure Treatment Corn Grain Yields



Appendix B: Soil Parameters for EPIC Simulations

Table B.1. Soil Parameters for Corn Silage/Ryelage and Alfalfa Crops.

Soil and EPIC Model Specifications:	
Soil Type:	Frederick-Lodi Silt Loam (29C2)
Latitude	38:27
Elevation	800 Feet
Slope	7 Percent
Watershed Drainage Area	2.47 Acres
Slope Length	164 Feet
Soil Albedo	0.18

EPIC Soil Specifications	Soil Layer 1	2	3	4	5	6	7	8
Depth to Bottom of Soil Layer (m)	0.010	0.203	0.405	0.750	1.110	1.250	1.510	1.800
Bulk Density (t/m_3)	1.358	1.358	1.470	1.486	1.486	1.486	1.486	1.486
Wilting Point (1500 kPa) (m/m)	0.163	0.163	0.261	0.285	0.290	0.295	0.295	0.295
Field Capacity (33 kPa) (m/m)	0.308	0.308	0.331	0.355	0.355	0.360	0.350	0.340
Sand Content (%)	11.4	11.4	7.5	16.7	16.7	16.7	16.7	16.7
Silt Content (%)	68.6	68.6	55.2	27.0	27.0	27.0	27.0	27.0
Organic N Concentration (g/t^3)	1300.	1190.	400.	0.0	0.0	0.0	0.0	0.0
Soil ph	6.0	6.0	6.0	5.8	5.7	5.5	5.4	5.4
Organic Carbon (%)	1.34	1.19	0.39	0.13	0.03	0.03	0.03	0.03
Cation Exchange Capacity (cmol/kg)	8.5	8.5	8.9	11.7	11.7	11.4	11.4	11.4
Coarse Fragment Content (%)	8.2	8.2	8.1	5.3	5.3	5.1	5.1	5.1
Nitrate Concentration (g/t^3)	7.	6.	8.	3.	1.	0.0	0.0	0.0
Labile P Concentration (g/t^3)	23.	23.	7.	0.0	0.0	0.0	0.0	0.0
Crop Residue (t/ha)	4.483	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bulk Density (oven dry) (t/m^3)	1.41	1.41	1.57	1.64	1.64	1.64	1.64	1.64
Saturated Conductivity (mm/hr)	1.38	1.38	0.71	0.60	0.60	0.54	0.54	0.54
Organic P Concentration (g/t)	185.	155.	49.	0.0	0.0	0.0	0.0	0.0

Table B.2. Soil Parameters for Grass Hay on 150-Cow Farm.

Soil and EPIC Model Specifications:	
Soil Type:	Frederick-Lodi Silt Loam (29C2)
Latitude	38:27
Elevation	800 Feet
Slope	9.5 Percent
Watershed Drainage Area	2.47 Acres
Slope Length	164 Feet
Soil Albedo	0.18

	Soil Layer							
EPIC Soil Specifications	1	2	3	4	5	6	7	8
Depth to Bottom of Soil Layer (m)	0.010	0.203	0.405	0.750	1.110	1.250	1.510	1.800
Bulk Density (t/m_3)	1.358	1.358	1.470	1.486	1.486	1.486	1.486	1.486
Wilting Point (1500 kPa) (m/m)	0.168	0.168	0.261	0.285	0.290	0.295	0.295	0.295
Field Capacity (33 kPa) (m/m)	0.308	0.308	0.331	0.355	0.355	0.360	0.350	0.340
Sand Content (%)	11.4	11.4	7.5	16.7	16.7	16.7	16.7	16.7
Silt Content (%)	68.6	68.6	55.2	27.0	27.0	27.0	27.0	27.0
Organic N Concentration (g/t^3)	2560.	1010.	388.	0.0	0.0	0.0	0.0	0.0
Soil ph	6.0	6.0	5.8	5.7	5.7	5.7	5.6	5.4
Organic Carbon (%)	2.55	1.11	0.39	0.13	0.03	0.03	0.03	0.03
Cation Exchange Capacity (cmol/kg)	8.5	8.5	8.9	11.7	11.7	11.4	11.4	11.4
Coarse Fragment Content (%)	12.2	12.2	12.1	8.1	8.1	7.4	7.4	7.4
Nitrate Concentration (g/t^3)	3.	3.	3.	6.	1.	0.0	0.0	0.0
Labile P Concentration (g/t^3)	39.	16.	5.	1.0	0.0	0.0	0.0	0.0
Crop Residue (t/ha)	6.245	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bulk Density (oven dry) (t/m^3)	1.41	1.41	1.57	1.64	1.64	1.64	1.64	1.64
Saturated Conductivity (mm/hr)	1.38	1.38	0.71	0.60	0.60	0.54	0.54	0.54
Organic P Concentration (g/t)	370.	106.	34.	0.0	0.0	0.0	0.0	0.0

Table B.3. Soil Parameters for Hay/Pasture Crops.

Soil and EPIC Model Specifications:					
Soil Type:	Frederick-Lodi Cherty Silt Loam (31C2)				
Latitude	38:27				
Elevation	800 Feet				
Slope	12.0 Percent				
Watershed Drainage Area	2.47 Acres				
Slope Length	164 Feet				
Soil Albedo	0.18				
	Soil Layers				
EPIC Soil Specifications	1	2	3	4	5
Depth to Soil Layer Surface (m)	0.01	0.203	0.405	0.950	1.300
Bulk Density (t/m_3)	1.358	1.358	1.470	1.486	1.486
Wilting Point (1500 kPa) (m/m)	0.168	0.168	0.261	0.285	0.295
Field Capacity (33 kPa) (m/m)	0.308	0.308	0.331	0.355	0.350
Sand Content (%)	11.4	11.4	7.5	16.7	16.7
Silt Content (%)	68.6	68.6	55.2	27.0	27.0
Organic N Concentration (g/t^3)	2523.0	1112.0	388.0	89.0	0.0
Soil ph	5.7	5.7	5.7	5.6	5.5
Organic Carbon (%)	2.52	1.11	.39	0.09	0.03
Cation Exchange Capacity (cmol/kg)	8.5	8.5	8.9	11.7	11.4
Coarse Fragment Content (%)	22.0	22.0	15.0	12.0	12.0
Nitrate Concentration (g/t^3)	1	2	4	1	0.0
Labile P Concentration (g/t^3)	58	51	6	1	0.0
Crop Residue (t/ha)	4.483	0.0	0.0	0.0	0.0
Bulk Density (oven dry) (t/m^3)	1.41	1.41	1.57	1.64	1.64
Saturated Conductivity (mm/hr)	1.38	1.38	0.71	0.60	0.54
Organic P Concentration (g/t)	335.0	79.0	24.0	11.0	0.0

Table B.4. Soil Parameters for Permanent Pasture.

Soil and EPIC Model Specifications:	
Soil Type:	Frederick-Lodi Rock Outcrop Silt Loam (34C)
Latitude	38:27
Elevation	800 Feet
Slope	15.0 Percent
Watershed Drainage Area	2.47 Acres
Slope Length	164 Feet
Soil Albedo	0.18

EPIC Soil Specifications	Soil Layer 1	2	3	4	5
Depth to Soil Layer Surface (m)	0.010	0.203	0.405	0.900	1.100
Bulk Density (t/m_3)	1.358	1.358	1.470	1.486	1.486
Wilting Point (1500 kPa) (m/m)	0.173	0.173	0.271	0.290	0.295
Field Capacity (33 kPa) (m/m)	0.298	0.298	0.321	0.345	0.340
Sand Content (%)	11.4	11.4	7.5	16.7	16.7
Silt Content (%)	68.6	68.6	55.2	27.0	27.0
Organic N Concentration (g/t^3)	1109.	553.	194.	45.	0.0
Soil ph	5.7	5.7	5.7	5.7	5.5
Organic Carbon (%)	2.21	1.10	0.39	0.09	0.03
Cation Exchange Capacity (cmol/kg)	8.5	8.5	8.9	11.7	11.4
Coarse Fragment Content (%)	40.0	40.0	30.0	25.0	25.0
Nitrate Concentration (g/t^3)	0.0	0.0	0.0	0.0	0.0
Labile P Concentration (g/t^3)	22.	22.	3.	1.	0.0
Crop Residue (t/ha)	4.483	0.0	0.0	0.0	0.0
Bulk Density (oven dry) (t/m^3)	1.41	1.41	1.57	1.64	1.64
Saturated Conductivity (mm/hr)	1.38	1.38	0.71	0.60	0.54
Organic P Concentration (g/t)	140.	38.	12.	6.	0.0

Table B.5. Soil Parameters for Base Unimproved Pasture.

Soil and EPIC Model Specifications:	
Soil Type:	Frederick-Lodi Rock Outcrop Silt Loam (34D)
Latitude	38:27
Elevation	800 Feet
Slope	15.0 Percent
Watershed Drainage Area	2.47 Acres
Slope Length	164 Feet
Soil Albedo	0.18

EPIC Soil Specifications	Soil Layers 1	2	3	4	5
Depth to Soil Layer Surface (m)	0.010	0.203	0.405	0.800	1.000
Bulk Density (t/m_3)	1.358	1.358	1.470	1.486	1.486
Wilting Point (1500 kPa) (m/m)	0.173	0.173	0.271	0.290	0.295
Field Capacity (33 kPa) (m/m)	0.298	0.298	0.321	0.345	0.340
Sand Content (%)	11.4	11.4	7.5	16.7	16.7
Silt Content (%)	68.6	68.6	55.2	27.0	27.0
Organic N Concentration (g/t^3)	810.0	453.0	164.0	35.	0.0
Soil ph	5.7	5.7	5.7	5.5	5.5
Organic Carbon (%)	1.91	1.10	0.39	0.09	0.03
Cation Exchange Capacity (cmol/kg)	8.5	8.5	8.9	11.7	11.4
Coarse Fragment Content (%)	40.0	40.0	30.0	25.0	25.0
Nitrate Concentration (g/t^3)	0.0	0.0	0.0	0.0	0.0
Labile P Concentration (g/t^3)	12.0	12.0	2.0	1.0	0.0
Crop Residue (t/ha)	4.483	0.0	0.0	0.0	0.0
Bulk Density (oven dry) (t/m^3)	1.41	1.41	1.57	1.64	1.64
Saturated Conductivity (mm/hr)	1.38	1.38	0.71	0.60	0.54
Organic P Concentration (g/t)	120.0	30.0	9.0	6.0	0.0

Appendix C:

FLIPSIM Parameters for the 60, 100, and 150-Cow Farms

Table C.1. FLIPSIM Parameters For the 60-Cow Farm.

OTHER COSTS -	
TOTAL PROPERTY TAXES	2250.0000
PROPERTY TAX RATE ($TAX/$VALUE)	0.006250
PERSONAL PROPERTY TAX RATE ON BASIS	0.0044
OTHER TAXES	70.0000
ACCOUNTANT & LEGAL FEES	450.0000
UNALLOCATED MAINTENANCE COSTS	8500.0000
INSURANCE ON MACHINERY	2500.0000
FUEL, LUBE & UTILITIES	6900.0000
HIRED FARM LABOR -	
NO. OF FULL TIME EMPLOYEES	0.0000
GROSS SALARY PER FULL-TIME EMPLOYEE	0.0000
TOTAL PART-TIME LABOR EXPENSE	11500.0000
HISTORY OF INCOME TAXES DUE & TAXABLE INCOME	
FEDERAL INCOME TAX DUE IN YEAR 1	1500.0000
SELF-EMPLOYMENT TAX DUE IN YEAR 1	2000.0000
STATE INCOME TAX DUE IN YEAR 1	1200.0000
SOLE PROPRIETOR"S INFORMATION -	
NO. OF INCOME TAX EXEMPTION CLAIMED	5.0000
RATIO OF PERSONAL DEDUC TO NET INCOME	0.2000
ANNUAL OFF-FARM INCOME (SALARY)	0.0000
NON-TAXABLE OFF-FARM INCOME	3840.0000
MINIMUM FAMILY LIVING EXPENSES	16000.0000
MAXIMUM FAMILY LIVING EXPENSES	22000.0000

ANNUAL RATE OF INFLATION FOR INPUT COSTS		2	3	4	5
NEW FARM MACHINERY	0.0000	0.0118	0.0189	0.0217	0.0215
USED FARM MACHINERY	-0.0400	-0.0400	-0.0400	-0.0400	-0.0400
MISC. COST & INSURANCE	0.0000	0.0121	0.0231	0.0266	0.0306
SEED COSTS	0.0000	0.0377	0.0177	0.0183	0.0242
FERTILIZER & LIME	0.0000	0.0058	0.0296	0.0173	0.0264
CHEMICAL COSTS	0.0000	0.0127	0.0226	0.0237	0.0264
FUEL & LUBE COSTS	0.0000	-0.0016	0.0426	0.0247	0.0353
HARVEST COSTS	0.0000	-0.0016	0.0426	0.0247	0.0353
HIRED LABOR COSTS	0.0000	0.0219	0.0214	0.0221	0.0216
INPUTS FOR LIVESTOCK	0.0000	0.0121	0.0231	0.0266	0.0306
FARMLAND VALUES	0.0000	0.0250	0.0250	0.0250	0.0250
BUILDING VALUES	-0.0200	-0.0200	-0.0200	-0.0200	-0.0200
CONSUMER PRICE INDEX	144.56	148.74	153.45	158.50	164.03
SELF EMPLOYMENT TAX RATE	0.153	0.153	0.153	0.153	0.153
MAXIMUM INCOME SUBJECT TO SELF EMPLOYMENT TAX	57500.	59340.	61298.	63505.	65982.

ENTERPRISE COSTS	SEED	FERTILIZER	HERBICIDE	OTHER COSTS	SUM OF CASH COSTS $/ACRE
Corn Silage	19.50	9.50	36.00	0.00	65.00
Corn Grain	19.50	9.50	36.00	23.40	88.40
Ryelage	18.75	0.00	0.00	10.20	28.95
Rye-Cover	11.75	0.00	0.00	10.20	21.95
Alfalfa Hay	0.00	58.00	21.75	0.00	79.75
Alfalfa-Plt	48.50	84.50	54.30	10.20	197.50
Grass Hay	0.00	10.00	4.00	0.00	14.00
Hay/Pasture	0.00	5.00	4.00	0.00	9.00
Pasture	0.00	0.00	2.00	0.00	2.00

Table C.1. (Continued) FLIPSIM Parameters For the 60-Cow Farm.

