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LCMR FINAL REPORT - SUMMARY June 30, 1993

I. TITLE: Effective Nitrogen and Water Management for Water Quality Sensitive Regions of Minnesota - Agriculture 5

Program Manager: H. H. Cheng
Department of Soil Science
University of Minnesota
1991 Upper Buford Circle
St. Paul, MN 55108
Tel: 612-625-9734 FAX: 612-625-2208

A.M.L.91 Ch 254, Art.1 Sec. 14 Subd.6 (c) Appropriation: $300,000
Balance: 0

Effective Nitrogen and Water Management for Sensitive Areas: This appropriation is to the Commissioner of Agriculture to provide an integrated research information base on risks of groundwater pollution involved in nitrogen and water management for crop production.

B. Compatible Data: During the biennium ending 30 June 1993, the data collected by 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 by the Information Policy Office. 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.

C. Match Requirement: Not applicable

II. NARRATIVE

The ultimate goal of this project is to develop and demonstrate ways to reduce nitrogen contamination of groundwater through more effective utilization of nitrogen from manure, legume, and fertilizer sources. A risk index based on an assessment of the soil and climatic characteristics of a locale, and the cropping, fertilization, and soil management practices used will be developed. The index will be generated from a process model which will be developed to account for water movement and nitrogen transformations and transport and validated at selected water quality sensitive regions in Minnesota. An education and demonstration program will be developed to disseminate information on the risk index concept and on the interrelationship of water quality and cropping and soil management practices in a specific soil and climatic setting. During the first biennium, the project will be devoted to the water quality-sensitive, central sands region of the state and to management practices under alfalfa-manure-tillage systems and irrigated potato production. This project is a direct response by the Minnesota Department of Agriculture and the University of Minnesota to a request by the Minnesota Irrigators Association to investigate the impacts of current practices on nitrate leaching losses and conduct research to improve nitrogen management guidelines. The project plans to be extended in subsequent years to other sensitive regions such as the karst area in southeastern Minnesota.

III. OBJECTIVES The following objectives are interdependent and sequential in nature:

A. Prepare an inventory of soil, climate, and management practices of the Central Sands of Minnesota

A.1. Narrative: Soils, climate and crop management practices all play an important role in determining the potential leaching of surface-applied nitrogen to ground water. Depending upon the soil physical and chemical characteristics and the climate of the area, nitrate will move at different rates through different soils. Since soils in the Central sands of Minnesota are very permeable, the nitrogen management practices such as application rate, source and timing and the irrigation management practices such as amount and time have a significant impact in controlling the potential of nitrate leaching to ground water. The focus of this objective is to prepare an inventory of soil physical and chemical properties, probable soil and aquifer recharge based on estimation of precipitation and evapotranspiration rates, and inventory of total nitrogen management practices. This inventory will provide inputs for models that can estimate nitrate leaching in soils of the Central Minnesota as well as identify best nitrogen management practices that will minimize nitrate losses.

A.2. Procedures: Soil survey maps will be used to identify major soils in the Central Sands of Minnesota. This study will focus on 3 to 5 of the major soils. Soil survey records and completed students theses will be searched for information on hydraulic and chemical characterizations of these soils. Soil hydraulic properties will include water retention characteristics and hydraulic conductivity- water content relationships by horizon. Soil characterization will include particle size distribution, soil organic matter content and cation exchange capacities. For those soils where this information is lacking, soil cores will be taken to the laboratory for hydraulic and chemical characterizations. Double ring infiltration tests will be conducted in the field at the primary experimental site at the Staples Irrigation Center to characterize in-situ saturated hydraulic conductivity of the surface layer.

Weather bureau records will be searched for information on rainfall amounts and time, pan evaporation, solar radiation and maximum and minimum air temperatures for the growing season. Air temperatures and solar radiation will be used to calculate potential evapotranspiration from areas where this information is lacking. Calculated evaporation or pan evaporation rates will be used in conjunction with a crop coefficient to calculate evapotranspiration for the crop under consideration. Rainfall and evapotranspiration data will be summarized in terms of probabilities of these parameters at various times of the growing season. Some of this information is already available for one or two sites in the area. This will be summarized along with similar information developed for other locations in the region. Rainfall and evapotranspiration data will be used to develop the probabilities of recharge of vadose zone and aquifer at various times of the year.

Irrigators in the Detroit Lakes Pitted Outwash Plain and the Park Rapids-Staples Outwash Plain will be surveyed for information on irrigation amounts and timing, fertilizer types and rates, crop rotations, tillage practices, manure rates and application times, and nitrogen credits for alfalfa and manure sources. There are two dominant reasons justifying the focus on these two regions within the Central Sands. First, management practices have not been previously inventoried in these areas which include the coarse-textured soils of the following counties: Becker, Cass, Hubbard, Otter Tail, Todd and Wadena. Secondly, these areas, particularly areas around Park Rapids and Osage, are of special interest because of recent evidence that nitrate levels are increasing and in some situations exceeding the 10 parts per million drinking water standard.

Inventory of management practices will collected in a two-phase approach. Originally this portion of the project intended to put most of its efforts and finances in a general mail out survey incorporating 200-300 farmer. Since the conception of the project, the Minnesota Extension Service has compiled similar agricultural inventory practices via mail out techniques. Upon review of this information, it was readily apparent that mail out surveys would not provide field specific information required for the computer modeling efforts described elsewhere within this project.

This study will redirect its efforts on the development of detailed nitrogen management inventory through one-on one interviews with 35 to 40 irrigators. In cooperation with the Minnesota Irrigators Association, growers in these two geomorphic regions will be interviewed in a case study format. Information will be gathered on nitrogen management strategies including rotations, irrigation testing, fertilizer sources, rates, timing, tillage, soil testing, yield goal setting, nitrogen credit and information sources. These data will be grouped by geographic regions, soils and crops grown, as well as management factors. The data will also serve as the data base to be organized in map format to illustrate differences in soil and cropping management practices in the are and to provide input for computer simulation.

A.3. Budget

| | LCMR Funds |
|---|---|
| a. Amount Budgeted: | $65,000 |
| b. Balance: | 0 |

A.4. Timeline

| | July91 | Jan92 | June92 | Jan93 | June93 |
|---|---|---|---|---|---|
| Inventory of soil properties | | | ..... | .......... | .......... |
| Characterization of soil properties | | .......... | .......... | .......... | |
| Inventory of climatic variables | .......... | .......... | .......... | ..... | |
| Probabilities of rainfall, ET and recharge | | | | .......... | .......... |
| Inventory of management practices | | .......... | .......... | .......... | |
| Summary, publication of results, and map preparation | | | | .......... | .......... |

A.5.1. Prepare an inventory of management practices

A.5.1. Status: There is a great deal of uncertainty in regards to how Minnesota farmers are managing their agricultural nitrogen resources; currently this is of most concern in the groundwater sensitive regions of the state. The goal of this portion of the project was to establish "baseline" information on current nitrogen management practices used by irrigators in the Central Sands. Detailed assessments and nutrient balances will serve as useful tools for the development of appropriate educational programs which emphasize water quality protection in balance with production agriculture.

Thirty-seven farmers in a five county area (Becker, Hubbard, Otter Tail, Todd and Wadena) of west-central Minnesota were extensively interviewed during the 1992 cropping season. Nitrogen (N) practices (i.e. rates, timing and methods of application) related to the usage of commercial fertilizer, manures, and legumes, along with related management practices which strongly affect leaching losses (i.e. irrigation scheduling), were quantified on a field by field basis.

Farmers were carefully selected to represent the diversity across the five county region; County Agricultural Educators and staff from the Staples Irrigation Center played an extremely valuable role in the selection of potential candidates. "On farm" nitrogen inventory assessment. Interview times ranged between 1 to 3 hours. Complex manure scenarios and high number of individual irrigation pivots confounded the process. Interviews were conducted in 1992 starting in mid-July and were finalized by the end of August. Each farmer was revisited (November-December) to obtain final yields and irrigation amounts.

Total area inventoried was 27,200 acres which would include all agricultural land (irrigated, non-irrigated, and pasture) and non-agricultural land (forest, homesteads, and wetlands/surface waters). Total cropland (irrigated and non-irrigated) area was 18,200 acres representing 1.3% of all cropland within the five county region. Eleven percent (12,300 acres) of the total irrigated acres in the five counties (113,000) was inventoried. Corn, edible beans, and alfalfa were the dominant crops representing 47, 25, and 15% of the cropland areas.

Animal inventory numbers, method of manure storage and handling, and application rates were collected. This information was used to calculate manure-N credits. Fertilizer rates, application dates, and sources were collected for every individual field. Irrigation information such as tools used for making scheduling decision, sources of climatic information, and future needs were also collected and analyzed. The vast majority of the total project was dedicated to establishing field by field nitrogen balances. Initial data analysis effort has been concentrated on corn acreage since nitrogen management in irrigated corn production is a major issue of concern.

