LCMR Final Report - Summary - Research

I. Project Title: NUTRIENT AVAILABILITY FROM LAND-APPLIED MANURE

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A. Legal Citation: M.L. 93 Chpt. 172, Sect. 14, Subd. 3(i)
Total Biennial LCMR Budget: $280,000.
Total Remaining LCMR Budget: $0.00

Balance:

Subd. 3(i) This appropriation is from the future resources fund to the commissioner of agriculture for a contract with the University of Minnesota to determine nutrient availability from manure/soil/crop systems to improve manure utilization by crops, reduce environmental impacts on water resources, and provide best management practices (BMPs) to guide manure management decisions.

B. LMIC Compatible Data Language: During the biennium ending June 30, 1995, the data collected by the projects funded under this section that have common value for natural resource planning and management must conform to information architecture as defined in guidelines and standards adopted on plans for data integration and distribution and shall submit semiannual status reports to the legislative commission on Minnesota resources on their findings. In addition, the data must be provided to and integrated with the Minnesota land management information center's geographic data bases with the integration costs borne by the activity receiving funding under this section.

II. Project Summary:

The overall goal of the Nutrient Availability from Land-Applied Manure project is to develop analytical tools to both measure and predict the availability of nutrients, primarily nitrogen (N), from animal manures applied to soils. Precision rates of dairy and hog manure will be applied in replicated field experiments over a wide array of soil, crop, and hydrogeologic conditions in Southern Minnesota. Nitrogen availability from the manure/soil systems will be assessed using a variety of N tests and sampling schemes, corn yield, N uptake, and residual nitrate remaining in the soil as influenced by cropping history, soil, and climate. Soil water from porous cup samplers and tile water from drainage plots at Waseca will also be obtained to measure potential nitrate movement to ground and surface waters. Hog producers from south-central Minnesota will be surveyed to determine current and anticipated future manure handling systems and manure utilization and nutrient management practices. The knowledge gathered in these investigations to meet these two highly-related objectives will provide BMPs to guide manure management decisions for thousands of farmers while reducing the environmental impacts of livestock manure on Minnesota's water resources.

III. Statement of Objectives:

A. Develop a soil test(s) that best predicts nitrogen (N) availability to plants when previously applied manure is a contributing source of N.

B. Determine the mineralization rate of incorporated manure on the release of N to succeeding crops and potential impact on nitrate leaching as affected by time and rate of manure application.

IV. Research Objectives:

A. Title of Objective: Develop a soil test(s) that best predicts nitrogen (N) availability to plants when previously applied manure is a contributing source of N.

A.1. Activity: The availability of N from liquid dairy and hog manure applied at least 12 months previously will be determined via numerous soil test methods on soil samples taken over time and from various depths in an effort to develop a soil test that best predicts N availability over a wide range of soil, crop and climatic conditions in Southern Minnesota.

A.1.a. Context within the project: A soil test(s) is currently being developed by the principal investigators for non-manure-based cropping systems in Minnesota. Manure applications complicate the system by adding substantial amounts of organic N which over time converts to nitrate. This objective will determine the organic N contribution from previously-applied manure to plants as affected by soil and climate.

A.1.b. Methods: The proposed research will involve both field and laboratory components. Field experiments will provide the required crop response data and soil samples while the laboratory work will furnish the necessary soil N measurements to permit correlation of the diagnostic tests under evaluation. Multiple sites will provide the necessary range in management history, soil characteristics, and climatic conditions.

A minimum of 5 experimental sites will be established in each of two years (1993 and 1994). The sites will be selected to represent soils and farming systems widely used for corn production on livestock farms. We will conduct these studies on a number of carefully selected farmer-cooperator sites and at the Southern Experiment Station. These sites will give us a variety of organically-based systems (manure and legumes). Two sites each year will be located in southeastern Minnesota where well-drained soils predominate and dairying is intensive while three or more will be in south-central Minnesota on poorly-drained soils where hog operations are concentrated. Members of the Minnesota Pork Producers Association will help locate farmer-cooperators. Detailed past management histories will be obtained from the farm manager at each location prior to initiation of an experiment. Sites chosen will provide the desired range of organic N contributions to corn and will be limited to those with histories of manure applications ending at least one year prior to initiation of this work.

A minimum of seven treatments will be repeated four times in a randomized, complete-block design at each field site. They will consist of a control (no N) and six N rates of preplant broadcast-applied urea in 30-lb increments. Three additional treatments will be split-applied as 30 lb N/A (preplant) plus 30, 60 and 90 lb N/A sidedress-applied (V5 stage) as urea when time and space permit. Various incremental rates of fertilizer N are necessary to determine the availability of manure N in a soil system. This is a well-established practice when developing a soil N test. These treatments will allow correlation and calibration of the soil test data with the plant data obtained with these N rates. Each site will occupy an area of about 0.6 acre of seemingly uniform soil planted to corn.