PLANTED ACRES	1	2	3	4	5
Corn Silage	50.00	50.00	50.00	50.00	50.00
Ryelage	50.00	50.00	50.00	50.00	50.00
Alfalfa Hay	15.00	15.00	15.00	15.00	15.00
Alfalfa-Plt	5.00	5.00	5.00	5.00	5.00
Hay/Pasture	20.00	20.00	20.00	20.00	20.00
Pasture	20.00	20.00	20.00	20.00	20.00

AVERAGE ANNUAL PRICES	1	2	3	4	5
Corn Silage	27.50	27.50	27.50	27.50	27.50
Corn Grain	2.75	2.40	2.56	2.49	2.46
Ryelage	39.00	39.00	39.00	39.00	39.00
Rye-Cover	0.00	0.00	0.00	0.00	0.00
Alfalfa Hay	114.00	114.00	114.00	114.00	114.00
Alfalfa-Plt	114.00	114.00	114.00	114.00	114.00
Grass Hay	81.00	81.00	81.00	81.00	81.00
Hay/Pasture	79.00	79.00	79.00	79.00	79.00
Pasture	77.00	77.00	77.00	77.00	77.00
Corn Dist	163.00	155.00	159.00	157.00	157.00
24% Conc	229.00	216.00	217.00	219.00	218.00
SBOM	281.00	259.00	262.00	266.00	265.00
Calf Starte	183.00	176.00	178.00	177.00	177.00
Milk Replac	80.29	79.90	79.75	80.11	80.05
Mineral	42.20	42.40	42.60	42.80	43.00

SUMMARY OF MACHINERY AND EQUIPMENT COMPLEMENT -

		YEAR PURCHASED	CURRENT MARKET VALUE	ORIGINAL BASIS	ESTIMATED SALVAGE VALUE	CURRENT REPLACE. COST
1	Loader	1984.0	1000.0	1769.0	177.0	5110.0
2	40 Hp Trac	1992.0	8000.0	10617.0	1062.0	15329.0
3	Bucket	1991.0	400.0	840.0	84.0	1022.0
4	60 Hp Trac	1986.0	9700.0	15483.0	1548.0	35768.0
5	85 Hp Trac	1988.0	4400.0	7697.0	770.0	18906.0
6	MB Plow	1982.0	800.0	3000.0	100.0	4500.0
7	Corn Plant	1978.0	2700.0	8000.0	500.0	12000.0
8	Scraper	1989.0	265.0	531.0	53.0	766.0
9	Sq Baler	1986.0	1000.0	2000.0	300.0	5000.0
10	Forg Harv	1989.0	2400.0	5000.0	400.0	10000.0
11	Forg Wagn	1978.0	1200.0	4500.0	300.0	8000.0
12	Forg Wagn	1982.0	1600.0	5500.0	300.0	8000.0
13	Haybine	1986.0	1000.0	3000.0	200.0	4000.0
14	55 Kw Alt	1983.0	3500.0	5109.0	511.0	6643.0
15	Stk Trlr	1986.0	2200.0	3362.0	336.0	4497.0
16	3/4 4x4 Trk	1992.0	12800.0	24571.0	500.0	18651.0
17	1/2 4x4 Trk	1983.0	950.0	1327.0	133.0	5110.0
18	Hayrake	1983.0	1020.0	1593.0	159.0	2453.0
19	Lawn Mower	1992.0	3000.0	2450.0	315.0	3781.0
20	ATV 4x4	1990.0	2100.0	3400.0	294.0	3883.0
21	Computer	1991.0	800.0	3100.0	310.0	2555.0
22	13' Fld Har	1983.0	700.0	1371.0	137.0	2555.0
23	Manure Spdr	1984.0	775.0	3822.0	382.0	5825.0
24	Replace Yr1	1973.0	100.0	2212.0	0.0	2750.0
25	Replace Yr2	1974.0	100.0	885.0	0.0	2750.0
26	Replace Yr3	1975.0	100.0	354.0	0.0	2750.0
27	Replace Yr4	1976.0	100.0	319.0	0.0	2750.0
28	Replace Yr5	1977.0	100.0	146.0	0.0	2750.0
29	Milk Equip	1978.0	5000.0	25000.0	1000.0	40000.0
30	Bulk Tank	1983.0	2500.0	8000.0	500.0	10000.0

Table C.1. (Continued) FLIPSIM Parameters For the 60-Cow Farm.

SUMMARY OF DAIRY INPUT DATA INITIAL HERD INFORMATION

	INITIAL HERD (NO.)	DIE ANNUALLY (NO.)	DIE ANNUALLY (FRAC)	CULL/SELL ANNUALLY (NO.)	CULL/SELL ANNUALLY (FRAC)	SALE OR PURCHASE WEIGHT
LACTATING AND DRY COWS	60.0	1.0	0.017	21.0	0.355	1350.0
REPLACE. CALVES 0-12 MONTHS	65.0	2.0	0.072	37.0	0.570	90 & 450
REPLACE. HEIFERS 12-24 MONTH	26.0	0.0	0.000	3.0	0.120	850.0
REPLACE. HEIFERS 24+ MONTHS	7.0	0.0	0.000	0.0	0.000	1150.0
DAIRY BULLS	0.0	0.0	0.000	0.0	0.000	1800.0

AVERAGE CALVING INTERVAL, IN MONTHS	13.5
AVERAGE DAYS DRY	65.0
AVERAGE AGE AT FIRST CALVING	27.5
AVERAGE NUMBER OF DRY COWS	9.0
AVERAGE NUMBER OF CALVES BORN	65.0
DAIRY PRODUCTION COSTS	
VET AND MEDICINE COSTS ($/COW)	70.0000
BREEDING COSTS ($/COW)	45.0000
MILK SUPPLIES ($/COW)	71.1000
DHIA & HERD TESTING COSTS ($/COW)	22.0000
LIVESTOCK COMMISSIONS ($/COW)	12.5000
BEDDING COSTS ($/COW)	12.5000
MISCELLANEOUS COSTS ($/COW)	35.6600
COOP RETAINS ($/CWT)	0.6290
PROMOTION ASSESSMENTS ($/CWT)	0.1500
MILK HAULING ($/CWT)	0.7200
INITIAL VALUE OF DAIRY HERD	
LACTATING AND DRY COWS	49660.2
0 TO 12 MONTH CALVES	9746.1
12 TO 24 MONTH HEIFERS	17073.9
24+ MONTH HEIFERS	7350.0
DAIRY BULLS	0.0
TOTAL	83830.2

ANNUAL VALUES FOR:	1	2	3	4	5
PRICE OF MILK	13.2200	13.2500	12.5500	12.4500	12.5400
PRICE FOR CULL COWS	0.4484	0.4256	0.4024	0.3811	0.3512
PRICE FOR REPLACEMENTS	1050.0	1050.0	1050.0	1050.0	1050.0
PRICE FOR CALVES	0.8330	0.8870	0.8600	0.8090	0.7340
MILK PER COW	180.00	182.00	184.00	186.00	188.00
NUMBER OF COWS	60.00	60.00	60.00	60.00	60.00

DAIRY FEED REQUIREMENTS

51 LACT. COWS & 0 BULLS		1	2	3	4	5
Corn Silage	Ton	6.4800	6.4800	6.4800	6.4800	6.4800
Corn Grain	Bu	59.1700	59.1700	59.1700	59.1700	59.1700
Ryelage	Ton	2.9500	2.9500	2.9500	2.9500	2.9500
Alfalfa Hay	Ton	1.3400	1.3400	1.3400	1.3400	1.3400
Pasture	Ton	1.0000	1.0000	1.0000	1.0000	1.0000
Corn Dist	Ton	0.7450	0.7450	0.7450	0.7450	0.7450
24% Conc	Ton	0.7960	0.7960	0.7960	0.7960	0.7960
SBOM	Ton	0.1720	0.1720	0.1720	0.1720	0.1720
Mineral	Ton	1.0000	1.0000	1.0000	1.0000	1.0000
9 DRY COWS						
Corn Silage	Ton	4.7900	4.7900	4.7900	4.7900	4.7900
Hay/Pasture	Ton	3.4500	3.4500	3.4500	3.4500	3.4500
Mineral	Ton	1.0000	1.0000	1.0000	1.0000	1.0000

Table C.1. (Continued) FLIPSIM Parameters For the 60-Cow Farm.

25 0-12 MONTH CALVES		1	2	3	4	5
Corn Silage	Ton	2.3400	2.3400	2.3400	2.3400	2.3400
Corn Grain	Bu	5.4900	5.4900	5.4900	5.4900	5.4900
Alfalfa Hay	Ton	0.4100	0.4100	0.4100	0.4100	0.4100
Hay/Pasture	Ton	0.4200	0.4200	0.4200	0.4200	0.4200
SBOM	Ton	0.1790	0.1790	0.1790	0.1790	0.1790
Calf Starte	Ton	0.0380	0.0380	0.0380	0.0380	0.0380
Milk Replac	Cwt	0.5600	0.5600	0.5600	0.5600	0.5600

22 12-24 MONTH HEIFERS		1	2	3	4	5
Corn Silage	Ton	6.2200	6.2200	6.2200	6.2200	6.2200
Hay/Pasture	Ton	1.1500	1.1500	1.1500	1.1500	1.1500
SBOM	Ton	0.4970	0.4970	0.4970	0.4970	0.4970

5 24+ MONTH HEIFERS		1	2	3	4	5
Corn Silage	Ton	7.0900	7.0900	7.0900	7.0900	7.0900
Hay/Pasture	Ton	1.0500	1.0500	1.0500	1.0500	1.0500
SBOM	Ton	0.5580	0.5580	0.5580	0.5580	0.5580

DAIRY POLICY VARIABLES

SUPPORT PRICE					
- P42	9.6300	9.6300	9.6300	9.6300	9.6300
ASSESSMENT FOR 1985 & 1990 PROGRAM					
- P47	0.1420	0.1500	0.1520	0.1400	0.1380

Table C.2. FLIPSIM Parameters For the 100-Cow Farm.

OTHER COSTS -		
TOTAL PROPERTY TAXES	2745.0000	
PROPERTY TAX RATE ($TAX/$VALUE)	0.005763	
PERSONAL PROPERTY TAX RATE ON BASIS	0.0044	
OTHER TAXES	300.0000	
ACCOUNTANT & LEGAL FEES	800.0000	
UNALLOCATED MAINTENANCE COSTS	12400.0000	
INSURANCE ON MACHINERY	3500.0000	
FUEL, LUBE & UTILITIES	10300.0000	
LAND LEASE COSTS -		
CROPLAND ACRES CASH LEASED	31.0000	
CASH RENT FOR CROPLAND ($/ACRE)	45.0000	
PRIVATE/STATE PASTURE AUMs LEASED	17.0000	
ANNUAL RATE OF INFLATION FOR PER ACRE CASH LEASE COST	0.0500	
HIRED FARM LABOR -		
NO. OF FULL TIME EMPLOYEES	0.5000	
GROSS SALARY PER FULL-TIME EMPLOYEE	15000.0000	
TOTAL PART-TIME LABOR EXPENSE	3500.0000	
HISTORY OF INCOME TAXES DUE & TAXABLE INCOME		
FEDERAL INCOME TAX DUE IN YEAR 1	3750.0000	
SELF-EMPLOYMENT TAX DUE IN YEAR 1	4500.0000	
STATE INCOME TAX DUE IN YEAR 1	400.0000	
NON-TAXABLE OFF-FARM INCOME	6400.0000	
PARTNERSHIP INFORMATION	PARTNER 1	PARTNER 2
SHARE OF NET INCOME TO PARTNER	0.5000	0.5000
NO. OF PERSONAL INCOME TAX EXEMPTIONS	4.0000	4.0000
PERSONAL TAX DEDUC AS FRACT INCOME	0.2000	0.2000
AVERAGE ANNUAL OFF-FARM INCOME (SALARY)	19000.0000	0.0000
MINIMUM ANNUAL DRAW FOR FAMILY LIVING	23000.0000	26000.0000
MAXIMUM ANNUAL DRAW FOR FAMILY LIVING	35000.0000	35000.0000
MARGINAL PROPENSITY TO CONSUME	0.2400	0.2400

ANNUAL RATE OF INFLATION FOR INPUT COSTS		2	3	4	5
NEW FARM MACHINERY	0.0000	0.0118	0.0189	0.0217	0.0215
USED FARM MACHINERY	-0.0400	-0.0400	-0.0400	-0.0400	-0.0400
MISC. COST & INSURANCE	0.0000	0.0121	0.0231	0.0266	0.0306
SEED COSTS	0.0000	0.0377	0.0177	0.0183	0.0242
FERTILIZER & LIME	0.0000	0.0058	0.0296	0.0173	0.0264
CHEMICAL COSTS	0.0000	0.0127	0.0226	0.0237	0.0264
FUEL & LUBE COSTS	0.0000	-0.0016	0.0426	0.0247	0.0353
OTHER PROD COST	0.0000	0.0121	0.0231	0.0266	0.0306
HARVEST COSTS	0.0000	-0.0016	0.0426	0.0247	0.0353
HIRED LABOR COSTS	0.0000	0.0219	0.0214	0.0221	0.0216
INPUTS FOR LIVESTOCK	0.0000	0.0121	0.0231	0.0266	0.0306
FARMLAND VALUES	0.0000	0.0250	0.0250	0.0250	0.0250
BUILDING VALUES	-0.0200	-0.0200	-0.0200	-0.0200	-0.0200
CONSUMER PRICE INDEX	144.55	148.74	153.45	158.50	164.03
PRIVATE/STATE PASTURE RENT ($/AUM)	32.50	32.50	32.50	32.50	32.50
SELF EMPLOYMENT TAX RATE	0.153	0.153	0.153	0.153	0.153
MAXIMUM INCOME SUBJECT TO SELF EMPLOYMENT TAX	57500.	59340.	61298.	63505.	65982.

Table C.2. (Continued) FLIPSIM Parameters For the 100-Cow Farm.

SUMMARY OF MACHINERY AND EQUIPMENT COMPLEMENT -

		YEAR PURCHASED	CURRENT MARKET VALUE	ORIGINAL BASIS	REPLACE-MENT YEAR	CURRENT REPLACE. COST
1	Skid Loader	1984.0	5000.0	1769.0	1999.0	8000.0
2	1Tractor 110	1979.0	16000.0	21000.0	1999.0	30000.0
3	Tractor 80	1980.0	10625.0	15483.0	2000.0	35768.0
4	Tractor 70	1988.0	5500.0	7697.0	2008.0	18906.0
5	Tractor 50	1991.0	9300.0	10617.0	2011.0	15329.0
6	Tractor 30	1979.0	3000.0	4000.0	1999.0	7000.0
7	1/4 4x4 trck	1992.0	12000.0	15571.0	2002.0	18651.0
8	1/2 4x4 trck	1983.0	775.0	1327.0	2003.0	5110.0
9	Stk Trailer	1986.0	1400.0	2362.0	1998.0	4497.0
10	Manure Sprdr	1984.0	1800.0	3822.0	2004.0	5825.0
11	Scraper	1989.0	265.0	531.0	1999.0	766.0
12	MB Plow	1982.0	900.0	3000.0	1999.0	4500.0
13	Fld Harrow	1983.0	700.0	1371.0	1999.0	2555.0
14	Offset Disc	1989.0	1500.0	3965.0	2004.0	3500.0
15	Cultimulcher	1981.0	1900.0	3100.0	2001.0	5000.0
16	Corn Planter	1978.0	2500.0	8000.0	1999.0	12000.0
17	Grain Drill	1979.0	450.0	900.0	1999.0	1000.0
18	Haybine	1991.0	1300.0	3000.0	2006.0	4000.0
19	Rd Baler	1985.0	3500.0	5500.0	2000.0	10000.0
20	Sq Baler	1977.0	1100.0	2000.0	1999.0	5000.0
21	Hay Rake	1983.0	750.0	2250.0	1999.0	4000.0
22	Hay Tedder	1984.0	800.0	2200.0	1999.0	3000.0
23	Hay Wagon	1981.0	500.0	900.0	2001.0	1000.0
24	Hay Wagon	1982.0	500.0	950.0	2002.0	1000.0
25	Forg Harv	1992.0	2500.0	7500.0	2007.0	10000.0
26	Blower	1981.0	750.0	1700.0	2001.0	3500.0
27	Forg Wagn	1978.0	1200.0	4500.0	2003.0	8000.0
28	Forg Wagn	1982.0	1600.0	5500.0	2007.0	8000.0
29	Gener 55kw	1983.0	2500.0	5109.0	2003.0	6643.0
30	ATV 4 wheel	1992.0	2300.0	2942.0	2002.0	3883.0
31	Computer	1991.0	1300.0	3097.0	1999.0	2555.0
32	Elevator	1991.0	400.0	7000.0	2011.0	1533.0
33	Mixer Unit	1983.0	1800.0	6200.0	1999.0	9000.0
34	Milk Equip	1978.0	5000.0	25000.0	2003.0	40000.0
35	Bulk Tank	1984.0	4500.0	8000.0	2009.0	10000.0
36	Milk Equip	1991.0	3000.0	15000.0	2011.0	20000.0
37	Replace Yr1	1983.0	100.0	354.0	1993.0	4500.0
38	Replace Yr2	1984.0	100.0	354.0	1994.0	4500.0
39	Replace Yr3	1985.0	100.0	319.0	1995.0	4500.0
40	Replace Yr4	1986.0	100.0	146.0	1996.0	4500.0
41	Replace Yr5	1987.0	100.0	354.0	1997.0	4500.0
42	MISC Equip	1989.0	100.0	3800.0	2009.0	1000.0
43	MISC Equip	1989.0	100.0	100.0	1999.0	1000.0
44	MISC Equip	1989.0	100.0	100.0	1999.0	1000.0
45	MISC Equip	1987.0	100.0	6300.0	2007.0	1000.0
46	MISC Equip	1991.0	100.0	7700.0	2001.0	1000.0

ENTERPRISE COSTS	SEED	FERTILIZER	HERBICIDE	LITTER	OTHER COSTS	SUM OF CASH COSTS $/ACRE
Corn Silage	19.50	16.00	36.00	12.00	0.00	83.50
Corn Grain	19.50	16.00	36.00	12.00	23.40	106.90
Ryelage	18.75	0.00	0.00	0.00	10.20	28.95
Rye-Cover	11.75	0.00	0.00	0.00	10.20	21.95
Alfalfa Hay	0.00	58.00	21.75	0.00	0.00	79.75
Alfalfa-Plt	48.50	84.50	54.30	0.00	10.20	197.50
Grass Hay	0.00	10.00	4.00	0.00	0.00	14.00
Hay/Pasture	0.00	5.00	4.00	18.00	0.00	27.00
Pasture	0.00	0.00	2.00	6.00	0.00	8.00

Table C.2. (Continued) FLIPSIM Parameters For the 100-Cow Farm.