Over-application of N on manured fields, by far, appears to have the most potential impact on water quality in the selected study area. Implications to the entire Central Sands can only be speculative. Manured corn accounted for 30% of the corn acreage yet contributed over 88% of the excess N. Based on the entire N balance calculated with "on-farm" generated manure-N on corn, producers could cut back by an average of 27 Lb/A (across both irrigated and non-irrigated fields) without suffering any apparent yield loss.

Current timing practices of commercial N fertilizers will also need changes to protect groundwater supplies. Producers are presently applying 45% of the recommended fertilizer N before or at planting time; this is 3 to 6 times more than the recommended starter amounts. Due to the high leaching fraction during the spring on these soils, a large percentage should be shifted to applications between early-late sidedress.

It is difficult to quantify the impacts of current irrigation management. Most irrigators appear to be using the correct tools. However, even if the proper adjustments were made to better match N inputs with recommended rates, N loss could occur during the cropping season due to improper irrigation scheduling. The likelihood of retaining any remaining residual soil nitrate, as a direct result of over application, for the following crop in rotation is low due to the high leaching characteristics of most soils found in the Central Sands. The impacts can not be quantified without some real-time monitoring.

A.5.2. Prepare an inventory of soil and climate of the Central Sands of Minnesota.

A.5.2. Status: A literature search of published articles, theses and reports resulted in one publication that detailed the hydraulic characterization of some Minnesota outwash soils. This report by Dylla et al. (1975) reported the available water capacity and in-situ sprinkler infiltration rates of 24 locations in Bonanza valley in the central sands of Minnesota. This valley encompasses over 200,00 acres out of which about 57 percent of the soils are in the Estherville series. Most of the 24 locations they evaluated belong to the Estherville series. They found that available water capacities of the top 36 inches varied between 3.2 and 5.9 inches with an average of 4.11. In-situ infiltration rates were as high as 2 inches per hour. Available water capacities calculated using the SCS soil texture based method was close to the measured values.

We also undertook the hydraulic characterization of Verndale sandy loam at the Staples Irrigation Center at Staples, MN. Since our field experiment was located on the Verndale soil, hydraulic characterization of this soil was much more extensive. This included the saturated and unsaturated hydraulic conductivity, the water retention characteristics, and in-situ spatial variability of the infiltration rates. As the unsaturated hydraulic conductivity measurements are expensive and time consuming, we also tested a simple procedure for calculating unsaturated hydraulic conductivity from the water retention characteristics data. This method predicted the slope of the unsaturated hydraulic conductivity vs. water content relationship well. The method looks promising for sandy outwash soils when field measured saturated conductivities or infiltration rates are available. This simplified procedure for characterizing the hydraulic conductivity from water retention characteristics curves will be extremely useful in future field characterization of water and nitrate fluxes in Minnesota outwash soils. Other hydraulic characterization included the water retention and hydraulic conductivity determinations on undisturbed soil cores taken from each soil horizon of LaPrarie loam in Stevens County and Fairhaven loam, Estherville sandy loam, and Haywick loamy sand in Stearns County.

A procedure to estimate the soil hydraulic properties needed for CERES-Maize and SUBSTOR-Potato models is also identified. This procedure uses the easily measurable soil textural analysis, soil permeability, and soil drainage classes defined by SCS to predict the lower and upper limits of water availability and drainage coefficient.

Since the two models (CERES-Maize and SUBSTOR-Potato) used in this study (Part D) were based on the daily mass balance approach for water flow, we also ran field experiments to validate this assumption that soil water in sandy outwash soils of Minnesota attains an equilibrium value within a day. Furthermore, since sandy outwash soils may have minor heterogeneities in soil profile characteristics that can lead to preferential transport of water and chemicals to groundwater, we also characterized the root zone of Verndale sandy loam for lateral flow and fingering by evaluating the flow paths marked by dye patterns. There was no lateral flow and only slight amount of fingering. Small fingers observed in the dye patterns appear to be related to mixing of Ap and Bt horizons by roots, animals, and/or deep tillage. This analysis gave us confidence in the application of the CERES-Maize and SUBSTOR-Potato models (which assume piston displacement of water) to the Verndale sandy loam. However, the question remains if other sandy outwash soils display a fingering mechanism and if the application of conventional models based on piston displacement to these soils is valid. This objective will be pursued in the next LCMR grant and will cover the relationship between the water flow patterns and the mode of soil formation.

Probabilities of percolation losses and timing for Minnesota outwash soils with various water holding capacities were also developed based on long-term (41 years) weather records. This analysis showed that peak percolation losses in central Minnesota occur around the middle of June. Average annual percolation losses range from 12 to 20 cm of water for soils with water holding capacities of 5.0 and 10.0 cm, respectively. Based on this analysis, the growing season can be divided into three periods for irrigation and fertilizer management: April-June, nitrogen losses can be minimized by managing the source and timing of fertilizer application; June-August, nitrogen losses can be minimized by managing the amount and timing of irrigation; and September-November, nitrogen losses can be minimized by growing a cover crop that will tie-up the residual nitrogen from the previous season, keeping it in the rooting zone.

A.6. Benefits: This inventory will quantify major factors influencing nitrate leaching at various times of the year in the soils of Central Minnesota. The inventory of climatic and management parameters will establish the probabilities of rainfall and evapotranspiration and fertilizer, irrigation, manure and tillage practices. Combined, this information will provide a data base for developing improved management of these soils. Data from this objective will allow development of computer decision aids that will be useful to growers in determining best management practices. The inventory of management practices will define the nitrogen management practices currently utilized by growers as well as define the rationale for the decision making process.

B. Evaluate tillage influences on nitrogen available to corn from manure and fertilizer sources as well as nitrate leaching losses on the Central Sand Soils of Minnesota

B.1. Narrative: More precision in nitrogen management is necessary on soils that pose a high risk to nitrate losses to exposed aquifers such as in the Central Sands Area of Minnesota. Also, due to the erosive nature of these soils by wind, most best management systems will include some form of conservation tillage to manage crop residues for erosion control. Tillage can affect soil physical properties that influence the mineralization of organic N sources such as manure and soil organic matter. Nitrogen fertilization guidelines that include not only consideration of profitability (grain yields and tillage inputs) but also the risk of nitrate losses to groundwater are necessary. The primary objectives are to estimate tillage effects on the nitrate concentration in soil water and availability to corn during several growing seasons from manure sources. This information in conjunction with the field validation of crop-environment models in objective D will allow a risk assessment based on yield and nitrate loss.

B.2. Procedures: Field plots will be established that evaluate tillage effects on the amount of nitrogen available from turkey, pig, and dairy manure; and urea and anhydrous ammonia fertilizers. The tillage systems evaluated will be moldboard plowing, chisel plowing, discing, and ridge tillage. Manure will be spring and fall applied. The rate of manure will be based on analysis of organic and mineral nitrogen and current University of Minnesota recommendations for anticipated crop available nitrogen. Incorporation will vary depending on the tillage system. In the year after application residual N from the year before will be evaluated. In addition, four rates of applied fertilizer nitrogen will be used to determine the economic fertilizer optimum. Urea will be applied as a split application with 20 kg/ha at planting and the remaining split 50% between the 4 to 6 and 8 to 12 leaf stage of corn (20, 80, 160 and, 240 kg/ha). Urea will be soil incorporated by irrigation to eliminate potential volatilization losses. Anhydrous ammonia will be side dressed.

Nitrogen availability to corn from manure will be estimated by measuring total plant uptake at maturity. Soil water N concentration will be monitored throughout the year by installing PCV access tubes with ceramic cups (1.5m, see objective D). The proposed wick web-glass plate samplers were found to be unacceptable due to excessive soil disturbance during installation, which affected water flow. The occurrence of soil "cave in" with the coarse textured soils with gravel lenses encountered in this study was also a problem. Soil water samples will be analyzed for ammonium and nitrate nitrogen. Soil water samples will be intensive during irrigation or rainfall events (every 6-8 hrs for two days) but year around at a reduced level (every week).

This and objective C with the data from D will allow construction of a yield response-leaching loss vs. N rate set of curves for corn and potatoes that will be extremely useful in developing risk guidelines for farmers on these soils.

B.3. Budget: Amount budgeted $85,000
balance 0

B.4. Timelines - Products/Tasks:

| Products/Tasks | July 91 | Jan92 | June92 | Jan93 | June93 |
|---|---|---|---|---|---|
| Establish tillage/manure treatments | ....... | | | | |
| Instrument plots for water and nitrate movement | ....... | | | | |
| Monitor plots for water and nitrate movement | | ...... | ...... | ...... | ...... |
| Estimate crop removal and water and nitrate movement for first crop season | | ..... | ..... | | |
| Reestablish tillage/manure treatments | | ... | ... | | |
| Estimate crop removal and water | | | ..... | ...... | |

and nitrate movement for
Second crop season

Develop recommendations for farmers and agency field staff on sandy soils .....