The following sampling protocol will be used. All soil samples will be air-dried.

Preplant:

Soil samples will be taken in 1-foot increments to 4 feet. Samples consisting of three cores/plot will be obtained from the control (no N) plot in each replication at each site.

Emergence:

Soil samples (8 cores/plot) will be taken in 1-foot increments to 3 feet from the control (no N) at all sites.

Presidedress (6 to 12-inch corn):

Soil samples (8 cores/plot) will be taken in 1-foot increments to 3 feet from the same plots as the "emergence stage".

Post-harvest:

Soil samples consisting of three cores per plot will be taken in 1-foot increments to 4 feet. Samples will be taken from the 0, 90 and 180 lb N/A preplant treatments. Residual NO_3 found in these samples will provide an indication of nitrate leaching potential associated with the various experimental treatments for a given soil/crop management system.

Soil water sampling:

To obtain additional information on nitrate loss from farming systems with long histories of organic N additions and on the nitrate leaching potential of selected experimental treatments, porous cup samplers will be installed at a minimum of two sites per year immediately after planting corn. Porous cup samplers will be installed in all plots receiving 0, 90, and 180 lb N/A as preplant broadcast urea. These samplers will allow monitoring of nitrate-N concentrations in soil water below the corn root zone (5 ft soil depth). Soil water samples will be collected monthly when soil moisture status permits collection of samples.

Nitrate-N will be determined on all soil samples and on all soil water samples. Ammonium-N will be determined on all soil samples except those taken at the post-harvest stage. N mineralization poten[illegible]ll be estimated by using the phosphate-borate N mineral[illegible] test (Gianello &

Bremner, 1988) and measurement of UV absorbance of 0.01 M $NaHCO_3$ soil extracts (Hong et al., 1990). These will be performed on 0 to 1, 1 to 2, and 2 to 3-foot depth increments from control plots (no N) at the preplant, emergence, and pre-sidedress sampling times. Routine soil tests for pH, available P and K, soil organic matter, and total N will be performed on 0 to 6 inch samples to characterize each experimental site.

Precipitation between the initial preplant sampling and post-harvest sampling will be measured at each site. Soil and air temperatures for calculating soil heat units or air growing degree unit accumulation will be obtained for those sites having a weather station in reasonable proximity to the experimental location or by cooperators who will record these daily measurements. Nitrogen availability will be determined by measuring total plant dry matter yield partitioned into grain and stover components and N uptake at physiological maturity.

Data collected at each site will be statistically analyzed each year to develop interpretations that relate soil test data to plant-available N data. Yield response models will be developed to determine critical soil test N concentrations separating responsive from non-responsive sites. Calibration functions will also be developed for predicting supplemental N required when soil N tests are below the critical level and a response to additional fertilizer N is expected. The climatic data will be used to characterize the site and provide assistance in data interpretation. Guidelines that indicate preferred test(s) under specific soil/crop/climate situations will be developed. The nitrate leaching potential at each site will be characterized through the post-harvest soil and porous cup water nitrate values.

A.1.c. Materials: Materials necessary to accomplish this objective include vehicles; a precision liquid manure applicator; hydraulic soil probe equipment; implements to till, plant, cultivate, and harvest the plots; preparation equipment for plant and soil analyses; analytical equipment for the laboratory conducted soil tests; weather monitoring instruments; and computer hardware and software to facilitate data management, analyses and interpretation.

A.1.d. Budget: $0.00. Initial Budget = $160,000.

A.1.e. Timeline:

	7/93 1/94 7/94 1/95 7/95
Establish field trials, manure application & climatic data collection systems	xxxxxxxxxxxxxxxxxx
Collect soil, plant & weather data	xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
Develop BMP's & conduct educational events	xxxxxxxxxxxxxxxxxxx

A.1.f. Status: Twelve field experiments were initiated in the 30-month period. Because rainfall in May and June exceeded 18" at the two Martin Co. sites established in 1993 and because corn yields at these sites were less than 100 bu/A, we abandoned them. This was unfortunate because of their previous hog manure histories. Of the 10 remaining sites, two had a hog manure history while ei[illegible] had received dairy manure. Five of the sites were located [illegible] loess soils in southeastern Minne[illegible]hile five were on glacial till soils in south-central Minn[illegible] In addition to these 10 sites, we examined soil tests for nitrate and ammonium concentrations in the second-yr (residual phase) of five manure mineralization studies that were established as part of objective B in this project. The soil N, plant N, and corn yield data from these 15 sites will give us the data base to either develop a new soil N test or adjust the present soil nitrate test to predict N availability from soils with a history of animal manure applications.

We were handicapped by the quality of data obtained in 1993 -- even at the four sites that we did not abandon. Soil nitrate concentrations were extremely low due to the three previous wet years and to the wet and cold conditions during 1993. In addition, corn yields were below normal; however, yield responses to fertilizer N occurred at all sites. Because of the poor data obtained in 1993, we filed for and received a 6-mo extension through Dec. 31, 1995 so that we could conduct research at additional sites in 1995.