PLANTED ACRES	1	2	3	4	5
Corn Silage	100.00	100.00	100.00	100.00	100.00
Ryelage	50.00	50.00	50.00	50.00	50.00
Rye-Cover	50.00	50.00	50.00	50.00	50.00
Alfalfa Hay	18.75	18.75	18.75	18.75	18.75
Alfalfa-Plt	6.25	6.25	6.25	6.25	6.25
Hay/Pasture	45.00	45.00	45.00	45.00	45.00
Pasture	25.00	25.00	25.00	25.00	25.00

AVERAGE ANNUAL PRICES	1	2	3	4	5
Corn Silage	27.50	27.50	27.50	27.50	27.50
Corn Grain	2.75	2.40	2.56	2.49	2.46
Ryelage	39.00	39.00	39.00	39.00	39.00
Alfalfa Hay	114.00	114.00	114.00	114.00	114.00
Grass Hay	81.00	81.00	81.00	81.00	81.00
Hay/Pasture	79.00	79.00	79.00	79.00	79.00
Pasture	77.00	77.00	77.00	77.00	77.00
Corn Dist	163.00	155.00	159.00	157.00	157.00
24% Conc	229.00	216.00	217.00	219.00	218.00
SBOM	281.00	259.00	262.00	266.00	265.00
Calf Starte	183.00	176.00	178.00	177.00	177.00
Milk Replac	80.29	79.90	79.75	80.11	80.05
Mineral	42.20	42.40	42.60	42.80	43.00

SUMMARY OF DAIRY INPUT DATA

INITIAL HERD INFORMATION	INITIAL HERD (NO.)	DIE ANNUALLY (NO.)	DIE ANNUALLY (FRAC)	CULL/SELL ANNUALLY (NO.)	CULL/SELL ANNUALLY (FRAC)	SALE OR PURCHASE WEIGHT
LACTATING AND DRY COWS	100.0	2.0	0.025	36.0	0.365	1300.0
REPLACE. CALVES 0-12 MONTHS	112.0	2.0	0.050	65.0	0.585	100 & 450
REPLACE. HEIFERS 12-24 MONTH	45.0	0.0	0.020	5.0	0.120	850.0
REPLACE. HEIFERS 24+ MONTHS	12.0	0.0	0.000	0.0	0.000	1150.0
DAIRY BULLS	2.0	0.0	0.000	1.0	0.500	1600.0

AVERAGE CALVING INTERVAL, IN MONTHS	13.5
AVERAGE DAYS DRY	70.0
AVERAGE AGE AT FIRST CALVING	27.5
AVERAGE NUMBER OF DRY COWS	15.5
AVERAGE NUMBER OF CALVES BORN	112.0

DAIRY PRODUCTION COSTS	
VET AND MEDICINE COSTS ($/COW)	45.0000
BREEDING COSTS ($/COW)	35.0000
MILK SUPPLIES ($/COW)	75.0000
DHIA & HERD TESTING COSTS ($/COW)	22.0000
LIVESTOCK COMMISSIONS ($/COW)	4.5000
BEDDING COSTS ($/COW)	15.0000
MISCELLANEOUS COSTS ($/COW)	37.0000
COOP RETAINS ($/CWT)	0.6290
PROMOTION ASSESSMENTS ($/CWT)	0.1500
MILK HAULING ($/CWT)	0.7200

INITIAL VALUE OF DAIRY HERD	
LACTATING AND DRY COWS	81646.0
0 TO 12 MONTH CALVES	16868.3
12 TO 24 MONTH HEIFERS	31043.5
24+ MONTH HEIFERS	12600.0
DAIRY BULLS	800.0
TOTAL	142157.7

Table C.2. (Continued) FLIPSIM Parameters For the 100-Cow Farm.

Table C.2. (Continued) FLIPSIM Parameters For the 100-Cow Farm.

ANNUAL VALUES FOR:		1	2	3	4	5
PRICE OF MILK		13.2200	13.2500	12.5500	12.4500	12.5400
PRICE FOR CULL COWS		0.4484	0.4256	0.4024	0.3811	0.3512
PRICE FOR REPLACEMENTS		1050.0	1050.0	1050.0	1050.0	1050.0
PRICE FOR CALVES		0.8330	0.8870	0.8600	0.8090	0.7340
MILK PER COW		180.00	182.00	184.00	186.00	188.00
NUMBER OF COWS		100.00	100.00	100.00	100.00	100.00
DAIRY FEED REQUIREMENTS						
84 LACT. COWS & 2 BULLS		1	2	3	4	5
Corn Silage	Ton	9.0600	9.0600	9.0600	9.0600	9.0600
Corn Grain	Bu	53.1000	53.1000	53.1000	53.1000	53.1000
Ryelage	Ton	1.7000	1.7000	1.7000	1.7000	1.7000
Alfalfa Hay	Ton	0.9600	0.9600	0.9600	0.9600	0.9600
Pasture	Ton	1.0000	1.0000	1.0000	1.0000	1.0000
Corn Dist	Ton	0.7450	0.7450	0.7450	0.7450	0.7450
24% Conc	Ton	0.8380	0.8380	0.8380	0.8380	0.8380
SBOM	Ton	0.1860	0.1860	0.1860	0.1860	0.1860
Mineral	Ton	1.0000	1.0000	1.0000	1.0000	1.0000
15 DRY COWS		1	2	3	4	5
Corn Silage	Ton	4.7900	4.7900	4.7900	4.7900	4.7900
Corn Grain	Bu	0.0000	0.0000	0.0000	0.0000	0.0000
Hay/Pasture	Ton	3.4500	3.4500	3.4500	3.4500	3.4500
Mineral	Ton	1.0000	1.0000	1.0000	1.0000	1.0000
45 0-12 MONTH CALVES		1	2	3	4	5
Corn Silage	Ton	2.3400	2.3400	2.3400	2.3400	2.3400
Corn Grain	Bu	5.4900	5.4900	5.4900	5.4900	5.4900
Alfalfa Hay	Ton	0.4100	0.4100	0.4100	0.4100	0.4100
Hay/Pasture	Ton	0.4200	0.4200	0.4200	0.4200	0.4200
SBOM	Ton	0.1790	0.1790	0.1790	0.1790	0.1790
Calf Starte	Ton	0.0380	0.0380	0.0380	0.0380	0.0380
Milk Replac	Cwt	0.5600	0.5600	0.5600	0.5600	0.5600
40 12-24 MONTH HEIFERS		1	2	3	4	5
Corn Silage	Ton	6.2200	6.2200	6.2200	6.2200	6.2200
Hay/Pasture	Ton	1.1500	1.1500	1.1500	1.1500	1.1500
SBOM	Ton	0.4970	0.4970	0.4970	0.4970	0.4970
9 24+ MONTH HEIFERS		1	2	3	4	5
Corn Silage	Ton	7.0900	7.0900	7.0900	7.0900	7.0900
Hay/Pasture	Ton	1.0500	1.0500	1.0500	1.0500	1.0500
SBOM	Ton	0.5580	0.5580	0.5580	0.5580	0.5580
SUPPORT PRICE						
- P42		9.6300	9.6300	9.6300	9.6300	9.6300
ASSESSMENT FOR 1985 & 1990 PROGRAM						
- P47		0.1420	0.1500	0.1520	0.1400	0.1380

Table C.3. FLIPSIM Parameters For the 150-Cow Farm.

OTHER COSTS -		
TOTAL PROPERTY TAXES	3548.0000	
PROPERTY TAX RATE ($TAX/$VALUE)	0.005089	
BASE PERSONAL PROPERTY TAX	0.0000	
PERSONAL PROPERTY TAX RATE ON BASIS	0.0044	
PERSONAL PROPERTY TAX RATE ON VALUE	0.0000	
OTHER TAXES	300.0000	
ACCOUNTANT & LEGAL FEES	1000.0000	
UNALLOCATED MAINTENANCE COSTS	19000.0000	
INSURANCE ON MACHINERY	5000.0000	
MISCELLANEOUS FIXED COSTS	0.0000	
FUEL, LUBE & UTILITIES	14600.0000	
TOTAL ANNUAL DEPRECIATION FOR BUILDINGS	8800.0000	
LAND LEASE COSTS -		
CROPLAND ACRES CASH LEASED	60.0000	
CASH RENT FOR CROPLAND ($/ACRE)	45.0000	
PRIVATE/STATE PASTURE AUMs LEASED	51.0000	
ANNUAL RATE OF INFLATION FOR PER ACRE CASH LEASE COST	0.0400	
HIRED FARM LABOR -		
NO. OF FULL TIME EMPLOYEES	1.0000	
GROSS SALARY PER FULL-TIME EMPLOYEE	18400.0000	
TOTAL PART-TIME LABOR EXPENSE	17000.0000	
HISTORY OF INCOME TAXES DUE & TAXABLE INCOME		
FEDERAL INCOME TAX DUE IN YEAR 1	6650.0000	
SELF-EMPLOYMENT TAX DUE IN YEAR 1	6900.0000	
STATE INCOME TAX DUE IN YEAR 1	1500.0000	
PARTNERSHIP INFORMATION	PARTNER 1	PARTNER 2
SHARE OF NET INCOME TO PARTNER	0.5000	0.5000
NO. OF PERSONAL INCOME TAX EXEMPTIONS	4.0000	4.0000
PERSONAL TAX DEDUC AS FRACT INCOME	0.2000	0.2000
MINIMUM ANNUAL DRAW FOR FAMILY LIVING	26000.0000	26000.0000
MAXIMUM ANNUAL DRAW FOR FAMILY LIVING	35000.0000	35000.0000
MARGINAL PROPENSITY TO CONSUME	0.2400	0.2400

ANNUAL RATE OF INFLATION FOR INPUT COSTS		2	3	4	5
NEW FARM MACHINERY	0.0000	0.0118	0.0189	0.0217	0.0215
USED FARM MACHINERY	-0.0400	-0.0400	-0.0400	-0.0400	-0.0400
MISC. COST & INSURANCE	0.0000	0.0121	0.0231	0.0266	0.0306
SEED COSTS	0.0000	0.0377	0.0177	0.0183	0.0242
FERTILIZER & LIME	0.0000	0.0058	0.0296	0.0173	0.0264
CHEMICAL COSTS	0.0000	0.0127	0.0226	0.0237	0.0264
FUEL & LUBE COSTS	0.0000	-0.0016	0.0426	0.0247	0.0353
OTHER PROD COST	0.0000	0.0121	0.0231	0.0266	0.0306
HARVEST COSTS	0.0000	-0.0016	0.0426	0.0247	0.0353
HIRED LABOR COSTS	0.0000	0.0219	0.0214	0.0221	0.0216
INPUTS FOR LIVESTOCK	0.0000	0.0121	0.0231	0.0266	0.0306
FARMLAND VALUES	0.0000	0.0250	0.0250	0.0250	0.0250
BUILDING VALUES	-0.0200	-0.0200	-0.0200	-0.0200	-0.0200
PRIVATE/STATE PASTURE RENT ($/AUM)	35.00	35.00	35.00	35.00	35.00
SELF EMPLOYMENT TAX RATE	0.153	0.153	0.153	0.153	0.153
MAXIMUM INCOME SUBJECT TO SELF EMPLOYMENT TAX	57500.	59340.	61298.	63505.	65982.

Table C.3. (Continued) FLIPSIM Parameters For the 150-Cow Farm.

SUMMARY OF MACHINERY AND EQUIPMENT COMPLEMENT -

		YEAR PURCHASED	CURRENT MARKET VALUE	ORIGINAL BASIS	ESTIMATED SALVAGE VALUE	ECONOMIC LIFE	CURRENT REPLACE. COST
1	Skid Loader	1984.0	5000.0	1769.0	177.0	18.0	5110.0
2	Tractor 130	1985.0	22000.0	29000.0	2900.0	20.0	35000.0
3	1Tractor 110	1979.0	16000.0	21000.0	2100.0	20.0	30000.0
4	Tractor 70	1983.0	5500.0	7697.0	770.0	20.0	18906.0
5	Tractor 50	1989.0	8300.0	10617.0	1062.0	9.0	15329.0
6	Tractor 30	1976.0	3000.0	4000.0	400.0	25.0	7000.0
7	1/4 4x4 trck	1992.0	11825.0	15571.0	1557.0	10.0	18651.0
8	1/2 4x4 trck	1983.0	775.0	1327.0	133.0	20.0	5110.0
9	Big Truck	1985.0	5000.0	7500.0	750.0	15.0	10000.0
10	Stk Trailer	1985.0	1400.0	2362.0	236.0	15.0	4497.0
11	Manure Sprdr	1985.0	2850.0	7600.0	760.0	15.0	12000.0
12	Manure Sprdr	1980.0	800.0	2825.0	283.0	20.0	5825.0
13	Scraper	1989.0	265.0	531.0	53.0	15.0	766.0
14	MB Plow	1979.0	1200.0	3000.0	100.0	20.0	4500.0
15	Chisel Plow	1982.0	550.0	1450.0	145.0	20.0	2000.0
16	Fld Harrow	1983.0	700.0	1371.0	137.0	16.0	2555.0
17	Offset Disc	1988.0	1500.0	2765.0	277.0	15.0	3500.0
18	Cultimulcher	1981.0	1500.0	3100.0	310.0	20.0	5000.0
19	Cultipacker	1978.0	500.0	800.0	80.0	21.0	1000.0
20	Corn Planter	1978.0	2500.0	8000.0	800.0	21.0	12000.0
21	Sprayer	1981.0	950.0	1300.0	130.0	20.0	2100.0
22	Grain Drill	1979.0	800.0	900.0	90.0	20.0	1000.0
23	Haybine	1988.0	4000.0	7500.0	750.0	15.0	9000.0
24	Rd Baler	1985.0	3500.0	5500.0	550.0	15.0	10000.0
25	Sq Baler	1986.0	1000.0	2000.0	200.0	15.0	5000.0
26	Hay Rake	1990.0	1350.0	1850.0	185.0	15.0	2000.0
27	Hay Rake	1979.0	750.0	1450.0	225.0	20.0	4000.0
28	Hay Tedder	1984.0	800.0	2200.0	220.0	15.0	3000.0
29	Hay Wagon	1981.0	500.0	900.0	90.0	20.0	1000.0
30	Hay Wagon	1982.0	500.0	950.0	95.0	20.0	1000.0
31	Forg Harv	1991.0	10500.0	17500.0	400.0	15.0	10000.0
32	Blower	1981.0	750.0	1700.0	170.0	20.0	3500.0
33	Forg Wagn	1978.0	1200.0	4500.0	300.0	25.0	8000.0
34	Forg Wagn	1982.0	1600.0	5500.0	300.0	25.0	8000.0
35	Forg Wagn	1987.0	3800.0	7500.0	750.0	25.0	9000.0
36	Gener 55kw	1983.0	2500.0	5109.0	511.0	20.0	6643.0
37	ATV 4 Wheel	1990.0	2300.0	2942.0	294.0	10.0	3883.0
38	Computer	1991.0	1300.0	3097.0	310.0	8.0	2555.0
39	Elevator	1979.0	400.0	885.0	88.0	20.0	1533.0
40	Mixer Unit	1983.0	1800.0	6200.0	620.0	16.0	9000.0
41	Milk Equip	1978.0	5000.0	25000.0	1000.0	25.0	40000.0
42	Bulk Tank	1991.0	10500.0	11000.0	500.0	25.0	10000.0
43	Milk Equip	1986.0	13000.0	22000.0	1000.0	20.0	20000.0
44	Feed Equip	1982.0	3000.0	7500.0	800.0	20.0	10000.0
45	Comp Feeder	1989.0	3500.0	8200.0	820.0	10.0	10000.0
46	Silo Unldr	1983.0	3500.0	6500.0	650.0	16.0	1000.0
47	MISC Equip	1982.0	100.0	354.0	35.0	20.0	7000.0
48	Replace Yr1	1983.0	100.0	319.0	32.0	10.0	7000.0
49	Replace Yr2	1984.0	100.0	146.0	15.0	10.0	7000.0
50	Replace Yr3	1985.0	100.0	354.0	35.0	10.0	7000.0
51	Replace Yr4	1986.0	100.0	319.0	32.0	10.0	7000.0
52	Replace Yr5	1987.0	100.0	146.0	15.0	10.0	7000.0

Table C.3. (Continued) FLIPSIM Parameters For the 150-Cow Farm.

