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Improving Water Quality Through BMPs For Crop Production Systems Whole Farm Soil and Water Management

Final Report for Project 810
Award # CT 0015393

Submitted to the
Arkansas Soil and Water Conservation Commission

By

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Final Report for Project 810

Improving Water Quality Through BMPs For Crop Production Systems Whole Farm Soil and Water Management

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Lead Agency

Department of Crop, Soil and Environmental Sciences
Arkansas Agricultural Experiment Station
UA Division of Agriculture

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EXECUTIVE SUMMARY

The major objective of this demonstration project was to assess the usefulness of Global Positioning Systems/Geographic Information Systems (GPS/GIS), water testing, soil testing and yield monitoring in a whole farm water and soil management plan. An important part of this objective was to make recommendations to increase crop productivity and decrease the potential for surface water degradation through erosion and runoff at the farm. The farm was located on 2400 acres in the Bayou de View watershed in Monroe County, Arkansas. The farm lies approximately five miles southwest of the town of Brinkley straddling Highway 17 just south of its intersection with County Road 302 and with U. S. Highway 70. Slightly over 2200 acres were under cultivation and this was generally in a 1:2 ratio of rice to soybeans, with approximately half of the soybean fields double-cropped with winter wheat each year.

While the soils on the demonstration farm were similar and not expected to cause large differences in crop production, irrigation water quality was found to be very different in different areas of the farm. Irrigation waters were divided into three groups based on water quality: good, fair and poor. None of the irrigation waters had sodium adsorption ratios greater than 10 and, so, were considered to have a low potential to cause sodic soil conditions. However, the potential for these waters to increase soil pH in flow areas and upper levees increased from the good through the poor quality irrigation water groups. These soil pH increases can cause zinc deficiencies in rice on silt loam soils. Total salt load (electrical conductivity) and chloride concentrations also increased as water quality decreased to a point where rice yields were predicted to decline using the fair and poor quality waters.

Soil test data reflected the water quality data. Low soil exchangeable sodium percentages were found because the waters had low sodium adsorption ratios. High soil pHs were observed due

to the high calcium bicarbonate contents of the irrigation waters. Low soil salt loads were found because the soluble salts added in the irrigation water had leached prior to soil sampling.

Both erosion and runoff were found to be small at the farm. Rice cropping resulted in the least erosion during the growing season, while the soybean/wheat rotation was least susceptible to runoff during intense storms year round. Soil test phosphorus was less than adequate on much of the farm, while soil test potassium tended to be higher than recommended for maximum yields.

Crop yields were good. No relationships between crop yields and soil test values or water quality groups was found. Apparently, soil fertility did not limit yields on the farm. The lack of correlation of yields with water quality was attributed to the farmer's substitution of good quality creek water in the poor water quality area of the farm.

The major outcome of this project is the recommendation that a reservoir be placed in the poor water quality area of the farm. The water in the reservoir would be obtained from the creek during winter months when creek water quality is highest and would replace wells in the poor water quality area of the farm. A secondary outcome is the recommendation that phosphorus be applied where soil test phosphorus is low to assure rapid crop seedling growth. Enhanced seedling growth coupled with use of reservoir water should more fully protect the soil surface during erosive rainfall events and decrease sediments in receiving streams.

Finally, water testing and routine soil testing do provide data that can be used to develop a whole farm soil and water management plan. Use of GIS/GPS produced interesting yield and soil test information, but was not helpful in the development of the plan on this farm.

Keywords: irrigation water management, irrigation water quality, soil testing, geographic information systems, global positioning systems, best management practices, erosion, runoff, crop yield

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INTRODUCTION

Surface and ground water quality must be protected in the row crop areas of Arkansas and the mid-South. Protecting aquatic life from contamination by agricultural chemicals, assuring acceptable drinking water quality in public and private wells, and minimizing sedimentation in surface water resources are examples of the outcomes of implementing best management practices (BMPs) in a whole farm plan that would benefit society.

Tools designed to aid farmers, consultants and public servants in the maintenance and improvement of surface and ground water quality exist in a wide range of locations and formats. Indeed, various components are available from USDA-NRCS and University Extension in the public sector. The problem is that these components are often not suitable for whole farm planning in the sense outlined here. Thus, there is a genuine need to bring together the technology that currently exists, apply that technology to real world situations, measure the success of the application and transfer technology that works to the public sector.

Farmers, consultants and those in the public sector were partners throughout the conduct of this demonstration project. They were involved in initial planning activities, in site visits during implementation and in the dissemination of the products of the project.

OBJECTIVE

The major objective of this demonstration project was to assess the utility of various tools such as GPS/GIS, water testing, soil testing and yield monitoring upon which BMPs can be based in a whole farm water and soil management plan. An important part of this objective was to make recommendations to the owner of the demonstration farm which would increase long-term crop productivity and decrease the potential for surface water degradation through erosion and runoff.

OVERVIEW

Whole farm water and soil resources management involved three phases. In Phase I, soil and water resources were characterized as to their potential to cause water quality degradation. Phase I utilized surveys, soil and water samples, and indexing models. In Phase II, a water management plan was prepared; the primary component of which was a reservoir that would be used to replace the poorest quality well water. In Phase III crop growth and yield were used to illustrate the effectiveness of the BMPs.

Soil and water resources were characterized to provide background information for the whole farm water management plan. Historical soil, water, and cropping information were collected. Wells and surface waters were assessed for quality, availability and volume. Soils were tested for the presence of adverse effects from prior years such as high pH and the presence of soluble salts. Aerial photographs, satellite images, soil surveys, topography, location of water resources, location of fields, structures and the like were put into a GIS data base.