The soil and plant data obtained in 1994 and 1995 were quite good. A wide range of soil nitrate-N concentrations from 4.6 to 11.9 ppm were just what we needed. Corn yields were also excellent and showed various degrees of response to N -- again what we needed. Residual N remaining in the second year of the five mineralization studies along with the yield response to the residual N was lower than we expected. But the data should help in the development of the new test or refinement of the present one. Porous cup samplers were not installed in the 10 primary studies because: (1) soil nitrate tests in 1993 were very low and (2) based upon subsequent experience after the proposal was written, nitrate-N is not likely to move to the 5-foot depth in one growing season on these soils.

Preliminary findings indicate that the present soil N test recommended by the University is helpful in arriving at better N recommendations in these manured systems, but that it is not perfect. It appears that the soil N credit may need to be adjusted upward slightly. Because the last soil N data were not received from the lab until late January and because we need to pool the data from all sites to determine the best relationships, it is too early to tell whether we will need a new test or whether we can refine the present one for manured soils. We should know, however, by April. Upon this determination and after validating with the data from the residual phase of the mineralization studies, we will implement these changes (provided changes are needed) into the recommended soil N test program for Minnesota. Extension bulletins will be written and distributed. Similar to the last 18 months, this material and talks will be delivered via a wide variety of educational programs.

In summary, we feel that the research program during the last 30 months has produced a data base that will lead to developing an improved soil N test to determine the availability of N from previous manure additions in Minnesota.

B. Title of Objective: Determine the mineralization rate of incorporated manure on the release of N to succeeding crops and potential impact on nitrate leaching as affected by time and rate of manure application.

B.1. Activity: The rate of release of available N (mineralization) from manure to the soil system as affected by time and rate of application and a nitrification inhibitor will be determined for liquid dairy and hog manure applied to a range of southern Minnesota soil/crop systems.

B.1.a. Context within the project: Fall application of manure, especially early fall application, has a greater potential to release N to the soil prior to the time of greatest plant demand than do spring applications. Late fall applications and/or the use of a nitrification inhibitor may slow the mineralization rate comparable to an early spring application. This objective will allow us to determine manure mineralization rates as influenced by livestock specie (dairy vs hog), by time and rate of application, and by the use of a nitrification inhibitor. This information will lead to BMP guidelines for manure application.

B.1.b. Methods: The proposed research will involve both field and laboratory components. Field experiments will provide the required crop response data and soil samples while the laboratory work will furnish the necessary soil N measurements to permit interpretation of the data. Multiple sites will provide the necessary range in management history, soil characteristics, and climatic conditions.

A minimum of 3 experimental sites will be established in each of the two years (1993 and 1994). The sites will be selected to represent soils and farming systems used for corn production on livestock farms. Sites will be located on University research stations and on private farms managed by carefully selected farmer-cooperators. Sites will be located in southeastern Minnesota where loess soils predominate and dairying is intensive and in south-central Minnesota on tile-drained soils where hog production is dominant. Detailed past management histories will be obtained from the farm manager at each location prior to initiation of an experiment.

Eighteen treatments will be replicated four times in a randomized, complete-block design at each field site. Sixteen of the 18 treatments will constitute a 4 x 2 x 2 factorial with four times of manure application (Sept. 1-10, Oct. 1-10, Nov. 1-10, and April 10-20), two manure rates (4000 and 8000 gal/A), and two rates of N-Serve, a nitrification inhibitor (0 and 2 quarts/A). All of the manure treatments will be sweep-injected--a method recently reported to be desirable compared to knife-injected and surface-broadcast application methods. To meet objective B we will focus on application time and not mix numerous manure sources, rates, and methods of application, which would compromise our objective. The remaining two treatments consist of a non-fertilized, non-manured control and a 150 lb N/A rate of spring-applied fertilizer (urea).

The following soil sampling protocol will be used to determine mineralization (N release) rates. All samples will be taken in 1-foot increments.

Time	Sampling Depth
9/10	0-5'
10/10 and 11/10	0-2'
4/15, 5/1, 5/15, 6/1, 6/15, 7/1 and 7/15	0-2'
10/15	0-5'

The soil system will be intensively sampled and analyzed to determine the fate of the manure-N. Nitrate-N will be determined on all soil samples. Ammonium-N will be determined on all samples except those taken at the post-harvest (10/15) stage. Selected soil samples will be analyzed for various hydrolyzable N fractions to determine if they relate to manure N. The methods and samples chosen will depend in part on the results from Objective A in this project. Routine soil tests will be performed on 0 to 6 inch samples to characterize each experimental site. Porous cup samplers will be installed at the 5' depth in the 8000 gal/A without N-Serve treatment in each replication at each of the application times plus in the control and fertilizer N treatments. Soil water samples will be collected monthly and will be analyzed for nitrate-N. Manure samples will be taken at each time of application at each site and will be analyzed for nutrient content. By knowing the nutrient content and the exact application rates, we can calculate the nutrient loading of each treatment at each site. This is a desirable approach since the nutrient content of the manure will vary among the sites. Additionally, liquid dairy manure will be applied to tile-drained plots at a rate of 6000 gal/A and compared to a fertilizer N rate of 180 lb N/A for continuous corn. The two treatments will be replicated four times. Soil NO_3-N and plant data will complement the tile drainage data (drainage volume, NO_3 concentration, and NO_3 flux) when evaluating the mineralization of the manure that will be annually applied each spring.