ENTERPRISE COSTS	SEED	FERTILIZER	HERBICIDE	LITTER	OTHER COSTS	SUM OF CASH COSTS $/ACRE
Corn Silage	19.50	16.00	36.00	12.00	0.00	83.50
Corn Grain	19.50	16.00	36.00	12.00	23.40	106.90
Ryelage	18.75	0.00	0.00	0.00	10.20	28.95
Rye-Cover	11.75	0.00	0.00	0.00	10.20	21.95
Alfalfa Hay	0.00	58.00	21.75	0.00	0.00	79.75
Alfalfa-Plt	48.50	84.50	54.30	0.00	10.20	197.50
Grass Hay	0.00	10.00	4.00	18.00	0.00	32.00
Hay/Pasture	0.00	5.00	4.00	9.00	0.00	18.00
Pasture	0.00	0.00	2.00	4.50	0.00	6.50

PLANTED ACRES	1	2	3	4	5
Corn Silage	150.00	150.00	150.00	150.00	150.00
Ryelage	60.00	60.00	60.00	60.00	60.00
Rye-Cover	60.00	60.00	60.00	60.00	60.00
Alfalfa Hay	30.00	30.00	30.00	30.00	30.00
Alfalfa-Plt	10.00	10.00	10.00	10.00	10.00
Grass Hay	10.00	10.00	10.00	10.00	10.00
Hay/Pasture	60.00	60.00	60.00	60.00	60.00
Pasture	110.00	110.00	110.00	110.00	110.00

AVERAGE ANNUAL PRICES	1993	1994	1995	1996	1997
Corn Silage	27.50	27.50	27.50	27.50	27.50
Corn Grain	2.75	2.40	2.56	2.49	2.46
Ryelage	39.00	39.00	39.00	39.00	39.00
Alfalfa Hay	114.00	114.00	114.00	114.00	114.00
Grass Hay	81.00	81.00	81.00	81.00	81.00
Hay/Pasture	79.00	79.00	79.00	79.00	79.00
Pasture	77.00	77.00	77.00	77.00	77.00
Corn Dist	163.00	155.00	159.00	157.00	157.00
24% Conc	229.00	216.00	217.00	219.00	218.00
SBOM	281.00	259.00	262.00	266.00	265.00
Calf Starte	183.00	176.00	178.00	177.00	177.00
Milk Replac	80.29	79.90	79.75	80.11	80.05
Mineral	42.20	42.40	42.60	42.80	43.00

MARKETING STRATEGIES AND CROP LINKAGE	NORMAL FRAC ACRE HARVESTED	BEGINNING INVENTORY OF CROP	FRACTION SOLD NEXT TAX YEAR
Corn Silage	1.000	1417.000	0.000
Alfalfa Hay	1.000	88.000	0.000
Grass Hay	1.000	17.000	0.000
Hay/Pasture	1.000	86.000	0.000
Pasture	1.000	50.000	0.000

SUMMARY OF DAIRY INPUT DATA

INITIAL HERD INFORMATION	INITIAL HERD	DIE ANNUALLY		CULL/SELL ANNUALLY		SALE OR PURCHASE WEIGHT
	(NO.)	(NO.)	(FRAC)	(NO.)	(FRAC)	
LACTATING AND DRY COWS	150.0	3.0	0.025	54.0	0.360	1300.0
REPLACE. CALVES 0-12 MONTHS	168.0	3.0	0.055	96.0	0.575	100 & 450
REPLACE. HEIFERS 12-24 MONTH	69.0	1.0	0.015	8.0	0.120	900.0
REPLACE. HEIFERS 24+ MONTHS	20.0	0.0	0.000	0.0	0.000	1150.0
DAIRY BULLS	2.0	0.0	0.000	1.0	0.500	1600.0

AVERAGE CALVING INTERVAL, IN MONTHS	13.9
AVERAGE DAYS DRY	72.0
AVERAGE AGE AT FIRST CALVING	28.0
AVERAGE NUMBER OF DRY COWS	23.0
AVERAGE NUMBER OF CALVES BORN	168.0

Table C.3. (Continued) FLIPSIM Parameters For the 150-Cow Farm.

DAIRY PRODUCTION COSTS	
VET AND MEDICINE COSTS ($/COW)	45.0000
BREEDING COSTS ($/COW)	40.0000
MILK SUPPLIES ($/COW)	74.0000
DHIA & HERD TESTING COSTS ($/COW)	22.0000
LIVESTOCK COMMISSIONS ($/COW)	2.5000
BEDDING COSTS ($/COW)	13.0000
MISCELLANEOUS COSTS ($/COW)	34.5000
COOP RETAINS ($/CWT)	0.6290
PROMOTION ASSESSMENTS ($/CWT)	0.1500
MILK HAULING ($/CWT)	0.7200

INITIAL VALUE OF DAIRY HERD	
LACTATING AND DRY COWS	133719.0
0 TO 12 MONTH CALVES	29497.5
12 TO 24 MONTH HEIFERS	56347.8
24+ MONTH HEIFERS	24000.0
DAIRY BULLS	1400.0
TOTAL	244964.3

ANNUAL VALUES FOR:	1	2	3	4	5
PRICE OF MILK	13.2200	13.2500	12.5500	12.4500	12.5400
PRICE FOR CULL COWS	0.4484	0.4256	0.4024	0.3811	0.3512
PRICE FOR REPLACEMENTS	1200.0	1200.0	1200.0	1200.0	1200.0
PRICE FOR CALVES	0.9500	0.9500	0.9500	0.9500	0.9500
MILK PER COW	184.00	186.00	188.00	190.00	192.00
NUMBER OF COWS	150.00	150.00	150.00	150.00	150.00

DAIRY FEED REQUIREMENTS

127 LACT. COWS & 2 BULLS		1	2	3	4	5
Corn Silage	Ton	9.4200	9.4200	9.4200	9.4200	9.4200
Corn Grain	Bu	53.1000	53.1000	53.1000	53.1000	53.1000
Ryelage	Ton	1.4500	1.4500	1.4500	1.4500	1.4500
Alfalfa Hay	Ton	0.9600	0.9600	0.9600	0.9600	0.9600
Pasture	Ton	1.0000	1.0000	1.0000	1.0000	1.0000
Corn Dist	Ton	0.7450	0.7450	0.7450	0.7450	0.7450
24% Conc	Ton	0.8380	0.8380	0.8380	0.8380	0.8380
SBOM	Ton	0.1860	0.1860	0.1860	0.1860	0.1860
Mineral	Ton	1.0000	1.0000	1.0000	1.0000	1.0000

23 DRY COWS		1	2	3	4	5
Corn Silage	Ton	4.7900	4.7900	4.7900	4.7900	4.7900
Grass Hay	Ton	1.3500	1.3500	1.3500	1.3500	1.3500
Hay/Pasture	Ton	2.1000	2.1000	2.1000	2.1000	2.1000
Mineral	Ton	1.0000	1.0000	1.0000	1.0000	1.0000

69 0-12 MONTH CALVES		1	2	3	4	5
Corn Silage	Ton	2.3400	2.3400	2.3400	2.3400	2.3400
Corn Grain	Bu	5.4900	5.4900	5.4900	5.4900	5.4900
Alfalfa Hay	Ton	0.4100	0.4100	0.4100	0.4100	0.4100
Grass Hay	Ton	0.4200	0.4200	0.4200	0.4200	0.4200
SBOM	Ton	0.1790	0.1790	0.1790	0.1790	0.1790
Calf Starte	Ton	0.0380	0.0380	0.0380	0.0380	0.0380
Milk Replac	Cwt	0.5600	0.5600	0.5600	0.5600	0.5600

Table C.3. (Continued) FLIPSIM Parameters For the 150-Cow Farm.

60 12-24 MONTH HEIFERS		1	2	3	4	5
Corn Silage	Ton	6.2200	6.2200	6.2200	6.2200	6.2200
Hay/Pasture	Ton	1.1500	1.1500	1.1500	1.1500	1.1500
SBOM	Ton	0.4970	0.4970	0.4970	0.4970	0.4970

14 24+ MONTH HEIFERS		1	2	3	4	5
Corn Silage	Ton	7.0900	7.0900	7.0900	7.0900	7.0900
Hay/Pasture	Ton	1.0500	1.0500	1.0500	1.0500	1.0500
SBOM	Ton	0.5580	0.5580	0.5580	0.5580	0.5580

SUPPORT PRICE					
- P42	9.6300	9.6300	9.6300	9.6300	9.6300
ASSESSMENT FOR 1985 & 1990 PROGRAM					
- P47	0.1420	0.1500	0.1520	0.1400	0.1380

Table C.4. Yields and Prices For Co-Variance Matrix.

yld	CrSil	CrGrn	Ryelge	Rye	Alfal	AlfSd	GrHay	Hy/Pas	Past
MEAN									
1983	10.5	47.00	3.43	0.0	3.07	0.0	2.80	2.25	0.86
1984	17.5	110.00	3.50	0.0	2.90	0.0	1.91	1.47	0.58
1985	18.0	103.50	2.73	0.0	5.85	0.0	4.02	3.47	1.21
1986	10.0	49.00	2.44	0.0	3.52	0.0	2.18	1.85	0.61
1987	10.0	55.00	3.58	0.0	3.30	0.0	1.66	1.33	0.49
1988	12.0	73.50	3.16	0.0	3.94	0.0	2.58	1.89	0.68
1989	17.0	116.00	2.77	0.0	4.38	0.0	2.97	2.12	0.85
1990	14.0	115.00	3.53	0.0	4.48	0.0	3.08	2.38	0.81
1991	16.0	126.00	3.70	0.0	3.90	0.0	2.46	1.83	0.70
1992	17.0	112.00	2.70	0.0	4.61	0.0	3.26	2.83	0.97

Prc	CrSil	CrGrn	Ryelge	Rye	Alfal	AlfSd	GrHay	Hy/Pas	Past
MEAN									
1983	28.0	3.70	25.0	0.0	114.0	0.0	74.0	72.0	70.0
1984	28.5	2.90	25.5	0.0	117.0	0.0	77.7	75.7	73.7
1985	29.0	2.40	26.0	0.0	102.0	0.0	82.0	80.0	78.0
1986	27.0	1.70	26.5	0.0	115.0	0.0	92.5	90.5	78.5
1987	29.5	2.05	27.0	0.0	113.0	0.0	83.0	81.0	79.0
1988	30.0	2.90	29.5	0.0	112.0	0.0	79.5	77.5	75.5
1989	29.0	2.60	28.0	0.0	113.0	0.0	82.5	80.5	78.5
1990	29.5	2.51	28.5	0.0	116.0	0.0	83.5	81.5	79.5
1991	30.0	2.60	29.0	0.0	115.0	0.0	82.0	80.0	78.0
1992	28.5	2.25	26.5	0.0	114.0	0.0	81.0	79.0	77.0

Prc	Other	CrMeal	Conc	SBOM	CfStr	MkRepl	Minerl
Mean							
1983	0	174.0	230.0	283.	120.0	.8970	40.0
1984	0	187.0	227.0	271.	130.0	.9480	41.0
1985	0	164.0	195.0	221.	140.0	.9500	43.0
1986	0	147.0	199.0	230.	122.0	.9470	42.0
1987	0	134.0	203.0	241.	110.0	.9190	41.5
1988	0	152.0	249.0	322.	105.0	.8550	41.0
1989	0	162.0	247.0	325.	126.0	.8150	40.5
1990	0	157.0	232.0	270.	130.0	.8130	41.5
1991	0	160.0	224.0	262.	129.0	.8230	42.0
1992	0	165.0	231.0	271.	122.0	1.100	42.5

	CULLPR	CALVES	STEER	FEEDER	MILKPR	MILKPD
Mean						
1983	37.20	54.30	1050.0		13.90	120.35
1984	36.30	52.60	930.0		13.90	119.70
1985	34.40	55.10	885.0		13.40	128.17
1986	32.90	55.50	850.0		13.00	135.28
1987	41.10	71.10	895.0		13.50	134.60
1988	44.30	82.10	960.0		13.30	138.83
1989	47.00	81.40	950.0		14.20	139.23
1990	49.50	84.40	1050.0		15.00	142.13
1991	47.60	88.70	1060.0		13.30	146.14
1992	43.90	80.60	1100.0		14.40	149.56

Appendix D: Individual EPIC Model Results

Table D.1. Summary of Estimated Mean Field Level Nutrient Losses Per Farm Acre.