B.5. Status: Tillage influenced the amount of nitrogen available to corn following manure application. Increased tillage has increased the amount of nitrogen available. Row cultivation has also increased N uptake with all tillage systems but more so with the no till system. With an urea N source tillage has not influenced the N response by corn.

Tillage has been shown to influence the the N response to first year corn on coarse textured soil. The N response of second and third year corn has genearlly not been affected by full width tillage. In cool years high levels of soil cover in the row area has limited the N response due to decreased development and growth. The N response has been consistently influenced by row cultivation. N uptake has been increased with row cultivation under moldboard, spring discing, and no till systems.

Soil water nitrate concentrations did not allow drawing conclusions concerning tillage effects due to extreme data variability.

B.6. Benefits: This research objective will yield data to support more precise nitrogen recommendations for farmers and farm advisors that includes an environmental risk assessment. Reduced fertilizer applications by utilizing more precise nitrogen credits from manure will reduce nitrate nitrogen contamination of groundwater and fertilizer purchases by farmers. Conservation tillage systems will be more readily adopted by farmers and erosion reduced.

C. Monitor soil nitrogen distribution and develop a nitrogen budget for irrigated potatoes

C.1. Narrative: Potatoes grown on sandy soils under irrigation are usually provided with high rates of nitrogen to promote growth and yield. The recent concern about ground water quality has raised questions about the fate of nitrogen applied to potatoes on irrigated soils. In part, this concern is due to the fact that potatoes have a relatively shallow root system, yet require high levels of nutrition to obtain high yields. Careful management is critical to reducing losses of nitrogen from the root zone. The emphasis of this objective, therefore, is characterize the pattern of soil nitrate-N movement during irrigated potato production under defined management regimes and to develop diagnostic tools for more accurate prediction of the need for nitrogen by potato during the growing season. Early applications of nitrogen are usually applied by growers yet this is also a time when there is little root development for nitrogen uptake.

C.2. Procedures: Replicated field plots will be established to evaluate various nitrogen management practices and to monitor nitrogen movement during potato production. Ten treatments will be tested to determine optimum rates of N at planting and effects of N source on potato production and N movement. The feasibility of using quick sap nitrate tests will also be evaluated. Treatments will include four rates (0, 45, 90, 135 kg N/ha) of nitrogen (ammonium nitrate) applied as a band at planting. Effects of delaying nitrogen application on tuber initiation will be determined. Different nitrogen sources (urea, ammonium nitrate, and a slow release N source) will also be included in the treatment design. The total amount of nitrogen applied will be 270 kg N/ha which is the recommended rate for a yield of 500 cwt/A. A control treatment (0 kg N/ha) and a 1/2 X treatment (135 kg N/ha) will also be included. Post-hilling nitrogen applications on two treatments will be based on monitoring petiole sap for nitrates. Sap tests for nitrate may provide a quick and accurate method for scheduling nitrogen fertilizer applications which in turn would reduce unnecessary use of nitrogen later in the season. The 10 specific treatments are as follows:

| | | N Application Rate (kg/ha) | | | |
|---|---|---|---|---|---|
| | N Source | Planting | Emergence | Hilling | Post-Hilling |
| 1) | Control | 0 | 0 | 0 | 0 |
| 2) | Am. nitrate | 0 | 135 | 135 | 0 |
| 3) | Am. nitrate | 45 | 110 | 110 | 0 |
| 4) | Am. nitrate | 90 | 90 | 90 | 0 |
| 5) | Am. nitrate | 140 | 65 | 65 | 0 |

| | | | | | |
|---|---|---|---|---|---|
| 6) | Urea | 90 | 90 | 90 | 0 |
| 7) | Slow Release | 90 | 90 | 90 | 0 |
| 8) | Am. nitrate | 45 | 45 | 45 | 0 |
| 9) | Am. nitrate | 45 | 45 | 45 | based on sap test |
| 10) | Am. nitrate | 90 | 90 | 0 | |

There will be two locations for this experiment: Becker and Staples, MN. At Becker, all 10 treatments will be tested while at Staples treatments were designed so that a direct comparison could be made with the corn/turkey manure experiment described in objective B.

Nitrogen uptake by the tubers and vines will be measured at four stages during the growing season. At both sites, irrigation will be provided according to the checkbook method. At Staples, an irrigation variable may be imposed if space and facilities permit an adequate experimental design. Soil nitrate will be measured to a depth of 3 feet prior to planting, during the growing season, and at harvest. Soil water movement and nitrates in soil water will be estimated as described in objectives B and D.

C.3. Budget: amount budgeted $50,000
balance 0

| C.4. Timelines - Products/Tasks: | July91 | Jan92 | June92 | Jan93 | June93 |
|---|---|---|---|---|---|
| Establish field plots | ...... | | ...... | | |
| Set up instrumentation | ...... | | | | |
| monitor water and nitrate movement | | ........ | ........ | ........ | ........ |
| Estimate crop N removal and residual soil nitrate | | ..... | | ..... | |
| Develop best management practices for potato nitrogen management on irrigated sandy soils | | | | | ..... |

C.5. Status: Field studies on irrigated potatoes conducted in 1991 and 1992 at the Sand Plain Research Farm at Becker have shown that nitrogen management significantly affects nitrate losses and potato productivity. In both years, greatest leaching losses were observed when high rates of nitrogen were applied at planting. Potato yield and quality were not detrimentally affected when the majority of fertilizer nitrogen was applied after emergence. Use of urea or slow release nitrogen as the nitrogen sources minimized nitrate leaching losses compared to equivalent rates of ammonium nitrate. Post-hilling applications also reduced nitrate leaching compared to similar rates of nitrogen applied before hilling. In 1991, a wet year with 5 leaching events, yields obtained with post-hilling applications of nitrogen were equal to or greater than those yields obtained with treatments where all nitrogen was applied before hilling. In 1992, a drier year with only one leaching event, post-hilling nitrogen applications resulted in lower yields compared to the pre-hilling applications. In a low leaching year, potatoes seem to benefit from higher applications of nitrogen applied at emergence and hilling. From this study, it is clear that high applications of nitrogen at planting are not necessary for profitable potato yields, and if high rates are use at planting, substantial nitrate leaching losses may potentially occur. The use of ammonium nitrate as the nitrogen source at planting should be discouraged and avoided.

An in-field petiole nitrate sap test was evaluated for determining the nitrogen status of the crop and predicting the need for supplemental nitrogen applications. Petiole sap nitrate concentrations were highly correlated with conventional petiole analysis and appear to have promise for predicting nitrogen needs during the season. A tentative table of critical sap nitrate levels at particular growth stages has been developed that will eventually need to be validated in commercial fields.

Nitrogen fertility studies on irrigated potatoes were also conducted at Staples. Results from these experiments were primarily used for modelling purposes and are discussed in objective D.

C.6. Benefits: As in objective B, this research objective will yield data to support more precise nitrogen recommendations. The target audience, however, in objective C will be potato growers on irrigated soils and farm advisors for these growers. More efficient nitrogen management by timing applications more accurately and by only applying nitrogen according diagnostic criteria will help to reduce leaching losses of nitrogen.

D. Field test and validate models for nitrate leaching

D.1.Narrative: Characterization of soils to nitrate leaching or identification of best management practices that will minimize nitrate leaching requires long term (10-20 years covering several types of climate cycles) data on crop yield, nutrient uptake and nitrate leaching past the root zone for a whole series of management scenarios on various soil types. This type of information is currently not available for the soils in the Central Sands area of Minnesota. The cost involved in setting up test plots to gather this information is prohibitive. One of the effective means of obtaining this type of data is through simulation models that integrate soil, climate and management information to predict crop growth, and availability and movement of nitrogen in the root zone. Though these models are based on the physical principles of water and nitrate movement in soil, they still use site and crop specific information. In other words, these models need testing and validation before they can be extensively used for whole series of soils, and management and climatic conditions. The focus of this objective will be to test and validate several of the crop-environment resource synthesis models for water and nitrate movement in field experiments described under objective B and C. The models tested under this objective will be CERES-Maize and SUBSTOR. CERES-Maize, and SUBSTOR have the same submodel for soil processes, however the former model simulates maize growth whereas the latter simulates potato growth. Since the NLEAP model does not account for interactive crop growth, does not have any provision for simulating potato yield, and does not simulate year by year leaching, this model is not suitable for the objective of this study.