Weather data (precipitation, air temp, and soil temp at 4") will be collected for each site between the initial manure application (September) and harvest the following year. Nitrogen availability to the corn crop will be determined by measuring total plant dry matter yield partitioned into grain and stover components and N uptake at physiological maturity.

Data collected at each site will be statistically analyzed each year to develop interpretations on mineralization rate, leaching potential, and availability of N to the crop. Guidelines for preferred manure application practices will be developed considering the specific crop/soil/weather situations that impacted the data.

B.1.c. Materials: Materials necessary to accomplish this objective include vehicles; a precision liquid manure applicator; hydraulic soil probe equipment; implements to till, plant, cultivate, and harvest the plots; preparation equipment for plant and soil analyses; analytical equipment for the labor onducted soil tests; weather monitoring instruments; and uter hardware and

software to facilitate data management, analyses and interpretation.

B.1.d. Budget: $0.00. Initial Budget = $100,000.

B.1.e. Timeline:

	7/93	1/94	7/94	1/95	7/95
Establish field trials, manure application & climatic data collection system	xxxxxxxxxxxxxxxxxx				
Collect soil, plant & weather data	xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx				
Develop BMPs & conduct educational events					xxxxxxxxxxxxxxxxx

B.1.f. Status: Seven field experiments were established in 1993, 1994 and 1995 to determine the availability (mineralization) of N from liquid manure as affected by time and rate of application and addition of a nitrification inhibitor to the manure. Six sites were on glacial till soils while one was a loess soil in Olmsted Co. Dairy manure was used at four sites while hog manure was used at three. The residual effects of the manure treatments were examined in the second year of the five studies started in 1993 and 1994.

With the exception of one site in 1993, where marginal data were obtained due to the wet conditions, excellent data were gathered. Mineralization of manure to form nitrate-N was quite rapid when the manure was applied before September 20. Some mineralization occurred from manure applied between September 20 and October 20 with almost no mineralization occurring after that time. N-Serve delayed the nitrification, especially when the manure was applied in early September. Hog manure appeared to mineralize faster than dairy manure and N-Serve was very effective at one site in 1993. Spring-applied manure had completely mineralized by the end of June. Broadcast application of manure on the soil surface in March resulted in less nitrate-N in the soil profile and indicates some volatilization from winter-applied manure.

Corn yield and response to the manure and N-Serve were largely a function of the weather. In 1993, a wet cool year, spring application of hog manure was clearly superior to fall application. When N-Serve was added to the fall-applied manure, 21 bu/A more corn was produced than when it was omitted. At the other six sites, spring application tended to give slightly higher yields than fall application. Yield response to N-Serve was marginal and only appeared with the early fall applications. Spring application of manure resulted in higher soil NO_3-N concentrations in the profile after harvest compared to the fall applications. This residual N could potentially lead to higher leaching losses or could result in somewhat higher yields in the residual year; this was not consistently found, however. Additionally, nutrient content in the manure varied considerably among the hog producers and even among dates of application. This demonstrates the need for manure analyses. If we were to conduct the studies again, more effort should go into determining the nutrient content of the manure from the various farms prior to applying the manure treatments.

In summary, results from these seven studies plus their residual years provide an excellent research-base upon which BMPs can be developed for both hog and dairy producers. These BMPs will be ped in conjunction with the Minnesota Dept. of Agricul the upcoming months.

Liquid dairy manure was compared to urea in a tile drainage study in 1994 and 1995. Although yields were slightly higher from urea, nitrate-N concentrations were identical between the two N sources applied at equal rates of "available" N. Detectable concentrations of ortho-P have been found in <1% of the tile water samples while detectable total P has been found in about 14% of the samples. Concentrations of total P were not different between the urea and manure plots and averaged <0.10 mg/L. Ammonium-N was detected in 54% of the samples and averaged 0.03 mg/L with no difference between urea and manure. Fecal coliform bacteria was not found in the tile water. These data indicate that dairy manure applied for two years can be used in a well-managed cropping system without impacting tile drainage water. We will need to continue this study for a few more years, however.

B.2. Activity: Conduct complementary manure handling system and utilization survey.