Crop	Acres	Soil Erosion (tons/acre)	Nitrogen Volatilized (lbs./acre)	Surface N Losses (lbs./acre)	Subsurface N Losses (lbs./acre)	Total N Losses (lbs./acre)	Phosphorus Losses (lbs./acre)
60-Cow Dairy							
BASE	110	1.45	44.8	4.7	22.1	26.8	4.7
INCORP	110	1.53	42.0	4.7	22.4	27.1	4.4
NLIMIT	110	1.45	41.4	4.7	14.0	18.7	4.4
PLIMIT	110	1.45	22.4	4.4	13.7	18.1	3.0
100-Cow Dairy							
BASE	195	1.7	39.6	5.6	24.9	30.5	5.0
INCORP	195	1.8	36.4	5.5	25.4	30.9	4.7
NLIMIT	195	1.7	35.7	5.6	15.3	20.9	4.7
PLIMIT	195	1.7	20.0	5.2	14.9	20.1	3.3
150-Cow Dairy							
BASE	370	1.44	30.1	4.7	15.8	20.5	4.0
INCORP	370	1.54	27.1	4.6	16.5	21.1	3.7
NLIMIT	370	1.44	28.3	4.7	12.2	16.9	3.9
PLIMIT	370	1.47	15.9	4.5	11.6	16.1	2.9
60-Cow D/P							
BASE	110	1.43	53.0	4.9	36.0	40.9	5.3
INCORP	110	1.48	50.4	4.8	36.7	41.5	4.8
NLIMIT	110	1.15	43.1	4.8	15.8	20.6	4.5
PLIMIT	110	1.45	22.4	4.4	13.7	18.1	3.0
100-Cow D/P							
BASE	195	1.7	42.1	5.7	26.5	32.2	5.2
INCORP	195	1.7	39.0	5.5	27.2	32.7	4.7
NLIMIT	195	1.7	40.2	5.7	17.8	23.5	4.9
PLIMIT	195	1.7	20.0	5.2	14.9	20.1	3.3

Table D.2. Statistical Values of Yields and Nutrient Losses for 60-Cow Dairy Farm.[1]

	Annual Yields (tons/acre)	Annual Erosion Losses (tons/acre)	Annual Volatilization Losses (lbs/acre)	Annual Surface Nit Losses (lbs/acre)	Annual Subsurface Nit Losses (lbs/acre)	Annual Phosphorus Losses (lbs/acre)
BASE - NT Corn Silage/MT Ryelage (N=211)						
Mean	13.7/3.2	2.83	66.44	9.68	9.19	7.31
Maximum	20.3/4.4	3.69	72.63	12.69	23.23	9.54
Minimum	6.0/2.3	1.61	61.69	5.05	3.86	3.75
St Deviation	3.5/0.5	0.47	2.86	1.69	3.03	1.26
Coef of Variation	25.8/15.3	16.77	4.30	17.49	32.95	17.21
INCORP - MT Corn Silage/MT Ryelage (N=224)						
Mean	13.7/3.2	3.03	59.28	9.53	9.99	6.36
Maximum	20.3/4.4	3.99	64.91	12.64	26.83	8.52
Minimum	6.0/2.3	1.64	54.00	4.88	4.97	3.47
St Deviation	3.5/0.5	0.55	2.63	1.80	3.43	1.14
Coef of Variation	25.9/15.2	18.08	4.44	18.85	34.36	17.96
PLIMIT - NT Corn Silage/MT Ryelage (N=211)						
Mean	13.6/3.5	2.96	35.76	9.32	9.68	5.30
Maximum	20.2/4.4	3.93	42.09	14.31	24.03	7.19
Minimum	5.9/2.4	1.62	31.75	4.70	4.41	2.74
St Deviation	3.6/0.4	0.55	2.50	2.25	3.12	1.00
Coef of Variation	26.1/11.9	17.47	6.98	24.13	33.71	18.80
BASE - MT Corn Silage/NT Ryelage (N=211)						
Mean	13.7/3.1	2.89	64.70	9.55	9.30	6.77
Maximum	20.3/4.4	4.04	71.49	13.55	24.03	9.55
Minimum	6.0/2.0	1.71	57.89	5.62	4.41	4.31
St Deviation	3.5/0.6	0.49	2.75	1.69	3.12	1.13
Coef of Variation	25.9/18.0	17.11	4.25	17.69	33.51	16.64
PLIMIT - MT Corn Silage/NT Ryelage (N=211)						
Mean	13.7/3.4	2.74	34.24	8.51	9.90	4.94
Maximum	20.3/3.4	3.96	38.75	13.10	25.83	7.27
Minimum	5.9/2.4	1.41	28.30	4.18	4.27	2.59
St Deviation	3.5/0.4	0.49	2.11	1.74	3.41	0.90
Coef of Variation	25.9/12.1	18.05	6.17	20.39	34.50	18.15
BASE - Hay/Pasture (N=138)						
Mean	2.77	0.10	49.18	0.96	55.32	3.83
Maximum	4.54	0.19	51.66	1.92	70.45	5.12
Minimum	1.25	0.04	45.70	0.39	41.84	2.01
St Deviation	0.70	0.04	1.48	0.39	6.00	0.69
Coef of Variation	25.40	42.62	3.02	40.08	10.85	18.14
NLIMIT- Hay/Pasture (N=103)						
Mean	2.77	0.11	39.86	0.92	31.29	3.04
Maximum	4.55	0.19	41.90	1.94	44.83	4.32
Minimum	1.28	0.04	36.73	0.37	22.22	1.58
St Deviation	0.70	0.05	1.21	0.39	5.04	0.56
Coef of Variation	25.38	43.24	3.03	41.83	16.11	18.60
PLIMIT - Hay/Pasture (N=100)						
Mean	2.75	0.12	18.35	0.96	31.13	1.22
Maximum	4.53	0.23	20.00	3.13	45.04	1.82
Minimum	1.23	0.05	16.19	0.38	19.65	0.63
St Deviation	0.70	0.05	0.85	0.55	5.46	0.24
Coef of Variation	25.52	44.95	4.62	57.26	17.53	20.11

[1] Crop yields are individual annual EPIC simulation yields. Nutreint losses are annual results from the five-year EPIC simulation.

Table D.2. (Continued) Statistical Values of Yields and Nutrient Losses for 60-Cow Dairy Farm.

	Annual Yields (tons/acre)	Annual Erosion Losses (tons/acre)	Annual Volatilization Losses (lbs/acre)	Annual Surface Nit Losses (lbs/acre)	Annual Subsurface Nit Losses (lbs/acre)	Annual Phosphorus Losses (lbs/acre)
BASE - Improved Pasture (N=137)						
Mean	1.80	0.08	51.88	0.48	69.51	4.10
Maximum	2.67	0.13	53.91	0.89	82.06	5.43
Minimum	0.80	0.03	49.17	0.19	54.84	1.95
St Deviation	0.41	0.02	1.26	0.13	6.59	0.70
Coef of Variation	22.78	25.57	2.42	27.72	9.48	17.12
NLIMIT - Improved Pasture (N=68)						
Mean	1.79	0.09	32.60	0.43	28.58	2.35
Maximum	2.63	0.15	34.09	0.75	36.63	3.12
Minimum	0.80	0.03	30.54	0.16	21.46	1.12
St Deviation	0.41	0.02	0.77	0.11	4.05	0.40
Coef of Variation	22.73	27.05	2.35	26.60	14.17	16.93
PLIMIT - Improved Pasture (N=60)						
Mean	1.78	0.10	19.59	0.42	22.92	1.17
Maximum	2.63	0.17	21.03	0.86	31.62	1.54
Minimum	0.79	0.03	17.65	0.15	16.49	0.57
St Deviation	0.40	0.03	0.63	0.14	3.48	0.20
Coef of Variation	22.43	28.11	3.21	33.76	15.17	16.93
BASE - Unimproved Pasture						
Mean	1.07	0.30	6.99	0.67	4.12	0.32
Maximum	2.21	0.52	7.51	1.27	6.95	0.50
Minimum	0.41	0.12	6.45	0.27	1.01	0.13
St Deviation	0.36	0.08	0.27	0.20	1.35	0.08
Coef of Variation	34.12	27.81	3.79	29.91	32.78	24.61

Table D.3. Statistical Values of Yields and Nutrient Losses for 60-Cow Dairy/Poultry Farm.[1]

	Annual Yields (tons/acre)	Annual Erosion Losses (tons/acre)	Annual Volatilization Losses (lbs./acre)	Annual Surface Nit Losses (lbs./acre)	Annual Subsurface Nit Losses (lbs./acre)	Annual Phosphorus Losses (lbs./acre)
BASE - NT Corn Silage/MT Ryelage (N=281)						
Mean	13.7/3.6	2.78	81.03	10.21	30.79	8.43
Maximum	20.3/4.5	3.65	88.65	13.76	66.87	11.20
Minimum	6.1/2.4	1.72	74.34	5.96	14.63	4.82
St Deviation	3.5/0.5	0.44	3.54	1.71	10.49	1.38
Coef of Variation	25.8/12.7	15.67	4.37	16.76	34.06	16.37
INCORP - MT Corn Silage/MT Ryelage (N=293)						
Mean	13.7/3.6	2.93	74.17	9.66	32.37	6.94
Maximum	20.3/4.6	3.93	81.85	13.19	71.27	9.42
Minimum	6.0/2.4	1.76	68.02	5.72	17.43	4.37
St Deviation	3.5/0.5	0.48	3.51	1.69	10.70	1.13
Coef of Variation	25.8/12.8	16.26	4.73	17.51	33.04	16.34
NLIMIT - NT Corn Silage/MT Ryelage (N=230)						
Mean	13.7/3.3	2.82	70.27	9.84	13.18	7.60
Maximum	20.3/4.4	3.67	76.59	12.85	32.24	9.96
Minimum	6.0/2.4	1.61	65.10	5.11	6.42	3.89
St Deviation	3.5/0.5	0.47	2.99	1.70	4.61	1.30
Coef of Variation	25.9/13.7	16.54	4.25	17.27	35.00	17.11
BASE - MT Corn Silage/NT Ryelage (N=281)						
Mean	13.7/3.6	2.83	78.81	9.87	31.00	7.52
Maximum	20.3/4.6	3.60	87.46	12.63	67.67	9.78
Minimum	6.0/2.4	1.74	71.93	5.86	16.03	4.92
St Deviation	3.5/0.5	0.48	3.58	1.74	10.07	1.24
Coef of Variation	25.8/12.6	16.90	4.54	17.68	32.50	16.51
NLIMIT - MT Corn Silage/NT Ryelage (N=230)						
Mean	13.7/3.3	2.89	68.38	9.69	13.52	6.99
Maximum	20.3/4.4	4.02	75.68	13.66	34.24	9.80
Minimum	6.0/2.1	1.76	61.56	5.67	6.96	4.48
St Deviation	3.5/0.5	0.49	2.97	1.72	4.57	1.16
Coef of Variation	25.8/15.3	16.98	4.34	17.74	33.82	16.54
BASE - Hay/Pasture (N=161)						
Mean	2.77	0.10	55.19	0.95	70.71	4.35
Maximum	4.54	0.18	58.37	1.90	84.27	5.53
Minimum	1.25	0.04	51.30	0.41	54.85	2.30
St Deviation	0.70	0.04	1.71	0.38	6.62	0.73
Coef of Variation	25.35	40.91	3.11	39.62	9.36	16.81
BASE - Improved Pasture (N=160)						
Mean	1.83	0.08	58.02	0.53	84.02	4.69
Maximum	2.72	0.13	60.63	1.00	98.07	6.21
Minimum	0.84	0.03	54.98	0.21	67.65	2.50
St Deviation	0.41	0.02	1.49	0.15	7.05	0.80
Coef of Variation	22.56	25.30	2.58	28.65	8.39	17.09

[1] Crop yields are individual annual EPIC simulation yields. Nutreint losses are annual results from the five-year EPIC simulation.

Table D.4. Statistical Values of Mean Yields and Nitrogen Losses for 100-Cow Dairy Farm.[1]

	Annual Yields (tons/acre)	Annual Erosion Losses (tons/acre)	Annual Volatilization Losses (lbs./acre)	Annual Surface Nit Losses (lbs./acre)	Annual Subsurface Nit Losses (lbs./acre)	Annual Phosphorus Losses (lbs./acre)
BASE - NT Corn Silage/MT Ryelage (N=180)						
Mean	13.7/2.9	2.93	51.72	9.49	5.56	6.60
Maximum	20.2/4.4	3.77	57.20	12.05	9.19	8.39
Minimum	6.0/1.8	1.63	47.71	4.87	2.63	3.35
St Deviation	3.5/0.7	0.50	2.31	1.67	1.43	1.16
Coef of Variation	25.8/23.1	16.92	4.47	17.61	25.66	17.59
INCORP - MT Corn Silage/MT Ryelage (N=190)						
Mean	13.7/2.9	3.12	45.31	9.46	5.89	5.95
Maximum	20.2/4.4	4.12	49.22	12.43	10.42	7.98
Minimum	6.0/1.9	1.65	40.75	4.76	2.49	3.16
St Deviation	3.5/0.7	0.57	2.02	1.80	1.49	1.10
Coef of Variation	25.9/22.6	18.41	4.46	19.07	25.36	18.45
PLIMIT - NT Corn Silage/MT Ryelage (N=180)						
Mean	13.5/3.4	3.01	30.73	9.24	6.06	5.17
Maximum	19.3/4.4	4.00	36.21	14.25	10.97	7.01
Minimum	5.9/2.4	1.65	27.34	4.68	2.61	2.69
St Deviation	3.5/0.4	0.55	2.15	2.23	1.72	0.96
Coef of Variation	25.5/11.97	18.43	6.98	24.15	28.43	18.66
BASE - MT Corn Silage/NT Ryelage (N=180)						
Mean	13.7/2.8	2.95	50.26	9.30	5.50	6.19
Maximum	20.3/4.4	4.16	55.37	13.31	9.40	8.83
Minimum	6.1.6/1.6	1.64	44.47	4.94	2.48	3.55
St Deviation	3.5/0.7	0.52	2.17	1.67	1.41	1.06
Coef of Variation	25.8/26.5	17.51	4.31	17.99	25.67	17.22
PLIMIT - MT Corn Silage/NT Ryelage (N=180)						
Mean	13.6/3.3	2.78	29.42	8.44	6.04	4.82
Maximum	19.7/4.4	4.02	33.25	12.83	11.22	7.09
Minimum	5.9/2.4	1.42	24.31	4.15	2.61	2.51
St Deviation	3.5/0.4	0.51	1.80	1.73	1.75	0.88
Coef of Variation	25.6/12.7	18.28	6.10	20.44	29.00	18.34
BASE - NT Corn Silage/MT Rye Cover (N=180)						
Mean	13.76	3.26	49.46	11.22	13.38	7.75
Maximum	20.27	4.31	54.57	14.64	38.06	10.61
Minimum	6.32	1.58	44.69	5.02	5.55	3.17
St Deviation	3.52	0.62	2.43	2.22	5.73	1.64
Coef of Variation	25.59	19.00	4.92	19.78	42.85	21.09
INCORP - MT Corn Silage/MT Rye Cover (N=190)						
Mean	13.69	3.34	38.78	10.55	16.34	6.35
Maximum	20.25	4.33	42.47	14.21	46.47	8.74
Minimum	6.08	1.66	34.35	4.98	7.42	2.97
St Deviation	3.49	0.64	2.00	2.14	7.25	1.29
Coef of Variation	25.47	19.06	5.16	20.25	44.36	20.39
NLIMIT - NT Corn Silage/MT Rye Cover (N=160)						
Mean	13.75	3.27	49.69	11.17	8.66	7.75
Maximum	20.27	4.32	55.32	14.56	26.24	10.60
Minimum	6.40	1.57	44.98	4.95	3.60	3.14
St Deviation	3.51	0.62	2.50	2.20	3.62	1.63
Coef of Variation	25.57	19.06	5.03	19.72	41.78	21.08
PLIMIT - NT Corn Silage/MT Rye Cover (N=160)						
Mean	13.75	3.29	30.05	10.42	8.69	5.98
Maximum	20.27	4.34	34.98	13.53	24.85	7.87
Minimum	6.40	1.59	26.86	4.70	4.22	2.76
St Deviation	3.51	0.63	2.12	2.03	3.24	1.16
Coef of Variation	25.57	19.04	7.05	18.53	37.26	19.33

[1] Crop yields are individual annual EPIC simulation yields. Nutreint losses are annual results from the five-year EPIC simulation.

Table D.4. (Continued) Statistical Values of Yields and Nitrogen Losses for the 100-Cow Dairy Farm.