D.2.Procedures: The models will be tested and field validated on a few selected treatments representing extreme conditions under objective B and C . The treatments will include two crops (corn and potatoes), two irrigation rates (existing practice, reduced level), two fertilizer rates for potatoes, two sources (fertilizer and manure) of nitrogen for corn and one type of tillage. Existing irrigation practices refers to the calculation of irrigation amount based on the available capacity of the rooting zone (1.5 m depth). Since the soil texture below 0.5 m depth is coarse sand and gravel and thus not likely to hold much water after irrigation, the reduced irrigation treatment will be based on the available water holding capacity of the top 0. 5m depth. For potatoes, the fertilizer treatments include an application of 270 kg/ha of ammonium nitrate applied as (1) 90, 90, 90 kg/ha or (2) 45, 45, 45 kg/ha at planting, emergence and at the time of hilling, respectively. For the second fertilizer treatment, additional amounts of fertilizer to total of 270 kg/ha or less will be applied after hilling based on the petiole sap analysis. For corn, urea and poultry manure will be applied at rate of 245 kg of N/ ha. Twenty kilograms of urea will be applied at the time planting and the remainder applied as two equal applications between the 4 to 6 and 10 to 12 leaf stage. Manure will be spring applied. Since soils are permeable, and low pressure irrigation systems will be employed, tillage will have minimal effect on water flux. Most of the tillage effect will be in the release of nitrogen from manure. Mathematical functions will be incorporated in the existing models to account for the release of nitrogen from manures under various tillage systems.

Selected field plots will be intensively instrumented with tensiometer and suction cup soil water samplers to monitor the quantity and quality of water flowing through the soil profile. Tensiometers will be connected to a data acquisition system to continuously monitored soil water potential. These measurements along with the laboratory measured soil hydraulic conductivity will be used to estimate water flux. Tensiometers and suction soil water samplers will be installed in the middle and bottom of $B_t$, and at 1.5 m depth in the C horizons. These instruments were not installed at the bottom of the $A_p$ horizon due to poor soil contact problems because of the shallow installation depth. Neutron probe readings will not be taken to measure the volumetric soil water content on a weekly basis. Our dye studies at the experimental site at Staples showed that the Verndale soil reaches field capacity within one day and the changes in soil moisture after that are relatively minimal. This suggested to us that neutron probe readings taken on a weekly basis may not show much difference and thus may be of minimal value in calculation the soil water budget. Instead, we have used the tensiometer readings along with the laboratory measured soil moisture retention data to calculate the soil water budget in the soil profile. Since the soils of the area are permeable and most of the nitrate movement will be during the rain or irrigation events, the nitrate flux will be measured by intensive sampling of soil water both before and after the irrigation event. A weather station already installed at the Staple Irrigation Experimental station will be used to monitor the weather information needed for computer modeling.

Field measurements will be used to calculate the nitrate and water flux both on event as well as on seasonal basis. These measurements will be used to validate and possible refine the models. Models once validated will then provide a tool to characterize the soils selected under objective A for risk characterization of nitrate leaching past the root zone and in developing soil management practices that will minimize nitrate leaching past the root zone.

D.3. Budget

| | LCMR Funds |
|---|---|
| a. Amount Budgeted: | $50,000 |
| b. Balance: | $ 0 |

| D.4. Timeline | July91 | Jan92 | June92 | Jan93 | June93 |
|---|---|---|---|---|---|
| Installation of equipment | ..... | | ...... | | |
| Collection and analysis of soil and water samples | ........ | ........ | ........ | | |
| Testing and validation of models | ........ | ........ | ........ | ........ | ........ |
| Sensitivity analysis of models | | | | ...... | ...... |

D.5. Status:
Field Experiment

Collection of data to field test and validate CERES-Maize (for corn *Zea mays L.*) and SUBSTOR (for potatoes *Solanum tuberosum L.*) computer models was done during 1991 and 1992 at the Staples, Minnesota, Irrigation Center. The influence of irrigation and nitrogen management on corn and Russet-Burbank potato yields and nitrate leaching under two very different climatic conditions was used for validation. The soil type is Verndale sandy loam (coarse loamy over sandy, mixed, frigid Udic Argiboroll). Variables included irrigation scheduling, nitrogen application rate and nitrogen sources. Nitrogen sources were urea $CO(NH_2)_2$ and turkey manure for corn, and $NH_4NO_3$ and turkey manure for potatoes. Commercial fertilizer rates ranged from 0 to 280 kg N $ha^{-1}$ applied. Turkey manure rates varied by crop and year, with rates of 268 to 500 kg estimated available N in 1991, and 62 to 247 kg estimated available N in 1992. One half of the manure plots received no additions in 1992, depending solely on mineralization of organic N from 1991 application. Two irrigation schedules were used, schedule #1 which irrigated at a fixed rate to field capacity or slightly greater, and schedule #2 which practiced deficit irrigation and varied irrigation inputs and timing based on crop growth stage. Timing of irrigation applications were determined by the Checkbook Method (Wright and Bergsrud, 1986).

Tensiometers were used to determine soil water content and matric potentials, and suction cup samplers were used to collect soil water for nitrate concentration determination. Leaching losses were estimated by multiplying water percolation and soil water nitrate concentrations. Water percolation was calculated by a mass balance approach in 1991, and from Darcy's law in 1992.

Corn grain yields responded up to the 180 kg N $ha^{-1}$ level of N application both years. The cooler growing season of 1992 reduced corn grain yields by up to 40%, compared to 1991. The previous crop of lupines (*Lupinus albus*) contributed significant amounts of N to the 1991 corn crop. Nitrate leaching under corn increased significantly at N application rates lower than those required to achieve optimum grain yield response. Nitrate leaching was primarily caused by precipitation events, either alone or occurring shortly after irrigations. Irrigation did not significantly affect corn yields in 1991, but deficit irrigation based on crop growth stage (schedule #2) produced higher yields with lower nitrate leaching.

Potatoes responded up to the highest N treatment (500 kg estimated available N $ha^{-1}$ from turkey manure) in 1991, commercial N treatments responded up to 280 kg N $ha^{-1}$. Early Blight (*Alternaria solani*) decreased tuber yields by up to 20% in 1992. Potatoes showed lower nitrate leaching losses both years, compared to corn. Nitrate leaching under potatoes, in 1992, was less than 55 kg N $ha^{-1}$ in all treatments and was most likely due to low precipitation amounts. Residual soil mineral nitrogen levels following potatoes in 1992 ranged from 70 to over 90 kg N $ha^{-1}$.

Turkey manure treatments showed fewer differences in crop yield parameters due to irrigation and produced crop yields at equal or greater levels compared to commercial N sources. Excess application of turkey manure was still susceptible to nitrate leaching, but overall produced equal or less nitrate leaching compared to comparable commercial N inputs. Turkey manure organic N mineralization for the second year following application were near the assumed rate of 5% of the original organic N available at the time of application.

In summary, the best management practices that will minimize nitrate leaching in Minnesota outwash soil should emphasize the following:

a) Under current best management practices for fertilizer N and irrigation scheduling, N rates that are lower than economic optimums would be necessary for minimization of nitrate leaching.

b) The use of deficit irrigation based on crop growth stage, with increased soil water monitoring to improve both water and nitrogen efficiency will be necessary.

c) The use of turkey manure (~40/60% mineral and organic N respectively), at proper rates as a source of nitrogen for corn and potatoes is an effective source of N under leaching conditions.

d) Ensuring proper nitrogen credits for previously grown legumes.

Test and Validate Models

Experimental data on crop yield, N-uptake and N leaching under corn and potato for 1991 and 1992 at Staples, MN were used to validate IBSNAT Crop-Environment-Resource-Synthesis models CERES-Maize and SUBSTOR-Potato. The validation treatments included two irrigation schedules and four fertilizer amounts. Simulated corn yield, N-uptake and N-leaching from CERES-Maize model matched well against the measured values for Verndale sandy loam over two years. Sensitivity analysis showed that because of low water holding capacity and rapid drainage of Minnesota outwash soils, most of the N leaching in these soils is due to rain either alone or in combination with irrigation. Frequent irrigations (even in smaller amounts) to keep the soil at field capacity results in greater N leaching. Conversely, less frequent irrigation with higher amounts (with more depletion from soil before application of irrigation) results in less water application and lower N leaching. Allowing the soil water to be depleted to 30% of the extractable water resulted in corn yields similar to those with more frequent irrigations. It is recommended that in order to minimize N leaching from Minnesota outwash soils, irrigation should be applied such that there is always some unfilled soil water holding capacity that will capture unforeseen precipitation that may occur right after irrigation.

Increases in application of commercial nitrogen fertilizer to corn resulted in higher N leaching. As the amount of N applied increases, the rate of yield increase is small but the rate of N leaching is large. In terms of economics, maximum yield occurs near the recommended N input of 284 kg/ha, however in terms of N leaching to groundwater, the best N application treatment in this study corresponded to N application of 101 kg/ha.

Simulations with 8 years of weather data showed that even with the most efficient irrigation schedule, rainfall relative to the timing of irrigation was a major determinant in the amount of N leaching. There was weak relationship between corn yield and N leaching. For a given fertilizer application and a given irrigation trigger level, crop yields were higher in warmer years and lower in cool years. Similarly, N leaching was higher in wet years and lower in dry years. Timing of precipitation relative to N application and irrigation was a major factor in controlling N leaching. It is concluded that splitting N application into many small applications in the low water holding capacity soils of Minnesota outwash region will be advantageous in minimizing N leaching.