B.2.a. Context within the project: To gain a better understanding of how leading hog producers handle their swine wastes (storage and transportation equipment) and apply them to their fields (rate and time of application) a survey will be conducted in south-central Minnesota. This sub-objective will assist in the transfer of findings obtained in this project to the livestock industry in a manner that is relevant to their needs.

B.2.b. Methods: Survey data will be collected from approximately 50 leading hog producers in Martin, Nicollet, Blue Earth, Freeborn, and Jackson counties. These counties have the highest hog densities in Minnesota. A successful survey format will be used that has been used by economists in other manure use investigations in the state.

B.2.c. Materials: An existing survey document will be used in the personal interview of each producer. Materials needed are a vehicle, survey forms, and computer hardware and software for data management and tabulation.

B.2.d. Budget: $0.00. Initial Budget = $20,000.

B.2.e. Timeline:

	7/93	1/94	7/94	1/95	7/95
Identify producers			xxx		
Conduct interviews			xxxxxxxx		
Tabulate results & integrate into BMP information					xxxxxx

B.2.f. Status: In cooperation with the Minnesota Pork Producers Assn. and the Minnesota Extension Service, 51 pork producing farms were identified and "on-farm" surveys were taken in Blue Earth, Freeborn, Jackson, Martin, and Nicollet Counties. Corn and soybeans accounted for 53% and 42% of the cropland acreage (45,000 acres), respectively. Producers applied 41% of the total N for corn in the fall (1993 and 1994) and 88% of this was in the form of anhydrous ammonia. Livestock produced an estimated 23000 lb of N and 17000 lb of P_2O_5 per farm. Plant available N in the first year was calculated to be 10,000 lb/farm. Pits under barns were the

dominant collection system (69%) with above ground tanks on 12% of the farms. Manure test results from pits under barns (45 samples) ranged from 9 to 99 lb N/1000 gal (avg. = 45), 5 to 107 lb P_2O_5/1000 gal (avg. = 37), and 3 to 77 lb K_2O/1000 gal (avg. = 26). These data emphasize that the nutrient content of manure is highly variable and that manure testing is highly recommended. Nitrogen supplied by fertilizer (74%), manure (9%), and legumes (17%) averaged 191 lb N/A applied to all corn acres. This was 41 lb/A in excess of what is currently recommended by the University of Minnesota. Categorizing the information into various corn production scenarios revealed that (1) fertilizer N rates applied to continuous corn was only 5 lb in excess of recommended, (2) when corn followed soybeans, fertilizer N was over-applied by 37 lb/A, (3) when manure was applied to a non-legume previous crop and corn was grown, N was over-applied by 35 lb/A, and (4) when manure was applied to a legume and corn was grown, N was over-applied by 80 lb N/A. These data clearly showed that N crediting from manure could be improved markedly, which in turn would result in less N being lost to Minnesota's ground and surface waters.

The surveys also showed strong evidence that producers are voluntarily adopting educational materials and strategies developed by the University of Minnesota and Minnesota Extension Service. It was also evident that the most recent technology and recommendations be targeted and promoted to livestock producers..

V. Evaluation: For the FY94-95 biennium the project can be evaluated by: 1) the number of experimental sites established, 2) the quality of the data obtained, 3) the initial interpretation of the field and laboratory data into possible best soil N tests and BMP guidelines for manure application, 4) success in determining the current practices used by hog producers in handling and utilizing their manure, and 5) awareness and anticipation by the livestock industry regarding the activities and results of the project.

In the long-term, the project should be evaluated by its ability to successfully develop a soil test that predicts available N from previously applied manure and by the data base necessary to establish statewide BMPs for liquid dairy and hog manure application systems.

VI. Context within field: Substantial N contributions from organic sources such as manure have generated concerns about the extent of nitrate loss from cropland to groundwater and the relationship between N management practices and nitrate concentrations in groundwater. In addition, it has stimulated research to predict availability of N from manure more accurately.

Concerns about groundwater quality in Minnesota are justified since more than 75% of the drinking water comes from groundwater. In Minnesota, well-water samples taken from the environmentally sensitive southeastern Minnesota area with high livestock density indicate that 39% of rural, private wells exceed the MCL (Minnesota Dept. of Health, 1989).

Many farming systems in Minnesota are animal-based and include land application of manure as a method of recycling nutrients removed in livestock feed production. Minnesota Agriculture Statistics in 1992 estimated 683,000 dairy cows (fourth highest state in nation) and 8.3 million hogs (third highest in nation). These two livestock species are estimated to produce over 142,000 tons of N annually of which most is returned to cropland (Wall and Montgomery, 1991). Moreover, a large proportion of dairy farms are located on the environmentally sensitive Karst soils of southeastern Minnesota. In summary, many farms in the study area have a long history of crop sequences that include repeated manure applications.