	Annual Yields (tons/acre)	Annual Erosion Losses (tons/acre)	Annual Volatilization Losses (lbs./acre)	Annual Surface Nit Losses (lbs./acre)	Annual Subsurface Nit Losses (lbs./acre)	Annual Phosphorus Losses (lbs./acre)
BASE - MT Corn Silage/NT Rye Cover (N=180)						
Mean	13.70	3.29	41.38	10.88	15.48	6.82
Maximum	20.25	4.59	45.77	15.19	43.87	9.53
Minimum	6.10	1.60	36.64	5.11	7.22	3.28
St Deviation	3.48	0.60	2.06	2.05	6.95	1.27
Coef of Variation	25.42	18.25	4.97	18.81	44.89	18.63
NLIMIT - MT Corn Silage/NT Rye Cover (N=160)						
Mean	13.70	3.30	41.49	10.83	10.66	6.82
Maximum	20.24	4.60	45.86	15.11	32.65	9.53
Minimum	6.26	1.60	36.74	5.07	4.91	3.28
St Deviation	3.47	0.61	2.04	2.03	4.81	1.27
Coef of Variation	25.35	18.32	4.91	18.75	45.09	18.65
PLIMIT - MT Corn Silage/NT Rye Cover (N=160)						
Mean	13.69	3.12	29.25	9.73	9.59	5.55
Maximum	20.25	4.43	33.21	13.84	27.65	7.88
Minimum	6.28	1.43	24.35	4.34	4.95	2.63
St Deviation	3.47	0.60	1.98	1.91	3.83	1.06
Coef of Variation	25.34	19.35	6.77	19.59	39.92	19.15
BASE - Hay/Pasture (N=160)						
Mean	2.77	0.10	55.20	1.00	72.70	4.36
Maximum	4.54	0.18	58.40	2.00	93.26	5.92
Minimum	1.25	0.04	51.28	0.41	56.25	2.33
St Deviation	0.70	0.04	1.71	0.40	6.89	0.79
Coef of Variation	25.36	41.91	3.10	39.73	9.48	18.14
NLIMIT - Hay/Pasture (N=102)						
Mean	2.76	0.11	40.06	0.96	39.48	3.15
Maximum	4.53	0.20	42.05	2.00	52.85	4.45
Minimum	1.24	0.04	37.13	0.38	29.43	1.65
St Deviation	0.70	0.05	1.18	0.40	5.27	0.59
Coef of Variation	25.47	43.50	2.95	41.88	13.35	18.63
PLIMIT - Hay/Pasture PLIMIT (N=100)						
Mean	2.75	0.12	18.35	0.99	38.13	1.32
Maximum	4.53	0.23	20.00	3.17	52.24	1.99
Minimum	1.23	0.05	16.19	0.39	26.63	0.69
St Deviation	0.70	0.05	0.85	0.56	5.49	0.27
Coef of Variation	25.52	44.96	4.62	56.61	14.40	20.48
BASE - Improved Pasture (N=138)						
Mean	1.80	0.10	25.93	0.48	30.29	2.78
Maximum	2.63	0.17	27.81	0.87	41.03	3.70
Minimum	0.80	0.03	24.46	0.17	21.13	1.31
St Deviation	0.41	0.03	0.81	0.14	4.79	0.49
Coef of Variation	22.78	28.92	3.13	28.91	15.81	17.77
NLIMIT -Pasture (N=69)						
Mean	1.79	0.11	19.49	0.46	19.78	2.18
Maximum	2.63	0.18	20.89	0.81	27.69	2.92
Minimum	0.80	0.03	18.43	0.16	13.36	1.03
St Deviation	0.41	0.03	0.59	0.13	3.57	0.39
Coef of Variation	22.78	29.43	3.02	28.29	18.06	17.75
PLIMIT - Pasture (N=60)						
Mean	1.76	0.13	0.00	0.44	17.73	0.35
Maximum	2.58	0.21	0.00	0.85	26.64	0.52
Minimum	0.79	0.04	0.00	0.14	11.67	0.15
St Deviation	0.40	0.04	0.00	0.16	3.40	0.08
Coef of Variation	22.69	29.32	0.00	35.41	19.17	23.00

Table D.5. Statistical Values of Yields and Nutrient Losses for 100-Cow Dairy/Poultry Farm.[1]

	Annual Yields (tons/acre)	Annual Erosion Losses (tons/acre)	Annual Volatilizatio Losses (lbs./acre)	Annual Surface Nit Losses (lbs./acre)	Annual Subsurface Nit Losses (lbs./acre)	Annual Phosphorus Losses (lbs./acre)
BASE - NT Corn Silage/MT Ryelage (N=226)						
Mean	13.7/3.2	2.86	61.58	9.71	11.78	7.25
Maximum	20.3/4.4	3.73	67.07	12.69	29.24	9.42
Minimum	6.0/2.2	1.63	56.98	5.08	5.61	3.73
St Deviation	3.5/0.5	0.48	3.64	1.69	3.86	1.23
Coef of Variation	25.9/15.8	16.73	4.29	17.38	32.80	17.04
INCORP - MT Corn Silage/MT Ryelage (N=238)						
Mean	13.7/3.2	3.02	55.40	9.46	12.76	6.27
Maximum	20.3/4.4	4.04	60.83	12.71	32.24	8.51
Minimum	6.0/2.2	1.66	50.72	4.91	6.62	4.47
St Deviation	3.5/0.5	0.52	3.48	1.72	4.27	1.10
Coef of Variation	25.9/15.5	17.22	4.48	18.15	33.45	17.51
NLIMIT - NT Corn Silage/MT Ryelage (N=232)						
Mean	13.7/3.4	2.80	65.32	9.72	16.50	7.46
Maximum	20.3/4.4	3.71	71.14	12.94	39.45	9.84
Minimum	6.0/2.3	1.63	60.32	5.14	7.21	3.87
St Deviation	3.5/0.5	0.42	2.79	1.59	5.75	1.24
Coef of Variation	25.9/13.8	15.14	4.27	16.36	34.84	16.63
BASE - MT Corn Silage/NT Ryelage (N=226)						
Mean	13.7/3.2	2.91	59.96	9.55	12.04	6.68
Maximum	20.3/4.4	4.07	66.20	13.50	30.24	9.42
Minimum	6.0/2.0	1.73	53.98	5.60	5.81	4.24
St Deviation	3.5/0.6	0.50	2.55	1.70	3.94	1.11
Coef of Variation	25.9/17.6	17.04	4.25	17.76	32.75	16.63
NLIMIT - MT Corn Silage/NT Ryelage (N=232)						
Mean	13.7/3.3	2.90	63.66	9.65	16.89	6.87
Maximum	20.3/4.4	4.04	70.30	13.64	41.05	9.66
Minimum	6.0/2.1	1.77	57.58	5.65	7.62	4.41
St Deviation	3.5/0.5	0.49	2.76	1.70	5.79	1.13
Coef of Variation	25.8/14.9	16.89	4.34	17.66	34.26	16.42

Table D.6. Statistical Values of Yields and Nutrient Losses for 150-Cow Dairy Farm.

	Crop Yields (tons/acre)	Annual Erosion Losses (tons/acre)	Annual Volatilization Losses (lbs./acre)	Annual Surface Nit Losses (lbs./acre)	Annual Subsurface Nit Losses (lbs./acre)	Annual Phosphorus Losses (lbs./acre)
BASE - NT Corn Silage/MT Ryelage (N=170)						
Mean	13.6/2.7	2.99	46.81	9.55	4.77	6.60
Maximum	19.9/4.4	3.84	51.53	12.39	7.94	8.78
Minimum	6.1/1.7	1.65	43.32	4.87	2.36	3.33
St Deviation	3.5/0.7	0.52	2.06	1.73	1.19	1.19
Coef of Variation	25.7/26.3	17.46	4.39	18.14	24.99	18.10
INCORP - MT Corn Silage/MT Ryelage (N=178)						
Mean	13.7/2.8	3.16	41.41	9.50	4.96	5.95
Maximum	20.1/4.4	4.23	45.13	12.65	8.13	8.05
Minimum	6.0/1.7	1.67	37.46	4.77	2.42	3.15
St Deviation	3.5/0.7	0.59	1.84	1.82	1.24	1.10
Coef of Variation	25.8/26.0	18.51	4.44	19.14	24.95	18.52
PLIMIT - NT Corn Silage/MT Ryelage (N=170)						
Mean	13.3/3.3	3.06	25.68	9.21	3.98	5.09
Maximum	18.6/4.4	4.08	30.27	14.31	6.88	6.94
Minimum	5.9/2.4	1.68	22.86	4.70	2.01	2.68
St Deviation	3.2/0.4	0.55	1.79	2.19	1.14	0.93
Coef of Variation	24.2/12.5	18.03	6.96	23.73	28.62	18.21
BASE - MT Corn Silage/NT Ryelage (N=170)						
Mean	13.7/2.6	2.97	45.51	9.26	4.70	6.11
Maximum	20.1/4.4	4.17	50.03	13.16	7.52	8.68
Minimum	6.1/1.5	1.65	40.53	4.92	2.16	3.49
St Deviation	3.5/0.8	0.52	1.94	1.67	1.22	1.05
Coef of Variation	25.8/29.8	17.45	4.25	17.99	25.84	17.17
PLIMIT - MT Corn Silage/NT Ryelage (N=160)						
Mean	13.5/3.2	3.05	24.58	9.13	4.94	5.14
Maximum	19.1/4.4	4.30	27.77	13.51	8.95	7.36
Minimum	5.9/2.4	1.63	20.31	4.69	2.39	2.77
St Deviation	3.4/0.4	0.56	1.49	1.85	1.44	0.93
Coef of Variation	25.1/13.6	18.22	6.08	20.25	29.11	18.16
BASE - NT Corn Silage/MT Rye Cover (N=170)						
Mean	13.76	3.41	45.48	11.45	11.82	7.81
Maximum	20.25	4.42	50.43	15.10	33.85	10.79
Minimum	6.71	1.63	40.99	5.10	4.56	3.19
St Deviation	3.49	0.63	2.26	2.19	5.10	1.59
Coef of Variation	25.35	18.41	4.97	19.17	43.11	20.34
INCORP - MT Corn Silage/MT Rye Cover (N=178)						
Mean	13.69	3.46	32.33	10.74	15.11	6.45
Maximum	20.24	4.60	35.64	14.91	42.46	9.09
Minimum	6.51	1.72	28.92	5.09	6.17	3.01
St Deviation	3.48	0.70	1.55	2.27	6.62	1.37
Coef of Variation	25.41	20.20	4.80	21.13	43.80	21.18
NLIMIT - NT Corn Silage/MT Rye Cover (N=160)						
Mean	13.72	3.41	45.54	11.42	10.13	7.81
Maximum	20.27	4.43	50.61	15.08	29.45	10.79
Minimum	6.28	1.64	41.05	5.09	4.03	3.19
St Deviation	3.52	0.63	2.28	2.18	4.35	1.59
Coef of Variation	25.68	18.44	5.00	19.11	42.96	20.34

[1] Crop yields are individual annual EPIC simulation yields. Nutreint losses are annual results from the five-year EPIC simulation.

Table D.6. (Continued) Statistical Values of Mean Yields and Nutrient Losses for 150-Cow Dairy Farm.

	Crop Yields (tons/acre)	Annual Erosion Losses (tons/acre)	Annual Volatilization Losses (lbs./acre)	Annual Surface Nit Losses (lbs./acre)	Annual Subsurface Nit Losses (lbs./acre)	Annual Phosphorus Losses (lbs./acre)
PLIMIT - NT Corn Silage/MT Rye Cover (N=160)						
Mean	13.72	3.29	30.19	10.46	10.34	5.98
Maximum	20.23	4.36	33.86	13.64	31.05	7.87
Minimum	6.19	1.59	26.80	4.77	5.06	2.75
St Deviation	3.51	0.63	1.70	2.03	4.20	1.16
Coef of Variation	25.56	19.00	5.65	19.42	40.60	19.31
BASE - MT Corn Silage/NT Rye Cover (N=170)						
Mean	13.69	3.40	36.71	11.03	14.11	6.87
Maximum	20.24	4.73	39.81	15.34	39.26	9.68
Minimum	6.57	1.64	32.29	5.15	5.48	3.26
St Deviation	3.48	0.61	1.70	2.04	6.32	1.27
Coef of Variation	25.38	17.98	4.64	18.50	44.77	18.49
NLIMIT - MT Corn Silage/NT Rye Cover (N=160)						
Mean	13.70	3.41	36.77	10.96	10.82	6.86
Maximum	20.24	4.43	39.85	14.34	31.45	9.07
Minimum	6.78	1.64	32.30	5.12	4.23	3.26
St Deviation	3.47	0.61	1.72	1.99	4.85	1.25
Coef of Variation	25.33	17.77	4.67	18.20	44.87	18.23
PLIMIT - MT Corn Silage/NT Rye Cover (N=160)						
Mean	13.69	3.53	24.80	10.78	9.99	6.08
Maximum	20.23	4.59	27.61	14.10	27.85	8.05
Minimum	6.76	1.66	20.14	4.96	4.66	2.94
St Deviation	3.47	0.65	1.59	2.02	4.06	1.11
Coef of Variation	25.33	18.32	6.43	18.59	40.08	18.21
BASE - NT Corn Silage/No Rye Cover (N=161)						
Mean	13.74	2.92	56.33	13.10	28.71	9.61
Maximum	20.32	3.77	59.71	17.19	56.05	12.65
Minimum	7.07	1.46	52.79	6.22	14.42	4.54
St Deviation	3.52	0.49	1.71	2.36	10.35	1.72
Coef of Variation	25.64	16.94	3.03	18.04	36.06	17.92
INCORP - MT Corn Silage/No Rye Cover (N=187)						
Mean	13.70	4.03	37.61	12.10	36.39	7.31
Maximum	20.22	5.08	41.14	15.99	67.06	9.80
Minimum	7.23	2.30	34.54	6.45	19.63	3.83
St Deviation	3.46	0.66	1.66	2.18	11.39	1.29
Coef of Variation	25.29	16.29	4.40	18.04	31.29	17.66
NLIMIT - NT Corn Silage/No Rye Cover (N=124)						
Mean	13.73	2.95	54.62	13.00	20.72	9.40
Maximum	20.21	3.64	58.98	16.50	45.44	12.29
Minimum	7.07	1.49	50.13	6.36	7.10	4.39
St Deviation	3.51	0.49	2.10	2.29	8.85	1.69
Coef of Variation	25.54	16.65	3.84	17.61	42.68	17.98
PLIMIT - NT Corn Silage/No Rye Cover (N=130)						
Mean	13.71	2.99	35.33	11.44	20.63	6.81
Maximum	20.14	3.69	37.85	14.36	45.84	8.74
Minimum	7.03	1.52	32.55	5.68	6.71	3.34
St Deviation	3.50	0.49	1.27	1.98	9.05	1.17
Coef of Variation	25.51	16.45	3.60	17.33	43.86	17.12

Table D.6. (Continued) Statistical Values of Mean Yields and Nutrient Losses for 150-Cow Dairy Farm.