A procedure is presented that characterizes the risk potential of soils to N leaching based on model simulation results. Examples are given that show the changes in risk potential of six major soils in Wadena County to N leaching with changes in nitrogen and irrigation management, and climate. Examples are also included that show how this procedure can be linked with the computerized soil survey to develop risk indices of various outwash soils to N leaching for various fertilizer (Fig. 1) and irrigation (Fig. 2) management, and climatic (Fig. 3) conditions. Simulation procedures are also discussed for identifying management practices that minimize N leaching without significantly affecting corn yield on a long-term basis.

Simulation of potato yield, N-uptake and N leaching with SUBSTOR-Potato showed that simulated values matched the patterns measured in the field i.e. increased yield, N uptake and N leaching with an increase in N application rate. The differences in measured and predicted potato yield were also within the range of differences observed in other validation studies in the literature. Like CERES-Maize, SUBSTOR-Potato also showed that while frequent irrigation to keep the soil at field capacity reduces water stress to plants, it does lead to N stress due to higher N leaching. As irrigation trigger levels increase above 30% of total plant-extractable water, potato yield does not change significantly, but the amount of N leaching consistently increase.In simulation with several years of weather data we found that the model was not able to predict any emergence and potato yield during 1982 and 1983. We are in touch with the developer of the model and trying to pin point the reasons for such behavior. Our initial diagnostics is that due to lack of rainfall during 1982 and 1983, the seedzone is dry and thus prevents emergence. Irrigation is not occurring because irrigation is triggered based on the total profile water content rather than just the seed zone water content. We are currently working to resolve this problem with the SUBSTOR-Potato code. It is suspected that since SUBSTOR has not been as extensively tested as CERES-Maize, some of the subroutines may need further refinement.

The results of our field experiments and model simulations were presented at the Soil and Water Conservation Society Conference "Agricultural research to Protect Water Quality" at Minneapolis, Mn during Feb. 21-24, 1993. The titles of our posters are as follows:

1. Sexton, B. T., J. F. Moncrief, C. J. Rosen, S. C. Gupta and H. H. Cheng. 1993. Assessment of Minnesota Glacial Outwash oils to nitrate leaching. I. Nitrogen and irrigation management effects on corn/potato yields and nitrate leaching.

2. Pang, X, S. C. Gupta, J. F. Moncrief, C. J. Rosen, and H. H. Cheng. 1993. Assessment of Minnesota Glacial Outwash oils to nitrate leaching. II. Validation of the CERES-Maize computer model to predict corn yield and nitrate leaching.

3. Perillo, C., S. C. Gupta, C. J. Rosen, J. F. Moncrief and H. H. Cheng. 1993. Assessment of Minnesota Glacial Outwash oils to nitrate leaching. III. Validation of the SUBSTOR computer model to predict potato yield and nitrate leaching.

Paper Presented:

Sexton, B. T., J. F. Moncrief, C. J. Rosen, S. C. Gupta and H. H. Cheng. 1992. Influence of nitrogen and irrigation management on nitrate leaching in the Central Sands of Minnesota. USDA-ARS Beltsville Symposium, "Agricultural Water Quality Priorities, A Team Approach to Conserving Natural Resources" May 4-8, 1992.

Pang, X. P., S. C. Gupta, J. F. Moncrief, G. J. Spoden and D. G. Baker. 1992. Probabilities of percolation losses in Minnesota outwash soils. Poser presented at the annual meetings of the Soil Science Society of America, Minneapolis, MN, Nov 1-6, 1992.

References:

Dylla, A. S., D. E. DeMartelaere, and C. K. Sutton. 1975. Physical properties of drought-hazard soils in Central Minnesota. University of Minnesota, Agricultural Experiment Station, Miscellaneous report 133.

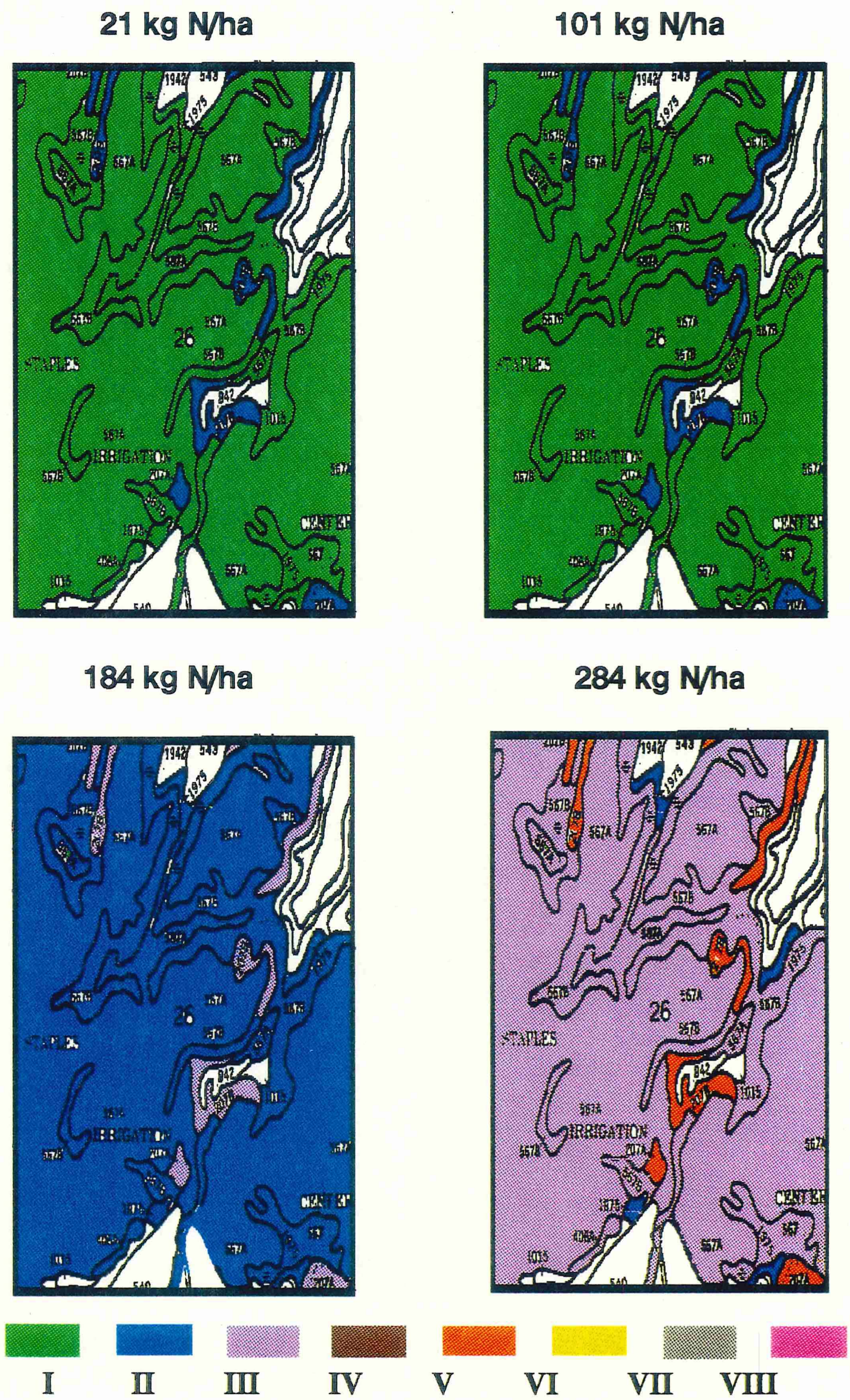


Figure 1: Effect of fertilizer application rate on risk characterization of soils to nitrate leaching for an irrigation trigger of 60 % and at a cumulative probability of 50%.