Little or no response to applied N is usually observed in first-year corn following alfalfa or when moderate to heavy manure applications are made for the current crop. However, the residual effects of long-term additions of manures are more difficult to quantify, but have a significant effect on the N needs of subsequent crops. In general, repeated additions of manure increases the readily mineralizable N fraction in soil organic matter resulting in release of larger quantities of available N during the growing season. To minimize loss of excess N from cropland and avoid unnecessary fertilizer N expense, it is imperative to develop and evaluate diagnostic techniques to estimate the amounts of available N that will be provided from soils with a history of organic N additions.

Soil testing, which allows site specific fertilizer recommendations, offers a means of improving manure-N management for corn production for a given soil/crop/climate. A recent review of advances in predicting N fertilizer needs for corn in humid regions of the Upper Midwest (Bundy et al., 1993) indicated substantial progress in evaluation and implementation of soil nitrogen tests in the region. Preplant soil nitrate tests have proven useful for predicting corn response to applied N in some cropping systems, and a preplant nitrate test has been implemented in Wisconsin and Minnesota. A pre-sidedress soil nitrate test is currently in use in Iowa. The preplant and pre-sidedress nitrate tests appear to be less reliable where organic N sources such as previous legumes or manure provide substantial amounts of available N. This problem is particularly apparent in second-year corn following alfalfa or where a long-term history of manure applications exists.

Improved estimates of N contributions from long-term organic N additions require improved techniques for estimating N mineralization. Although substantial research effort has been devoted to this topic, accurate predictions of N mineralization have not been achieved (Peterson and Russelle, 1991). In addition to appropriately timed soil inorganic N measurements, recently-proposed chemical tests for N availability may have potential for assessing these N contributions. The phosphate-borate buffer N availability test found that this test was well correlated with corn yield on loess-derived soils in Minnesota (Schmitt et al. (1991). The UV absorbance of sodium bicarbonate soil extracts was well correlated with soil N supplying capability in Pennsylvania studies where substantial contributions from organic N sources existed.

Dr. Randall will take the primary lead in coordinating this project. He has been involved in N and manure research since 1972 and in soil N testing since 1989. Dr. Michael Schmitt, Dept. of Soil Science will be the co-principal investigator. His Ph.D. thesis research centered on nutrient availability from manure and has been heavily involved in manure research and education since. He will provide specific leadership in the analytical phases, data interpretation, and education. Mr. Bruce Montgomery, Minn. Dept. of Agriculture, will take the lead in conducting the survey of hog producers.

This project will complement and integrate with an on-going project to evaluate soil N tests in Minnesota, Iowa, and Wisconsin. The focus of these investigations in our neighboring states is also turning to animal-based cropping sy[illegible] Thus, the pooled findings from the three states should [illegible]e our knowledge more

quickly and give us more precise guidelines for manure management over an array of soil/crop/climatic conditions.

VII. Benefits: Processing of Minnesota grown feed grains through livestock represents a huge "value added" opportunity to boost agricultural income in the state. However, animal manure produced in this process becomes a distinct environmental liability due to the high amounts of nutrients [primarily nitrogen (N) and phosphorus (P)] added to the land when the manure is inappropriately applied. Currently, there are between 45,000 and 60,000 feedlots in Minnesota that annually produce 269,000 Tons of N as animal manure -- equivalent to the amount produced by 77 million people. Surveys of livestock producers show manure often to be grossly over-applied. High concentrations of NO_3 leaching out of the root zone have been found with "realistic" application rates of hog manure.

This project will specifically address nutrient availability from manure/crop/climate systems in southern Minnesota to improve manure utilization, to reduce environmental impacts on water resources, and to provide BMP's to guide manure management decisions by Minnesota farmers. Developing a soil test that predicts N availability to plants when manure has been applied previously will greatly aid manure management decisions and improve N management on a field by field basis. Matching the release of N from manure to coincide with optimum N uptake by the plant plays a large role in reducing NO_3 leaching out of the root system. Obtaining manure mineralization data as impacted by soil/crop/climate systems will allow prediction of N release from various manure sources as affected by time and rate of application. Best management practices for land application of manure can then be developed. This information will not only aid the thousands of Minnesota livestock producers but will aid society in general by minimizing the eutrophication of our water supplies by animal manures.

VIII. Dissemination: Results from this project will be presented to livestock producers throughout the conduct of the study. These presentations will be facilitated and/or sponsored by producer groups, i.e., Minnesota Pork Producers Assn., etc., and by county, cluster and regional extension agents. The findings will also be presented at national, regional, and state scientific meetings to peers and practitioners in the field. Following presentation of results at such meetings, they will be published in the peer-reviewed literature in the major national journals in the field.

A goal of this project is to provide a data base for BMP development. This BMP development will be done in concert with the Minnesota Dept. of Agriculture and the Minnesota Pollution Control Agency through constant communication throughout this project.