	Crop Yields (tons/acre)	Annual Erosion Losses (tons/acre)	Annual Volatilization Losses (lbs./acre)	Annual Surface Nit Losses (lbs./acre)	Annual Subsurface Nit Losses (lbs./acre)	Annual Phosphorus Losses (lbs./acre)
BASE - MT Corn Silage/No Rye Cover (N=170)						
Mean	13.69	3.58	39.30	11.20	37.51	7.16
Maximum	20.22	4.41	44.71	14.33	68.26	9.14
Minimum	7.30	1.80	35.70	5.44	21.03	3.57
St Deviation	3.48	0.60	2.15	2.02	11.51	1.22
Coef of Variation	25.41	16.73	5.47	18.06	30.70	17.09
NLIMIT - MT Corn Silage/No Rye Cover (N=128)						
Mean	13.7	3.70	30.37	11.27	25.00	6.89
Maximum	20.18	4.73	36.25	15.11	53.04	9.28
Minimum	7.30	1.94	26.46	5.74	11.77	3.43
St Deviation	3.46	0.63	2.54	2.07	9.83	1.24
Coef of Variation	25.25	17.06	8.35	18.37	39.32	17.95
NLIMIT - MT Corn Silage/No Rye Cover (N=128)						
Mean	13.7	3.70	30.37	11.27	25.00	6.89
Maximum	20.18	4.73	36.25	15.11	53.04	9.28
Minimum	7.30	1.94	26.46	5.74	11.77	3.43
St Deviation	3.46	0.63	2.54	2.07	9.83	1.24
Coef of Variation	25.25	17.06	8.35	18.37	39.32	17.95
PLIMIT - MT Corn Silage/No Rye Cover (N=130)						
Mean	13.69	3.84	19.75	11.19	22.15	6.21
Maximum	20.12	5.01	23.10	15.24	48.24	8.40
Minimum	7.25	1.98	17.52	5.60	8.93	3.12
St Deviation	3.45	0.67	1.48	2.09	9.27	1.12
Coef of Variation	25.22	17.49	7.51	18.67	41.86	18.01
BASE - Grass Hay (N=169)						
Mean	2.93	0.03	59.16	0.45	64.38	0.92
Maximum	5.03	0.06	63.72	0.88	88.65	1.90
Minimum	1.63	0.01	52.09	0.10	44.24	0.36
St Deviation	0.62	0.01	3.04	0.17	8.35	0.28
Coef of Variation	21.20	5.14	37.06	37.06	12.98	30.94
NLIMIT - Grass Hay (N=118)						
Mean	2.92	0.03	44.54	0.45	39.55	0.77
Maximum	5.02	0.06	47.94	0.82	54.44	1.63
Minimum	1.61	0.01	38.90	0.12	25.22	0.30
St Deviation	0.62	0.01	2.32	0.16	6.25	0.24
Coef of Variation	21.27	29.92	5.21	35.27	15.81	31.22
PLIMIT - Grass Hay (N=120)						
Mean	2.92	0.03	21.28	0.41	37.07	0.49
Maximum	5.01	0.06	23.84	1.26	55.24	1.08
Minimum	1.60	0.01	15.94	0.08	21.22	0.20
St Deviation	0.62	0.01	1.71	0.22	6.97	0.15
Coef of Variation	21.39	28.91	8.03	53.00	18.81	31.73
BASE - Hay/Pasture (N=82)						
Mean	2.75	0.12	29.70	0.80	20.30	2.44
Maximum	4.49	0.22	31.13	1.73	30.83	3.54
Minimum	1.24	0.04	27.75	0.30	13.21	1.27
St Deviation	0.70	0.05	0.87	0.35	4.08	0.47
Coef of Variation	25.48	45.25	2.94	43.75	20.08	19.11

Table D.6. (Continued) Statistical Values of Mean Yields and Nutrient Losses for 150-Cow Dairy Farm.

	Crop Yields (tons/acre)	Annual Erosion Losses (tons/acre)	Annual Volatilization Losses (lbs./acre)	Annual Surface Nit Losses (lbs./acre)	Annual Subsurface Nit Losses (lbs./acre)	Annual Phosphorus Losses (lbs./acre)
PLIMIT - Hay/Pasture (N=82)						
Mean	2.55	0.14	11.04	0.85	22.13	0.97
Maximum	4.24	0.30	12.02	3.07	33.63	1.41
Minimum	1.15	0.05	9.73	0.32	13.75	0.51
St Deviation	0.66	0.07	0.51	0.58	4.61	0.19
Coef of Variation	25.74	50.32	4.58	67.73	20.84	19.65
BASE - Improved Pasture (N=82)						
Mean	1.80	0.09	31.25	0.44	26.84	2.58
Maximum	2.59	0.15	32.45	0.78	36.63	3.46
Minimum	0.80	0.03	29.72	0.16	18.35	1.22
St Deviation	0.41	0.03	0.73	0.12	4.53	0.44
NLIMIT - Improved Pasture (N=62)						
Mean	1.78	0.10	24.79	0.42	15.06	1.95
Maximum	2.57	0.17	25.78	0.76	22.48	2.63
Minimum	0.80	0.03	23.52	0.15	9.18	0.93
St Deviation	0.40	0.03	0.56	0.12	3.18	0.33
Coef of Variation	22.48	28.72	2.25	27.46	21.13	17.12
PLIMIT - Improved Pasture (N=60)						
Mean	1.77	0.11	11.77	0.41	11.21	0.83
Maximum	2.57	0.18	12.63	1.21	20.00	1.12
Minimum	0.80	0.04	10.61	0.14	6.52	0.40
St Deviation	0.40	0.03	0.37	0.20	3.04	0.14
Coef of Variation	22.47	29.06	3.15	49.55	27.15	17.31

Appendix E: FLIPSIM Simulation Results

For Sensitivity Analysis

Table E.1. Mean FLIPSIM Results For the 60-Cow Dairy Farm.

Financial Parameters	BASE	INCORP	NLIMIT	PLIMIT
	Alternative Manure Management Policies			
60-Cow Dairy Farm[1]				
Probability of Survival[2]	100	100	100	100
Probability of Success[3]	100	100	100	100
Beginning Debt/Asset Ratio	0.293	0.293	0.293	0.293
Ending Debt/Asset Ratio	0.198	0.198	0.197	0.203
Ending Net Worth ($1000)[4]	449.56	450.34	451.17	443.92
Avg Net Cash Income ($1000)[5]	27.62	27.70	27.80	25.63
Net Cash Available ($1000)[6]	24.35	24.57	24.73	20.23
Less 2000 Lbs Milk/Cow				
Probability of Survival	100	100	100	100
Probability of Success	0.0	0.0	0.0	0.0
Beginning Debt/Asset Ratio	0.293	0.293	0.293	0.293
Ending Debt/Asset Ratio	0.287	0.286	0.286	0.307
Ending Net Worth ($1000)	390.68	391.46	391.78	380.61
Avg Net Cash Income ($1000)	16.21	16.30	16.27	13.82
Net Cash Available ($1000)	6.89	6.99	6.93	4.16
Plus 2000 Lbs Milk/Cow				
Probability of Survival	100	100	100	100
Probability of Success	100	100	100	100
Beginning Debt/Asset Ratio	0.293	0.293	0.293	0.293
Ending Debt/Asset Ratio	0.197	0.197	0.196	0.197
Ending Net Worth ($1000)	467.76	468.24	469.02	465.34
Avg Net Cash Income ($1000)	36.39	36.47	36.56	34.60
Net Cash Available ($1000)	41.45	41.59	41.75	37.76
Debt Level $2000/Cow				
Probability of Survival	100	100	100	100
Probability of Success	100	100	100	100
Beginning Debt/Asset Ratio	0.195	0.195	0.195	0.195
Ending Debt/Asset Ratio	0.135	0.135	0.135	0.132
Ending Net Worth ($1000)	513.51	514.01	514.80	511.53
Avg Net Cash Income ($1000)	33.17	33.25	33.34	31.38
Net Cash Available ($1000)	46.70	46.80	46.96	43.27
Debt Level $4500/Cow				
Probability of Survival	100	100	100	100
Probability of Success	2.0	2.0	4.0	0.0
Beginning Debt/Asset Ratio	0.440	0.440	0.440	0.440
Ending Debt/Asset Ratio	0.410	0.409	0.407	0.427
Ending Net Worth ($1000)	328.19	328.95	330.06	318.47
Avg Net Cash Income ($1000)	17.74	17.83	17.93	15.53
Net Cash Available ($1000)	2.70	2.79	2.91	0.21
Milk Price Less 5%				
Probability of Survival	100	100	100	100
Probability of Success	66.0	65.0	65.0	4.0
Beginning Debt/Asset Ratio	0.293	0.293	0.293	0.293
Ending Debt/Asset Ratio	0.246	0.244	0.243	0.272
Ending Net Worth ($1000)	417.97	419.01	420.26	406.83
Avg Net Cash Income ($1000)	19.55	19.67	19.78	17.31
Net Cash Available ($1000)	11.72	10.75	10.93	7.19

1. Initial Parameters are 18,000 pounds of milk per cow, debt of $3000 per cow, and $16,000 annual family living costs.
2. Probability of Survival - Chance that the farm's D/A ratio does not exceed the maximum of 0.75.
3. Probability of Economic Success - Chance that the farm will earn a return on initial equity greater than 5.4 percent.
4. Ending Net Worth - Discounted value of net worth in the last year simulated.
5. Average Net Cash Income - Total cash receipts minus total cash expenses, excludes family living expenses, principal payments, and capital asset replacement costs.
6. Net Cash Available - Average total cash available after paying principal payments, machinery replacements, and taxes.

Table E.2. Mean FLIPSIM Results For the 100-Cow Dairy Farm.

Financial Parameters	Alternative Manure Management Policies			
	BASE[1]	INCORP	NLIMIT	PLIMIT
100-Cow Dairy Farm[1]				
Probability of Survival[2]	100	100	100	100
Probability of Success[3]	100	100	100	100
Beginning Debt/Asset Ratio	0.333	0.333	0.333	0.333
Ending Debt/Asset Ratio	0.247	0.247	0.246	0.253
Ending Net Worth ($1000)[4]	601.58	602.22	603.33	596.62
Avg Net Cash Income ($1000)[5]	60.71	60.92	61.35	58.19
Net Cash Available ($1000)[6]	48.14	48.52	49.42	42.85
Less 2000 Lbs Milk/Cow				
Probability of Survival	100	100	100	100
Probability of Success	94.0	94.0	94.0	80.0
Beginning Debt/Asset Ratio	0.333	0.333	0.333	0.333
Ending Debt/Asset Ratio	0.312	0.310	0.309	0.320
Ending Net Worth ($1000)	544.35	545.13	546.34	539.19
Avg Net Cash Income ($1000)	44.66	44.86	45.35	42.03
Net Cash Available ($1000)	21.34	21.56	22.19	18.16
Plus 2000 Lbs Milk/Cow				
Probability of Survival	100	100	100	100
Probability of Success	100	100	100	100
Beginning Debt/Asset Ratio	0.333	0.333	0.333	0.333
Ending Debt/Asset Ratio	0.236	0.236	0.236	0.238
Ending Net Worth ($1000)	643.96	644.56	645.56	632.32
Avg Net Cash Income ($1000)	75.73	75.93	76.31	70.87
Net Cash Available ($1000)	80.75	81.11	82.02	70.11
Debt Level $2000/Cow[1]				
Probability of Survival	100	100	100	100
Probability of Success	100	100	100	100
Beginning Debt/Asset Ratio	0.222	0.222	0.222	0.222
Ending Debt/Asset Ratio	0.163	0.163	0.163	0.163
Ending Net Worth ($1000)	714.00	714.86	715.62	710.09
Avg Net Cash Income ($1000)	69.41	69.60	69.99	67.17
Net Cash Available ($1000)	85.53	86.18	86.80	80.90
Debt Level $4500/Cow				
Probability of Survival	100	100	100	100
Probability of Success	85.0	85.0	88.0	7.0
Beginning Debt/Asset Ratio	0.500	0.500	0.500	0.500
Ending Debt/Asset Ratio	0.470	0.470	0.468	0.477
Ending Net Worth ($1000)	423.04	423.73	424.86	418.56
Avg Net Cash Income ($1000)	44.30	44.51	44.97	41.70
Net Cash Available ($1000)	9.91	10.06	10.50	8.04
Less 5% Milk Price				
Probability of Survival	100	100	100	100
Probability of Success	100	100	100	95.0
Beginning Debt/Asset Ratio	0.333	0.333	0.333	0.333
Ending Debt/Asset Ratio	0.301	0.300	0.298	0.310
Ending Net Worth ($1000)	560.81	561.61	563.16	555.31
Avg Net Cash Income ($1000)	46.89	47.11	47.62	44.32
Net Cash Available ($1000)	24.03	24.30	24.98	20.64

[1] Initial farm parameters are 100-cows, 18,000 pounds of milk per cow, debt of $3000 per cow, $49,000 annual family living costs for two families, and $18,000 in off-farm income.
[2] Probability of Survival - Chance that the farm's D/A ratio does not exceed the maximum of 0.75.
[3] Probability of Economic Success - Chance that the farm will earn a return on initial equity greater than 5.4 percent.
[4] Ending Net Worth - Discounted value of net worth in the last year simulated.
[5] Average Net Cash Income - Total cash receipts minus total cash expenses, excludes family living expenses, principal payments, and capital asset replacement costs.
[6] Net Cash Available - Average total cash available after paying principal payments, machinery replacements, and taxes.

Table E.3. Mean FLIPSIM Results For the 150-Cow Dairy Farm.

Financial Parameters	Alternative Manure Management Policies BASE	INCORP	NLIMIT	PLIMIT
150-Cow Dairy Farm[1]				
Probability of Survival[1]	100	100	100	100
Probability of Success[2]	100	100	100	100
Beginning Debt/Asset Ratio	0.331	0.331	0.331	0.331
Ending Debt/Asset Ratio[3]	0.278	0.278	0.276	0.290
Ending Net Worth ($1000)[4]	870.45	870.28	872.49	856.22
Avg Net Cash Income ($1000)[5]	84.74	84.66	85.54	80.38
Net Cash Available ($1000)[6]	52.72	52.60	53.70	46.93
Less 2000 Lbs Milk/Cow				
Probability of Survival	100	100	100	100
Probability of Success	80.0	80.0	85.0	66.0
Beginning Debt/Asset Ratio	0.331	0.331	0.331	0.331
Ending Debt/Asset Ratio	0.330	0.330	0.329	0.336
Ending Net Worth ($1000)	806.38	805.98	807.41	796.61
Avg Net Cash Income ($1000)	59.23	59.07	60.02	54.96
Net Cash Available ($1000)	26.31	26.18	26.93	22.89
Plus 2000 Lbs Milk/Cow				
Probability of Survival	100	100	100	100
Probability of Success	100	100	100	100
Beginning Debt/Asset Ratio	0.331	0.331	0.331	0.331
Ending Debt/Asset Ratio	0.238	0.238	0.237	0.242
Ending Net Worth ($1000)	930.19	929.97	931.97	917.10
Avg Net Cash Income ($1000)	109.51	109.43	110.29	105.27
Net Cash Available ($1000)	91.62	91.54	92.32	85.93
Debt Level $2000/Cow				
Probability of Survival	100	100	100	100
Probability of Success	100	100	100	100
Beginning Debt/Asset Ratio	0.220	0.220	0.220	0.220
Ending Debt/Asset Ratio	0.156	0.156	0.155	0.161
Ending Net Worth ($1000)	1038.89	1038.67	1040.71	1025.49
Avg Net Cash Income ($1000)	100.50	100.41	101.29	96.20
Net Cash Available ($1000)	92.89	92.87	93.44	89.93
Debt Level $4500/Cow				
Probability of Survival	100	100	100	100
Probability of Success	66.0	66.0	73.0	50.0
Beginning Debt/Asset Ratio	0.496	0.496	0.496	0.496
Ending Debt/Asset Ratio	0.484	0.484	0.483	0.490
Ending Net Worth ($1000)	624.42	624.13	625.37	614.76
Avg Net Cash Income ($1000)	60.55	60.47	61.33	56.25
Net Cash Available ($1000)	13.17	13.10	13.76	9.75
Milk Price Less 5%				
Probability of Survival	100	100	100	100
Probability of Success	95.0	95.0	95.0	83.0
Beginning Debt/Asset Ratio	0.331	0.331	0.331	0.331
Ending Debt/Asset Ratio	0.321	0.321	0 .320	0.327
Ending Net Worth ($1000)	824.84	824.44	825.95	814.54
Avg Net Cash Income ($1000)	63.81	63.72	64.60	59.47
Net Cash Available ($1000)	30.11	30.04	30.75	26.61

1. Initial parameters are 150-cows, 18,400 pounds of milk per cow, debt of $3000 per cow, and $52,000 annual family living costs.
2. Probability of Survival - Chance that the farm's D/A ratio does not exceed the maximum of 0.75.
3. Probability of Economic Success - Chance that the farm will earn a return on initial equity greater than 5.4 percent.
4. Ending Net Worth - Discounted value of net worth in the last year simulated.
5. Average Net Cash Income - Total cash receipts minus total cash expenses, excludes family living expenses, principal payments, and capital asset replacement costs.
6. Net Cash Available - Average total cash available after paying principal payments, machinery replacements, and taxes.

Table E.4. Mean FLIPSIM Results For the 60-Cow Dairy/Poultry Farm.