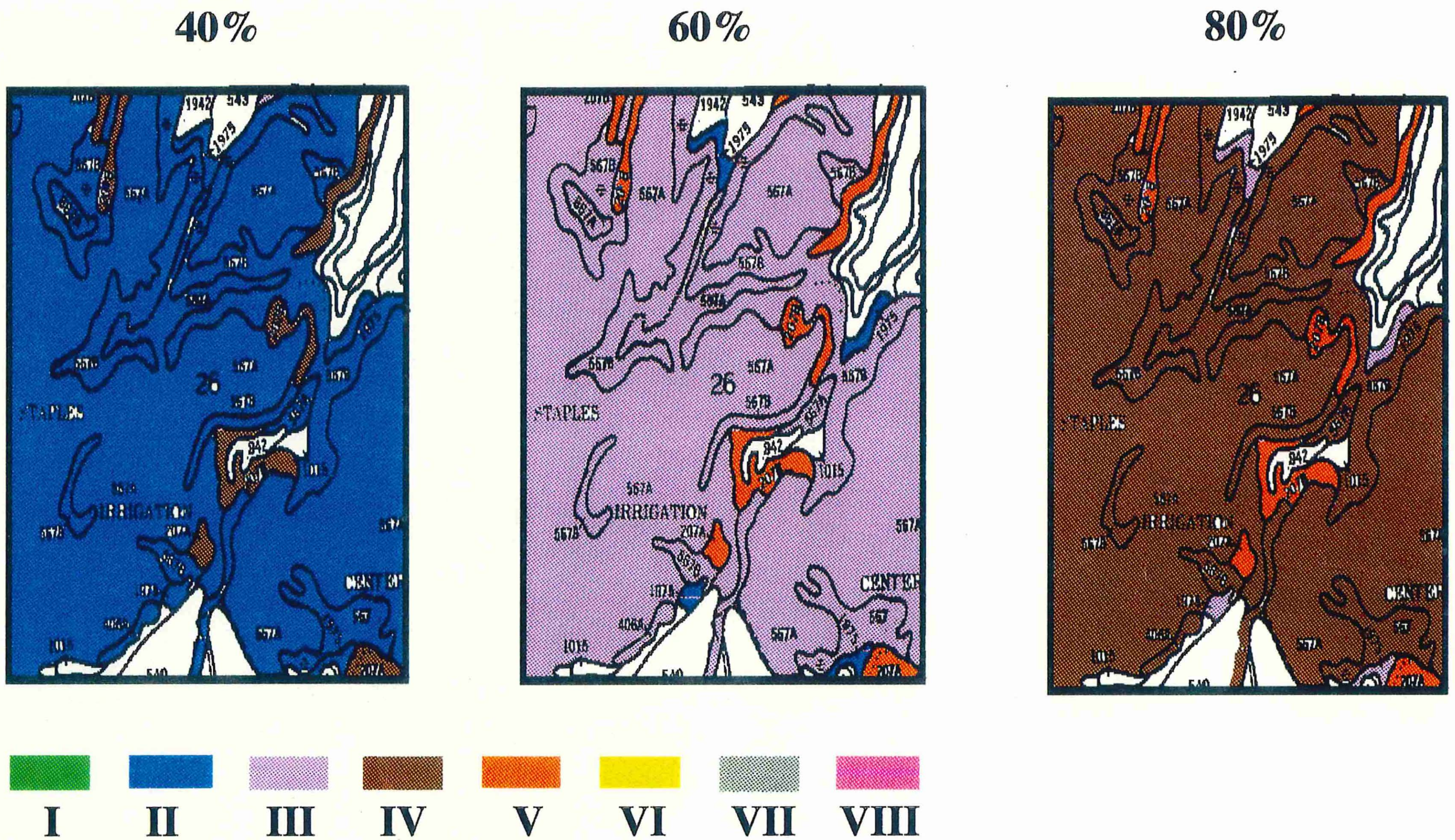


**Figure 2 :Changes in risk indices of soils to nitrate leaching as a function of various irrigation trigger levels at a fertilizer application rate of 284 kg N/ha and at a cumulative probability of 50%.**

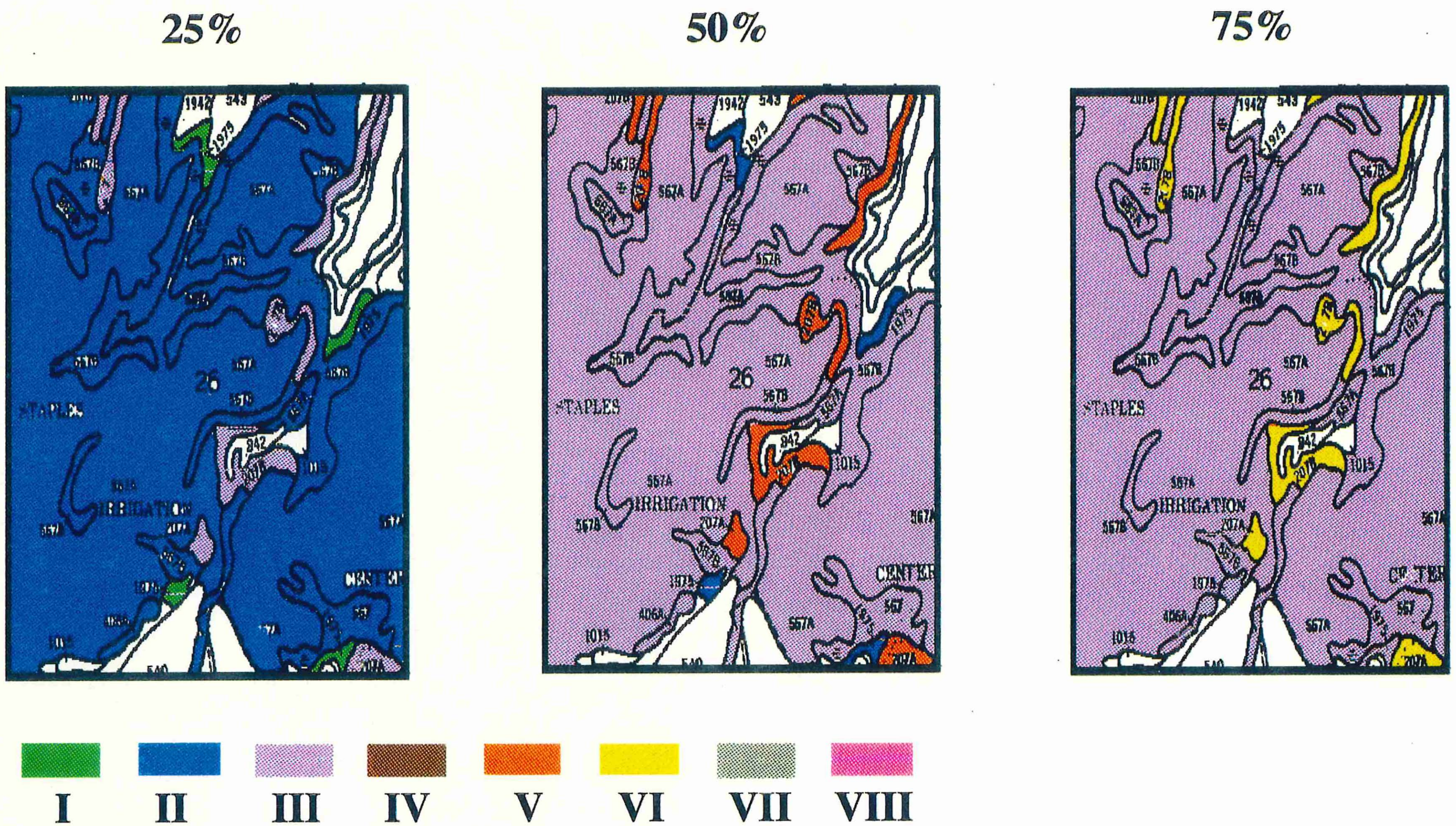


**Figure 3 : Changes in risk indices of soils to nitrate leaching at various cumulative probabilities with an irrigation trigger of 60% and at a fertilizer application rate of 284 kg N/ha .**

D.6. Benefits: These models after testing and validation will provide the tools necessary to delineate soils as to their potential for nitrate leaching and to identify alternate management practices that will not only help to manage fertilizer use more efficiently but also reduce potential ground water contamination in the central sands of Minnesota.

E. Develop network of demonstrations to use as a core for an educational effort

E.1. Narrative: One of the best tools for educating farmers is quality demonstration ("seeing is believing"). It is often difficult for farmers and agency field staff to integrate research results from many different sources. Cropping system demonstrations with all the necessary facets integrated and optimized to fit the local set of circumstances can help the farmers "put it all together".

E.2. Procedures: The core of this educational program is strategically-placed "on farm" demonstrations. Potential cooperators will be identified through County Extension Agents, Soil Conservation Service District Conservationists, Soil and Water District Employees, non-profit rural advocacy groups, and other interested organizations. Cooperators will be visited and the sites evaluated for demonstration suitability. Treatments that demonstrate current and improved practices will be defined at this time. At each site there will be tillage, fertilizer, or manure, management strategies demonstrated for potato or corn production. Plots for corn production will be large to accommodate cooperator's operation and randomly replicated 3 to 8 times. Treatments and crop responses will be characterized in enough detail to determine probable cause and effect on yields differences and inputs tallied to assess influences on profitability. Data collected from growers fields on nitrate movement will be used to allow a comparison as to how their practices affect nitrate losses and crop production. Demonstrations will be utilized by field tours, winter meetings, and popular publications.

Nitrate-N will be determined in soil and water samples collected in potato and corn fields at various depths through the growing season. Five cooperators will be included in the demonstration. Fertilizer rates, timing and method of application will be recorded, but actual rates, timing, and methods will be left up to the individual grower. Yields will be determined by harvesting small areas within each field. Once results are processed, the information will be summarized in tables and graphs to allow growers to compare how their practices affect nitrate movement and production.