IX. Time: A comfortable understanding of an appropriate soil test(s) and manure-N release rates to crops under an array of soil/crop/climate scenarios requires a long-term investigation. The intent of this project is to establish a strong base for the selection of "best" soil N tests and for the development of BMPs based on time and rate of manure application. However, the time frame necessary to quantify adequately the biological effects as affected by climatic conditions on soil N tests and manure mineralization rates exceeds two years. Thus, funding beyond the FY94-95 biennium will continue to be requested from LCMR.

X. Cooperation:

Dr. Gyles Randall will be the program manager and coordinator of this project. He will spend about 25% of his time on the project, equally divided between the two objectives.

1. Dr. Michael Schmitt will spend 15% of his time equally divided between the two objectives.
   Extension Soils Specialist and Dept. of Soil Science, Univ. of Minnesota

   Dr. James L. Anderson will spend less than 1% of his time on the project.
   Director of Center for Agricultural Impacts on Water Quality
   Dept. of Soil Science, Univ. of Minnesota

   Dr. Schmitt has extensive experience in manure application, analyses, and management research. He will provide specific leadership in the soil analyses for the soil N test, data and model interpretation, and education. Dr. Anderson will provide support and lend his expertise in water quality affairs and approaches related to this project.

2. Greg Buzicky and Bruce Montgomery will spend less than 5% of their time on the project.
   Agronomic Services Division
   Minn. Dept. of Agriculture

   Mr. Montgomery will be the MDA liaison for this project and will be responsible for the survey aspects of the project. Mr. Buzicky will oversee MDA's involvement in the research phase of the project as well as the development of BMPs.

3. Wayne Anderson and Dave Nelson will spend less than 1% of their time on the project.
   Division of Water Quality
   Minn. Pollution Control Agency

   Mr. Anderson and Mr. Nelson will provide support and advice throughout the conduct of the project that leads to networking with other appropriate water quality investigations and to awareness by the agricultural and regulatory community. They will also be involved in the development of BMPs.

4. Pat McGonegle, Exec. Director and Charlie Woehler, Past Pres., Minn. Pork Producers Assn. will spend less than 1% of their time on the project.

Mr. McGonegle and Mr. Woehler have been involved in the development of this project and will continue to be active during its conduct. They will identify potential farmer-cooperators, will promote BMPs through various avenues in their organization, and will help in seeking additional financial assistance.

XI. Reporting Requirements:

Semiannual status reports will be submitted not later than January 1, 1994, July 1, 1994, January 1, 1995 and

a final status report by June 30, 1995.

XII. Literature Cited: (for the "Context within field" section):

Bundy, L. G., M. A. Schmitt, and G. W. Randall. 1992. Predicting N fertilizer needs for corn in humid regions: Advances in the Upper Midwest. p. 000-000. In B. R. Bock et al. (ed.) Predicting N fertilizer needs for corn in humid regions. Tennessee Valley Authority, Muscle Shoals, Al. (In press).

Minnesota Dept. of Health. 1989. Pesticides and Groundwater: A survey of selected private wells in Minnesota. August, 1989.

Peterson, T. A., and M. P. Russelle. 1991. Alfalfa and the nitrogen cycle in the Corn Belt. J. Soil Water Cons. 46:229-235.

Schmitt, M. A., G. W. Randall, G. W. Rehm, and G. L. Malzer. 1991. Calibration and correlation of soil N tests for corn's N recommendations. p. 212-221. In A report on field research in soils. Minnesota Agric. Exp. Stn. Misc. Publ. 71.

Wall, D. B. and B. R. Montgomery. 1991. Nitrogen in Minnesota Groundwater. In Minnesota Pollution Control Agency and Minnesota Dept. of Agriculture Report to Legislative Water Commission. St. Paul, MN.

XIII. Literature Review

Objective A.

Soil testing, which allows site specific fertilizer recommendations, offers a means of improving N management for corn production for a given soil/crop/climate. Preplant soil profile nitrate measurements are widely used to predict crop N fertilizer needs in low-rainfall areas in the Great Plains and western regions of the United States. Recent work in humid regions indicates that substantial over-winter retention of profile nitrate occurs in some soils and years and that preplant nitrate tests may have potential for improving N recommendations. Magdoff et al. (1984) first proposed a pre-sidedress soil nitrate test (PSNT) taken from the 0 to 30-cm layer when the corn was 20 to 30 cm tall as a soil test to predict N needs of corn. Under their conditions, the PSNT accurately separated fields that responded to fertilizer N from those that did not respond, but was an imprecise indicator of the fertilizer N needed for economically optimum N rates. After additional research and validation, the PSNT is now being used to provide fertilizer N recommendations in many northeastern states (Magdoff et al., 1990). It is suggested that this test will help minimize the practice of applying "insurance N" when contributions from manure and legumes in rotation are uncertain.