Financial Parameters	Dairy Base	Alternative Manure Management Policies			
		BASE	INCORP	NLIMIT	PLIMIT
60-Cow Dairy/Poultry Farm[1]					
Probability of Survival[2]	100	100	100	100	100
Probability of Success[3]	100	100	100	100	100
Beginning Debt/Asset Ratio	0.293	0.536	0.536	0.536	0.536
Ending Debt/Asset Ratio	0.198	0.346	0.346	0.346	0.350
Ending Net Worth ($1000)[4]	449.56	491.41	491.87	492.60	485.56
Avg Net Cash Income ($1000)[5]	27.62	51.09	51.17	51.12	48.05
Net Cash Available ($1000)[6]	24.35	34.47	34.52	34.62	26.67
Less 2000 Lbs Milk/Cow					
Probability of Survival	100	100	100	100	100
Probability of Success	0.0	100	100	100	94.0
Beginning Debt/Asset Ratio	0.293	0.536	0.536	0.536	0.536
Ending Debt/Asset Ratio	0.287	0.384	0.383	0.384	0.404
Ending Net Worth ($1000)	390.68	451.37	452.11	451.68	338.09
Avg Net Cash Income ($1000)	16.21	40.36	40.44	40.16	37.05
Net Cash Available ($1000)	6.89	13.61	13.75	13.30	9.03
Plus 2000 Lbs Milk/Cow					
Probability of Survival	100	100	100	100	100
Probability of Success	100	100	100	100	100
Beginning Debt/Asset Ratio	0.293	0.536	0.536	0.536	0.536
Ending Debt/Asset Ratio	0.197	0.338	0.337	0.337	0.338
Ending Net Worth ($1000)	467.76	517.97	518.51	518.94	513.84
Avg Net Cash Income ($1000)	36.39	59.64	59.72	59.68	57.01
Net Cash Available ($1000)	41.45	54.24	54.40	54.26	48.25
Debt Level $2000/Cow					
Probability of Survival	100	100	100	100	100
Probability of Success	100	100	100	100	100
Beginning Debt/Asset Ratio	0.195	0.465	0.465	0.465	0.465
Ending Debt/Asset Ratio	0.135	0.289	0.289	0.289	0.291
Ending Net Worth ($1000)	513.51	525.71	526.29	526.74	517.52
Avg Net Cash Income ($1000)	33.17	56.25	56.32	56.28	53.61
Net Cash Available ($1000)	46.70	59.37	59.53	59.47	52.87
Debt Level $4500/Cow					
Probability of Survival	100	100	100	100	100
Probability of Success	2.0	100	100	100	100
Beginning Debt/Asset Ratio	0.440	0.642	0.642	0.642	0.642
Ending Debt/Asset Ratio	0.410	0.474	0.473	0.473	0.494
Ending Net Worth ($1000)	328.19	389.96	390.73	390.99	375.81
Avg Net Cash Income ($1000)	17.74	41.99	42.08	42.02	38.77
Net Cash Available ($1000)	2.70	7.54	7.65	7.57	3.80
Milk Price Less 5%					
Probability of Survival	100	100	100	100	100
Probability of Success	66.0	100	100	100	100
Beginning Debt/Asset Ratio	0.293	0.536	0.536	0.536	0.536
Ending Debt/Asset Ratio	0.246	0.421	0.420	0.420	0.433
Ending Net Worth ($1000)	417.97	469.30	469.88	470.24	461.69
Avg Net Cash Income ($1000)	19.55	43.24	43.32	43.27	40.37
Net Cash Available ($1000)	11.72	18.04	18.17	18.03	13.63

1. Initial parameters: 60-cows, 18,000 pounds of milk per cow, farm debt of $3000 per cow plus $274,000 for poultry building, and $16,000 annual family living costs.
2. Probability of Survival - Chance that the farm's D/A ratio does not exceed the maximum of 0.75.
3. Probability of Economic Success - Chance that the farm will earn a return on initial equity greater than 5.4 percent.
4. Ending Net Worth - Discounted value of net worth in the last year simulated.
5. Average Net Cash Income - Total cash receipts minus total cash expenses, excludes family living expenses, principal payments, and capital asset replacement costs.
6. Net Cash Available - Average total cash available after paying principal payments, machinery replacements, and taxes.

Table E.5. Mean FLIPSIM Results For the 100-Cow Dairy/Poultry Farm.

Financial Parameters	Dairy Base	Alternative Manure Management Policies BASE	INCORP	NLIMIT	PLIMIT
100-Cow Dairy/Poultry Farm[1]					
Probability of Survival[2]	100	100	100	100	100
Probability of Success[3]	100	100	100	100	100
Beginning Debt/Asset Ratio	0.333	0.507	0.507	0.507	0.507
Ending Debt/Asset Ratio	0.247	0.343	0.341	0.343	0.346
Ending Net Worth ($1000)[4]	601.58	669.81	675.57	671.32	660.97
Avg Net Cash Income ($1000)[5]	60.71	85.31	85.53	85.96	80.59
Net Cash Available ($1000)[6]	48.14	62.76	66.89	64.11	53.33
Less 2000 Lbs Milk/Cow					
Probability of Survival	100	100	100	100	100
Probability of Success	94.0	100	100	100	100
Beginning Debt/Asset Ratio	0.333	0.507	0.507	0.507	0.507
Ending Debt/Asset Ratio	0.312	0.372	0.371	0.369	0.395
Ending Net Worth ($1000)	544.35	620.84	621.48	622.80	599.26
Avg Net Cash Income ($1000)	44.66	70.21	70.41	70.95	62.16
Net Cash Available ($1000)	21.34	34.87	35.09	35.93	24.36
Plus 2000 Lbs Milk/Cow					
Probability of Survival	100	100	100	100	100
Probability of Success	100	100	100	100	100
Beginning Debt/Asset Ratio	0.333	0.507	0.507	0.507	0.507
Ending Debt/Asset Ratio	0.236	0.335	0.335	0.334	0.337
Ending Net Worth ($1000)	643.96	702.98	703.43	704.39	694.74
Avg Net Cash Income ($1000)	75.73	100.07	100.26	100.71	95.64
Net Cash Available ($1000)	80.75	91.67	92.01	93.09	82.48
Debt Level $2000/Cow					
Probability of Survival	100	100	100	100	100
Probability of Success	100	100	100	100	100
Beginning Debt/Asset Ratio	0.222	0.418	0.418	0.418	0.418
Ending Debt/Asset Ratio	0.163	0.267	0.267	0.267	0.269
Ending Net Worth ($1000)	714.00	777.98	778.45	779.44	769.69
Avg Net Cash Income ($1000)	69.41	93.92	94.12	94.56	89.49
Net Cash Available ($1000)	85.53	96.51	96.84	97.82	87.27
Debt Level $4500/Cow					
Probability of Survival	100	100	100	100	100
Probability of Success	85.0	100	100	100	100
Beginning Debt/Asset Ratio	0.500	0.639	0.639	0.639	0.639
Ending Debt/Asset Ratio	0.470	0.499	0.499	0.498	0.513
Ending Net Worth ($1000)	423.04	500.22	500.89	501.98	487.71
Avg Net Cash Income ($1000)	44.30	69.88	70.10	70.61	64.80
Net Cash Available ($1000)	9.91	18.34	18.52	16.02	13.70
Milk Price Less 5%					
Probability of Survival	100	100	100	100	100
Probability of Success	100	100	100	100	100
Beginning Debt/Asset Ratio	0.333	0.507	0.507	0.507	0.507
Ending Debt/Asset Ratio	0.301	0.361	0.361	0.359	0.375
Ending Net Worth ($1000)	560.81	638.23	638.86	640.14	626.20
Avg Net Cash Income ($1000)	46.89	72.37	72.59	73.10	67.30
Net Cash Available ($1000)	24.03	37.87	38.21	39.09	30.42

1. Initial farm parameters are 100-cows, 18,000 pounds of milk per cow, debt of $3000 per cow, $49,000 annual family living costs for two families, and $18,000 in off-farm income.
2. Probability of Survival - Chance that the farm's D/A ratio does not exceed the maximum of 0.75.
3. Probability of Economic Success - Chance that the farm will earn a return on initial equity greater than 5.4 percent.
4. Ending Net Worth - Discounted value of net worth in the last year simulated.
5. Average Net Cash Income - Total cash receipts minus total cash expenses, excludes family living expenses, principal payments, and capital asset replacement costs.
6. Net Cash Available - Average total cash available after paying principal payments, machinery replacements, and taxes.

Table E.6. Mean FLIPSIM Results For the 150-Cow Dairy/Poultry Farm.

Financial Parameters	Dairy Base	Alternative Manure Management Policies BASE	INCORP	NLIMIT	PLIMIT
150-Cow Dairy/Poultry Farms[1]					
Probability of Survival[2]	100	100	100	100	100
Probability of Success[3]	100	100	100	100	100
Beginning Debt/Asset Ratio	0.331	0.454	0.454	0.454	0.454
Ending Debt/Asset Ratio	0.278	0.338	0.338	0.337	0.350
Ending Net Worth ($1000)[4]	870.45	939.24	939.02	941.18	919.99
Avg Net Cash Income ($1000)[5]	66.04	89.92	89.83	90.78	82.88
Net Cash Available ($1000)[6]	52.72	60.05	59.92	61.18	51.37
Less 2000 Lbs Milk/Cow					
Probability of Survival	100	100	100	100	100
Probability of Success	80.0	100	100	100	94.0
Beginning Debt/Asset Ratio	0.331	0.454	0.454	0.454	0.454
Ending Debt/Asset Ratio	0.330	0.382	0.381	0.380	0.395
Ending Net Worth ($1000)	806.38	871.34	871.75	873.66	849.49
Avg Net Cash Income ($1000)	59.23	84.54	84.72	85.47	77.59
Net Cash Available ($1000)	26.31	34.28	34.42	35.02	28.61
Plus 2000 Lbs Milk/Cow					
Probability of Survival	100	100	100	100	100
Probability of Success	100	100	100	100	100
Beginning Debt/Asset Ratio	0.331	0.454	0.454	0.454	0.454
Ending Debt/Asset Ratio	0.238	0.307	0.307	0.306	0.314
Ending Net Worth ($1000)	930.19	994.32	994.11	996.24	975.50
Avg Net Cash Income ($1000)	109.51	134.13	134.05	134.99	127.20
Net Cash Available ($1000)	91.62	99.62	99.54	100.45	89.39
Debt Level $2000/Cow					
Probability of Survival	100	100	100	100	100
Probability of Success	100	100	100	100	100
Beginning Debt/Asset Ratio	0.220	0.360	0.360	0.360	0.360
Ending Debt/Asset Ratio	0.155	0.235	0.235	0.234	0.243
Ending Net Worth ($1000)	1038.89	1104.14	1103.93	1106.03	1085.54
Avg Net Cash Income ($1000)	100.50	125.13	125.05	125.99	118.28
Net Cash Available ($1000)	92.89	104.95	104.91	105.34	99.54
Debt Level $4500/Cow					
Probability of Survival	100	100	100	100	100
Probability of Success	66.0	100	100	100	94.0
Beginning Debt/Asset Ratio	0.496	0.595	0.595	0.595	0.595
Ending Debt/Asset Ratio	0.484	0.539	0.539	0.537	0.554
Ending Net Worth ($1000)	624.42	688.11	687.89	690.37	664.80
Avg Net Cash Income ($1000)	60.55	85.81	85.72	86.67	78.71
Net Cash Available ($1000)	13.17	21.73	21.67	22.42	16.12
Milk Price Less 5%					
Probability of Survival	100	100	100	100	100
Probability of Success	95.0	100	100	100	100
Beginning Debt/Asset Ratio	0.331	0.454	0.454	0.454	0.454
Ending Debt/Asset Ratio	0.321	0.371	0.371	0.369	0.385
Ending Net Worth ($1000)	824.84	893.28	893.05	895.41	871.32
Avg Net Cash Income ($1000)	63.81	89.13	89.05	90.01	82.06
Net Cash Available ($1000)	30.11	38.23	38.17	38.95	32.42

1. Initial farm parameters are 150-cows, 18,400 pounds of milk per cow, farm debt of $3000 per cow plus $274,000 for poultry building, and $52,000 annual family living costs.
2. Probability of Survival - Chance that the farm's D/A ratio does not exceed the maximum of 0.75.
3. Probability of Economic Success - Chance that the farm will earn a return on initial equity greater than 5.4 percent.
4. Ending Net Worth - Discounted value of net worth in the last year simulated.
5. Average Net Cash Income - Total cash receipts minus total cash expenses, excludes family living expenses, principal payments, and capital asset replacement costs.
6. Net Cash Available - Average total cash available after paying principal payments, machinery replacements, and taxes.

Table E-7. Mean FLIPSIM Results For the Dairy/Poultry Farms With a 5% Revenue Reduction.				
	Alternative Manure Management Policies			
Financial Parameters	BASE	INCORP	NLIMIT	PLIMIT
60-Cow D/P Reduced Inc[1]				
Probability of Survival[4]	100	100	100	100
Probability of Success[5]	100	100	100	100
Beginning Debt/Asset Ratio	0.536	0.536	0.536	0.536
Ending Debt/Asset Ratio	0.352	0.351	0.351	0.461
Ending Net Worth ($1000)[6]	481.94	482.73	483.11	475.53
Avg Net Cash Income ($1000)[7]	47.27	47.36	47.31	44.52
Avg Net Cash Available ($1000)[8]	25.17	25.37	25.33	20.72
100-Cow D/P Reduced Inc[2]				
Probability of Survival[4]	100	100	100	100
Probability of Success[5]	100	100	100	100
Beginning Debt/Asset Ratio	0.507	0.507	0.507	0.507
Ending Debt/Asset Ratio	0.345	0.345	0.345	0.350
Ending Net Worth ($1000)[6]	661.81	662.68	663.25	652.04
Avg Net Cash Income ($1000)[7]	68.57	68.77	69.26	63.63
Avg Net Cash Available ($1000)[8]	55.79	56.13	57.15	46.15
150-Cow D/P Reduced Inc[3]				
Probability of Survival[4]	100	100	100	100
Probability of Success[5]	100	100	100	100
Beginning Debt/Asset Ratio	0.454	0.454	0.454	0.454
Ending Debt/Asset Ratio	0.344	0.344	0.343	0.356
Ending Net Worth ($1000)[6]	930.90	930.68	932.85	911.55
Avg Net Cash Income ($1000)[7]	105.70	105.62	106.57	98.66
Avg Net Cash Available ($1000)[8]	55.40	55.27	56.46	47.03

1. Initial parameters are 18,000 pounds of milk per cow, farm debt of $3000 per cow plus $273,000 for poultry building, and $16,000 annual family living costs.
2. Initial parameters are 18,000 pounds of milk per cow, debt of $3000 per cow plus $273,000 for poultry building, and $49,000 annual family living costs for 2 families.
3. Initial parameters are 18,400 pounds of milk per cow, debt of $3000 per cow plus $273,000 for poultry building, and $52,000 annual family living costs for two families.
4. Probability of Survival - Chance that the farm's D/A ratio does not exceed the maximum of 0.75.
5. Probability of Economic Success - Chance that the farm will earn a return on initial equity greater than 0.0540.
6. Ending Net Worth - Discounted value of net worth in the last year simulated.
7. Average Net Cash Income - Total cash receipts minus total cash expenses; excludes family living expenses, principal payments, and costs to replace capital assets.
8. Net Cash Available - Average total cash available after paying principal payments, machinery replacements, and taxes.

Vita

Robert Lee Parsons was born on February 28, 1953, in Bellefonte, Pennsylvania, the oldest son of Bill and Racheal Parsons. He was reared on a family dairy farm in Centre County, Pennsylvania, and graduated from State College Area High School in 1971. Following a brief stint at Penn State University, he worked for a dairy equipment dealership before returning to Penn State for a B.S. in Agricultural Business Management (1985) and a M.S. in Agricultural Economics (1987). Bob spent several years working before continuing for a Ph.D. in Agricultural Economics at Virginia Tech, graduating in 1995.