There will be joint training of field staff of the Minnesota Extension Service, the Soil Conservation Service, and Soil and Water Conservation Districts. This will multiply greatly the information dissemination effort by using "in place" agency field staff as a vehicle for information transfer.

E.3. Budget

| | LCMR Funds |
|---|---|
| a. Amount Budgeted: | $50,000 |
| b. Balance: | 0 |

| E.4. Timeline | July91 | Jan92 | June92 | Jan93 | June93 |
|---|---|---|---|---|---|
| Identify Cooperators | ...... | | | | |
| Assess farming operation and design demonstration | ...... | ...... | | | |
| Implement demonstrations and monitor crop response | | | ..... | | |
| Organize field tours and winter meetings in cooperation with local agency advisors | | | ..... | ..... | ..... |
| Field Staff Training | | | | | ..... |

E.5. Status: Five on-farm demonstration projects were designed to present ways to reduce nitrogen contamination of groundwater through more effective utilization of nitrogen from manure, legumes and fertilizer sources for corn and potato production in the central sands region. Commonly used management practices were compared to alternative, input conserving practices that have the potential to maintain crop productivity while preserving ground water quality. Tillage effects on availability of nitrogen from different sources and the effect of practices on profitability were also addressed.

The results from the five demonstration sites represent one year data collected during an abnormally cold year. Yields were not representative of normal area averages. Nitrogen uptake and movement are affected by weather conditions; the abnormally cool conditions may alter expected uptake and movement.

Demonstration results indicated that management strategies utilizing alternative sources of nitrogen such as 28% vs. anhydrous, alfalfa, or manure, or scheduling nitrogen application based on plant need (sap test), were effective in maintaining or improving yields while protecting water quality.

Comparison of Fertilizer Nitrogen Source Under Two Tillage Systems - Farmer experience contradicts preliminary research results that anhydrous ammonia is a better nitrogen source that 28% on sand. Because 28% is partially nitrate when applied, more nitrogen is predicted to be available for leaching when 28% is applied in a single application. Farmers would normally apply 28% as a split application for this reason. Comparable rates of anhydrous ammonia and 28% were compared on corn at a site with a strong Bt horizon. Deep tillage was used to break up that horizon in one treatment to allow deeper root penetration with a possible increase in water and nitrogen movement. Data indicated that there was no significant effect of tillage practice on corn yield, soil water nitrogen or moisture stress. Deep tillage did not result in increased nitrate in soil water or water stress to plants. With 1992 weather conditions, 28% increased yield dramatically as well as affected the height and color of plants - 28% plots were greener and taller. Increased leaching of nitrate into soil water did not occur under trial conditions when 28% was used as one application.

Manure Credits - Nitrogen availability to corn from manure was demonstrated to assist producers in properly crediting manure nitrogen and avoid over application of purchased fertilizer for sidedress applications. This on-farm plot was lost due to producer harvesting before yield samples were taken.

Alfalfa Credits Based on Tillage Practice to Turndown Alfalfa Stand - Additional first year nitrogen from alfalfa appeared to be available to the following corn crop when spring tilled alfalfa was moldboard plowed vs. chisel plowed. Corn yields were significantly higher when alfalfa was moldboard plowed. Sidedressed anhydrous ammonia produced a slight but significant yield increase over alfalfa nitrogen alone; legumes provided substantial nitrogen the first year to produce satisfactory corn yields.

Interaction of Turkey Manure with Fall Seeded Rye - Fall seeded rye serves as a sink for available fall applied nitrogen, a winter cover/green manure crop and as weed control in the next crop year. Fall seeded rye killed in the spring with herbicide with no additional herbicide application provided weed control comparable to conventional herbicide practices and to rye tilled in the spring followed by herbicide based weed control. There were no significant differences in weed counts or corn yields among the different management strategies.

Varying Nitrogen Starter Rates to Improve Nitrogen Management in Potato - To evaluate the sap nitrate test for predicting nitrogen needs of irrigated potatoes, three nitrogen management strategies were compared. More efficient nitrogen management in potatoes will maintain crop productivity and improve ground water quality. Lowering nitrogen starter rates and total nitrogen rates did not affect potato yield when compared to grower traditional rates as long as nitrogen is available at later stages of growth. The sap nitrogen test appears to be a useful indicator of plant nitrogen status and could be a useful tool for growers to manage nitrogen based on plant need.

Information gathered from the five demonstrations was presented at two farmer/ag professional workshops in cooperation with the Staples Irrigation Center, the County Extension offices in several counties, the Anoka Sand Plains Project and the MDA Energy and Sustainable Agriculture Program. On-farm demonstrations will be repeated during the 1993 growing season and field days will be scheduled for the summer of 1993. On-farm demonstration of nitrogen management research results is essential to improving farmer utilization of nitrogen.

E.6. Benefits: On-farm demonstrations will increase the rural and urban public awareness of water quality issues via the graphic visual demonstration on alternative management practices. They will also increase the rate of adoption of management practices that preserve water supplies. On-farm demonstrations involve the whole agricultural arena: farmers, researchers, and policy makers.

The adoption of new guidelines by farmers will decrease losses of nitrate nitrogen to groundwater while still maintaining profitable farming operations. Training of in place agency field staff (Minnesota Extension Service, Soil Conservation Service, and Soil and Water Conservation District employees) will facilitate the technology transfer process.

Data from this demonstration will provide background information needed to assess the extent of nitrate leaching over the growing season. The impact of this phase of the project on grower awareness will be very great since the data will come directly from their fields. The adoption of new guidelines by farmers will decrease losses of nitrate nitrogen to groundwater while still maintaining profitable farming operations.

IV. EVALUATION: For the FY 91-93 biennium the program can be evaluated by its ability to meet the objectives as outlined above. Specifically, information will be gathered on: (1) hydraulic characteristics of several major soils of the central Minnesota; estimates of rainfall, evapotranspiration and recharge in the area; and summary of the tillage, irrigation and fertilizer management practices; (2) database to develop precise nitrogen recommendation for manure and fertilizer applications under various tillage systems in the irrigated soils of Central Minnesota; (3) a validated computer model that can be used to characterize soils as to their risk potential for nitrate leaching past the root zone and (4) development of a technique for characterizing the soil's risk potential to nitrate leaching.

In the long term, evaluation of this project's success will be in the risk characterization of soils as to their potential for nitrate leaching and identification of tillage, fertilizer and manure application rates and timing of application that minimize the nitrogen leaching losses past the root zone in soils in water quality sensitive regions.

V. CONTEXT

A. This is the first study that will summarize soil physical and chemical properties; probabilities of rainfall and evapotranspiration; recharge of soils and surficial aquifers; and soil management practices of the Central Sands of Minnesota. This information will be useful to other planned research and demonstration water quality efforts in the region.
The study will also test and validate a family of computer models that considers the soil-plant-atmosphere interactions in predicting the crop yields, nitrogen uptake and leaching of nitrate past the root zone. These tested and validated models will be used to characterize risk potential of soils to nitrate leaching and to develop management scenarios that minimize leaching of nitrate past the root zone under corn and potatoes, the two high nitrogen demand crops of the Central Sands of Minnesota. The family of CERES models have the advantage that the soil portion of the model is common for different crops.

The data base developed under objectives A, B and C will also be useful source to other researchers to test and validate their models.

This project has several unique variables not addressed by other projects. There have been very few previous research efforts in Minnesota related to nitrogen use and movement during potato production. Other states such as Wisconsin have conducted nitrogen related research on irrigated potatoes and these results have been used to help formulate the treatments proposed in the present project. Two other projects have recently been initiated in the sand plains area. Several Soil Science faculty members are participating in these projects. The Anoka Sand Plain demonstration project is based on current knowledge of best management practices, not on potential improvements of these practices. For a high value crop such as potatoes, untested changes in production could lead to substantial monetary losses. Therefore, changes in nitrogen management practices have to be studied on a small scale before they can be recommended to growers. The Management Systems Evaluation Area (MSEA) project has been set up to quantify losses of nitrate in a defined system, with emphasis on fertilizer use and corn production, but does not address nitrogen management practices or diagnostic techniques to help reduce these losses.

B. The demonstration component will be incorporated into several existing programs: the Anoka Sand Plains Project, the SCS-Extension Nutrient Management/Conservation Tillage Program, and the Sustainable Agriculture Demonstration Grant Program. In addition the demonstrations will be incorporated into local county programs via field days and winter meetings.

C. In the past, research has focused largely on crop production with the emphasis on economics. From a purely economic view point, it is better to err on the high side when making nitrogen management decisions. Consequently, most of the research dealt with fertilizer correlation/calibration and recommendations were conservative. Farmer utilization strategies of manure and legume sources of nitrogen, again viewed in the context of pure economics, in most instances tended to underestimate the amount of nitrogen available for successive crops. In recent years there have been studies in Minnesota that are focused on groundwater protection.