A recent review of advances in predicting N fertilizer needs for corn in humid regions of the Upper Midwest (Bundy et al., 1993) indicated substantial progress in evaluation and implementation of soil nitrogen tests in the region. Preplant soil nitrate tests have proven useful for predicting corn response to applied N in some cropping systems, and a preplant nitrate test has been implemented in Wisconsin and Minnesota. A pre-sidedress soil nitrate test is currently in use in Iowa (Blackmer et al., 1991). The preplant and pre-sidedress nitrate tests appear to be less reliable where organic N sources such as previous legumes or manure provide substantial amounts of available N. This problem is particularly apparent where a long-term history of manure applications exists.

Improved estimates of N contributions from long-term organic N additions require improved techniques for estimating N mineralization. Although substantial research effort has been devoted to this topic, accurate predictions of N mineralization have not been achieved. Frequent additions of legume residues and/or manure in farming systems increases the readily mineralizable N fraction in soil organic matter resulting in release of larger quantities of available N during the growing season (Bonde et al., 1988).

In addition to appropriately timed soil inorganic N measurements, recently-proposed chemical tests for N availability may have potential for assessing these N contributions.

LITERATURE CITATIONS:

Blackmer, A. M., T. F. Morris, D. R. Keeney, R. D. Voss, and R. Killorn. 1991. Estimating nitrogen needs by soil testing. Ext. Publ. Pm-1381. Iowa State Univ. Ext. Serv., Ames, IA.

Bonde, T. A., J. Schnurer, and T. Rosswall. 1988. Microbial biomass as a fraction of potentially mineralizable nitrogen in soils from long-term field experiments. Soil Biol. Biochem. 20:447-452.

Bundy, L. G., M. A. Schmitt, and G. W. Randall. 1992. Predicting N fertilizer needs for corn in humid regions: Advances in the Upper Midwest. p. 000-000. In B. R. Bock et al. (ed.) Predicting N fertilizer needs for corn in humid regions. Tennessee Valley Authority, Muscle Shoals, AL. (In press).

Magdoff, F.R., D. Ross, and J. Amadon. 1984. A soil test for nitrogen availability to corn. Soil Sci. Soc. Am. J. 48:1301-1304.

Magdoff, F. R., W. E. Jokela, R. H. Fox, and G. F. Griffin. 1990. A soil test for nitrogen availability in the northeastern United States. Comm. Soil Sci. Plant Anal. 21:1103-1115.

Objective B.

Accurate predictions of N mineralization from manure have not been achieved and the effect of time of application (soil temperature) on mineralization rate of manure-N and availability to the subsequent crop has not been adequately examined. Magdoff (1978) conducted one of the earlier studies investigating the mineralization of organic N from dairy manure and found that mineralization was less and manure-N accumulated at a greater rate in clay soils compared to loam soils. He concluded that further research is needed to determine the effects of soil and manure characteristics on the rate of N mineralization from manure. Residual N availability to corn from various sources of manure applied 1 to 2 years previously showed a lower yield response from liquid dairy and swine manure compared to poultry manure in southern Ontario.

Large losses of manure N occurred following fall applications of liquid swine manure in Indiana (McCormick et al., 1984). However, nitrapyrin (N-Serve) added at a rate of 50 mg/L to the manure was effective in

reducing the losses of applied manure N. Studies in Wisconsin reported by Comfort et al. (1988) indicated that nitrapyrin (13 mg/L) was not effective in inhibiting nitrification in liquid dairy manure.

Sawyer et al. (1990) compared injection methods of liquid beef manure in Illinois and found the sweep injection method to produce lower concentrations of ammonium than with knife injection. Their studies also showed nitrification to be slowed with nitrapyrin (N-Serve) with sweep injection but not with knife injection. Additional research by Schmitt et al. (1992) characterized N transformations in the injection zone and described the impact that method of manure application can have on N availability to the crop. Wisconsin researchers found that inorganic N in the top 12" of soil 4 to 6 weeks after manure application proved to be a better index of N availability in the soil system than all other indices examined, but concluded that more reliable biological or chemical indices are necessary to determine nutrient availability on a routine basis.

LITERATURE CITATIONS:

Comfort, S. D., K. A. Kelling, D. R. Keeney, and J. C. Converse. 1988. The fate of nitrogen from injected liquid manure on a silt loam soil. J. Environ. Qual. 17:317-322.

Magdoff,F.R. 1982. Influence of manure application rates and continuous corn on soil N. Agron. J. 70:629-632.

McCormick, R. A., D. W. Nelson, A. L. Sutton, and D. M. Huber. 1984. Increased N efficiency from nitrapyrin added to liquid swine manure used as a fertilizer for corn. Agron. J. 76:1010-10114.

Sawyer, J. E., M. A. Schmitt, and R. G. Hoeft. 1990. Inorganic nitrogen distribution and soil chemical transformations associated with injected liquid beef manure. Agron. J. 82:963-969.

Schmitt, M. A., J. E. Sawyer, and R. G. Hoeft. 1992. Incubation of injected liquid-beef manure: Effect of time and manure rate. Agron. J. 84:224-228.