The water quality effort funded in part by the LCMR in the past was focused largely on continuous corn and fertilizer management at two sites, the Lawler farm in Olmstead County and the Westport facility in Pope County.

There are two treatments out of 13 at the Lawler farm looking at liquid pig manure but at disposal rates and with continuous corn. There are also two no till treatments and 11 chisel plowing treatments. The bulk of the treatments are timing of fertilizer application and rates.

What is being proposed in the second biennium of this project is to look at "manure and alfalfa as a source of nitrogen" as a focus, in the context of a corn-alfalfa rotation and define tillage effects on availability. Sites will not be relatively flat like the Lawler farm site but more characteristic of the southeastern part of Minnesota (8-12% slope). This is important when considering the water runoff component of the water accounting. The water moving through the plots at the Lawler farm would be higher than more typical topography of the southeast. Although there has been much sampling of soil water for nitrate at this site the water movement has not been intensively quantified.

There is a less intensive study at the Kalmes farm in Winona county also looking primarily at nitrogen rates. 1989 was the third year of this study and there was still no response to applied N. This is because the cooperator (Gene Kalmes) applied a heavy application of manure with unknown amount or composition prior to initiation of the study. The proposed project will be looking at manure utilization with well defined rates, uniformity of application and known chemical characteristics.

At the Westport site the water movement for the nitrogen part of the study is primarily being done under drip irrigation which is also not characteristic of the irrigators of central Minnesota. This is in part out of necessity due to the preexisting system of irrigation for the lysimeters at this site and the limitation of funding. The rotations at this site are continuous corn and corn following soybeans. There are no manure or alfalfa variables at this site. Irrigation scheduling is not being addressed at this site.

The primary extension of the previous work is to recognize the impact of manure and alfalfa on the amount of nitrogen being lost to groundwater. This will be done in the context of the historical climatic data base which, in conjunction with the soils data base will allow a risk assessment and management options that will minimize this risk while still optimizing yields. This risk will also be established considering tillage effects on water and nitrate movement through soil.

Water flow through different soils (ultimately statewide) with consideration of manure and alfalfa sources of nitrogen will be a major emphasis.

D. Not applicable.

E. Biennial Budget System Program Title and Budget: Not available at this time.

VI. QUALIFICATIONS:

1. Program Manager: Dr. H.H. Cheng
Professor and Head of the Soil Science Dept., Univ. of MN.

Ph.D. Soil Science, University of Illinois, 1961
M.S. Agronomy, University of Illinois, 1958
B.A. Berea College, Kentucky, 1956

Dr. Cheng has been active in research on soil nitrogen transformations and availability, kinetics of pesticide transformations, and allelochemicals in the rhizosphere. He has published extensively on these subjects and provided national and international leadership in many professional societies. Dr. Cheng has recently served as editor in chief of the Soil Science Society of America monograph: Pesticides in the Soil Environment: Processes, Impacts, and Modeling.

In addition to Dr. Cheng's research in areas germane to this project he has also had extensive administrative experience. Dr. Cheng will be the program manager of the project, providing advice and leadership on all aspects of this project. He will participate in the potato-nitrogen research and modeling efforts.

2. Major Cooperators:

A. Dr. Satish. C. Gupta
Professor, Department of Soil Science, Univ. of MN.
Ph.D. Soil Science, Utah State University, 1972
M.S. Soil Science, Punjab Agric. Univ.,1968
B.S. Soil Science, Punjab Agric. Univ., 1966

Dr. Gupta's research involves modeling of soil physical properties and processes in crop production and environmental protection systems. Recent project include macropore, tillage and surface seal effects on water entry into karst soils of southeast Minnesota, modeling of heat and water flow under various tillage systems, models of soil compaction from agricultural machinery, modeling the optimum use of crop residues for erosion control and bioenergy, and use of dredged and wastes material for improving agricultural lands. Dr. Gupta earlier work involved modeling simultaneous transport of water and salt through soils. Dr. Gupta is an associate editor of the Soil Science Society of America Journal and author or co author of over 65 research publications. Dr. Gupta's primary role will be in (1) the hydraulic characterization of soils , (2) developing probabilities of various rainfall and evapotranspiration and recharge amount, (3) and testing and validation of soil-plant-atmosphere continuum models for risk characterization of soils to nitrate leaching.

B. Mr. Greg Buzicky
Assistant Director, Agronomy Services Div., MN. Dept. of Ag.
M.S. Soil Science, University of Minnesota, 1982.
B.S. Soil Science, University of Minnesota, 1978

Mr. Buzicky currently has responsibility for the Minnesota Department of Agriculture's environmental protection programs for pesticides and fertilizers. These programs include pesticides regulation; pesticide and container disposal; agricultural chemical superfund and emergency response; water resources monitoring; and development of best management practices for pesticides and fertilizers.

Mr. Buzicky has been involved in technical support and evaluation of the impact pesticides and fertilizers have on the environment since 1985. Prior to 1985, he was involved in nitrogen leaching research utilizing 15-N isotope on irrigated and tiled soils. In addition to nitrogen research, Mr. Buzicky conducted field trials across Minnesota on a variety of crops and soils for the University of Minnesota, Soil Science Department for four years.

Mr. Buzicky's primary objective will be to coordinate the nitrogen management practices information effort.

C. Mr. Bruce R. Montgomery
Soil Scientist, Aron. Serv., MN Dept. of Ag
M.S. Soil Science, North Dakota State Univ., 1984
B.S. Soil Science, Univ. of WI, Stevens Point, 1975

Mr. Montgomery has 13 years experience at North Dakota State University working in the area of agriculture and environmental quality. He administered several research grants and has authored 10 refereed publications dealing with groundwater and pesticides. His research interest were focused on environmental impacts of agricultural practices. He has provided input into development of best management practices by farmers.

Mr. Montgomery presently holds a Soil Scientist position assigned to the MN Dept. of Ag. Nitrogen and Best Management Practices program. He researched and authored the MN Dept. of Ag. portion of the legislatively mandated "Nitrogen in Groundwater Study" in 1991.

Mr. Montgomery has the responsibility of developing the nitrogen management practices survey instrument (in consultation with other team members) as well as overseeing the implementation and summary phases.

C. Dr. John F. Moncrief
Assoc. Professor, Dept. of Soil Science, Univ. of MN.
Ph.D. Soil Science, University of Wisconsin, 1981
M.S. Soil Science, Montana State University, 1977
B.S. Soil Science and Natural Resource Management
Univ. of WI-Stevens Point, 1975

Dr. Moncrief's teaching and research responsibilities are focused in the area of tillage effects on soil physical and chemical properties. Of special interest is how tillage affects: water and contaminant transport through soil; and influences on soil biological effects on nitrogen and carbon transformations from organic sources.

Dr. Moncrief has extensive experience with technology transfer efforts to help farmers adopt systems that minimize environmental degradation. Program efforts include training agency field staff of the Minnesota Extension Service, the Soil Conservation Service, and Soil and Water Conservation Districts.

Coordination of field validation of modeling efforts and technology transfer of research results will be a major responsibility of Dr. Moncrief.

D. Dr. Carl J. Rosen
Assoc. Professor, Dept. of Soil Science, Univ. of MN.
Ph.D., Soil Science, Univ. of California, Davis, 1983
M.S., Horticulture, Penn State University, 1978
B.S., Horticulture, Penn State University, 1976

Dr. Rosen's primary research and extension focus is fertilizer needs and use efficiency for horticultural crops. Current projects include nutritional effects on tuber quality and productivity of two potato genotypes. In addition to research, Dr. Rosen has an active educational component through the Minnesota Extension Service that emphasizes efficient use of fertilizer to prevent pollution problems yet maintain productivity of horticultural crops. Dr. Rosen's primary role will be to assist with the research and educational efforts related to nitrate losses and nitrogen management practices for irrigated potato production.

E. Dr. Mary J. Hanks
Director, MDA, Energy and Sustainable Agriculture Program
Ph.D. Plant Pathology, Iowa State University, 1980
M.S. Plant Pathology, Iowa State University, 1977
B.S. Biology, University of Missouri, 1973

Dr. Hanks present responsibilities within the Minnesota Department of Agriculture are directing the Energy and Sustainable Agriculture Program which includes: the Sustainable Agriculture Loan Program, On-Farm Demonstration/Research Grant Program, the Energy Audit Program, and Integrated Pest Management Program. These programs are designed to encourage farmers to learn about, consider, and try more sustainable farming systems. Dr. Hanks will provide leadership in the demonstration/education aspects of this project.

VII. REPORTING REQUIREMENTS

Semiannual status reports will be submitted not later than 1 January 1992, 1 July 1992, 1 January 1993, and a final status report by 30 June 1993.