Data collected were evaluated using models that assess potential for ground water contamination, high amounts of surface water runoff and excessive erosion on a field by field basis. A whole farm water management plan was prepared based on the available information. Key components of the whole farm water management plan were a reservoir and a water distribution system that would allow transfer of the water resources to fields in a manner that minimized the impact of poorer quality water on soil productivity, yet would be economically feasible. The current University of Arkansas irrigation water quality assessment program served as a basis for this component. These approaches assured adequate crop growth, which, in turn, minimized runoff and erosion.

DEMONSTRATION FARM DESCRIPTION

As previously mentioned, the Project 810 demonstration farm was located on 2400 acres in the Bayou de View watershed in Monroe County, Arkansas. The farm lies approximately five miles southwest of the town of Brinkley straddling Highway 17 just south of its intersection with County Road 302 and with U. S. Highway 70. Slightly over 2200 acres were under cultivation for the duration of the project and this was generally cultivated in a 1:2 ratio of rice to soybeans, with approximately half of the soybean fields double-cropped with winter wheat each year. Figure 1 shows an aerial view of the demonstration farm with Highway 17 running north and south in the left center and the St. Louis and Southwestern Railroad cutting diagonally from NE to SW through the middle of the farm. The black outline is the outer boundary of the farm located using the Differential Global Positioning System (DGPS).

Figure 2 shows the farm aerial view with its 28 fields and boundaries, 13 wells, 3 relifts, and numerous distribution lines located using DGPS. There are numerous flumes and surface recovery ditches to catch and channel excess rainfall and irrigation runoff to collection areas. There is a small creek that flows east to west from the upper boundary of field L9 through the lower boundary of field 1M. There are two recovery relift pumps that have been located along this creek to divert water to fields in the southern third of the farm. Additionally, there is a third relift pump that performs a similar function located on the recovery collection flume between fields M11 and M18 in the north central area of the farm.

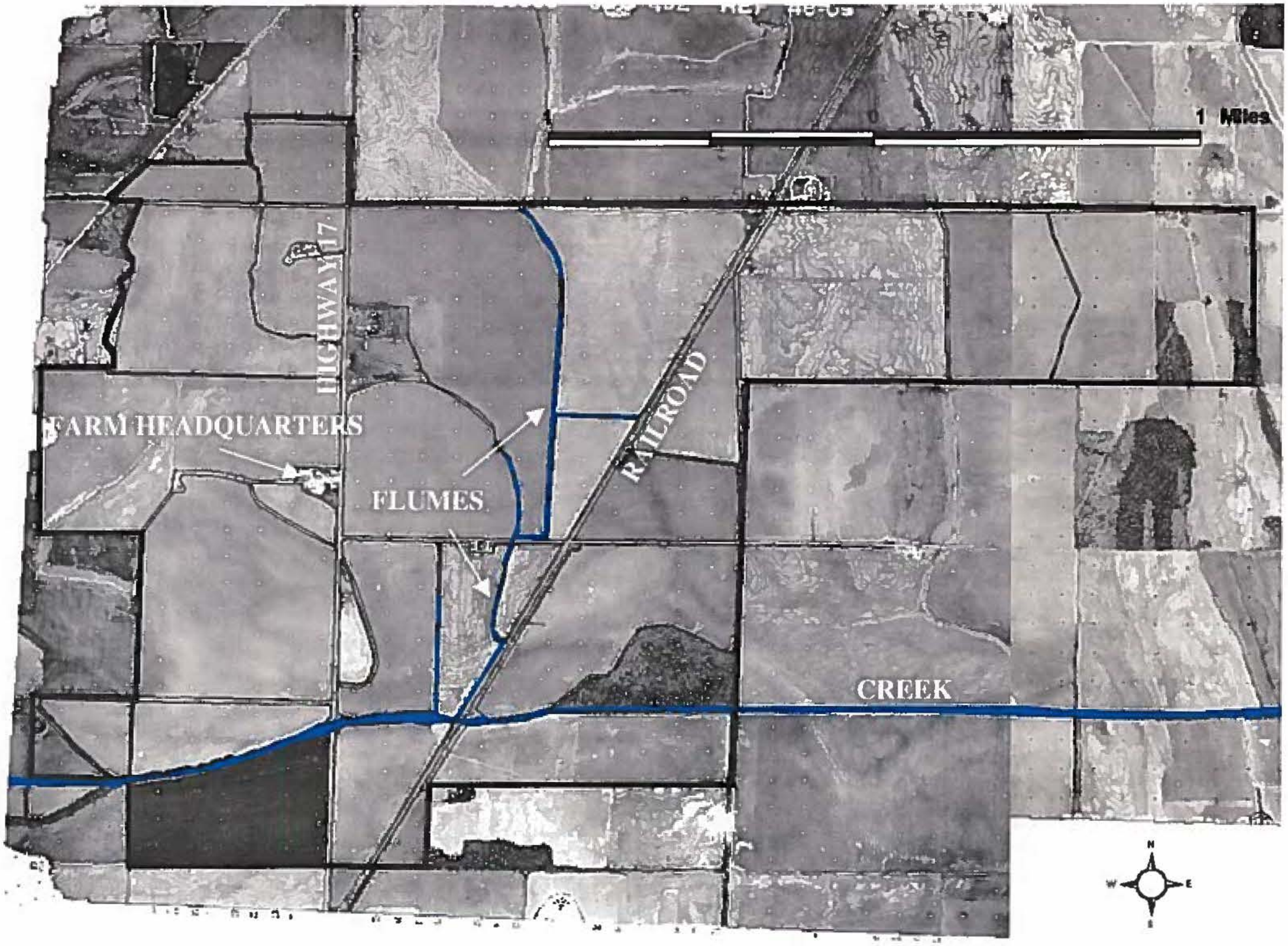


Figure 1. Demonstration farm with surface water sources.

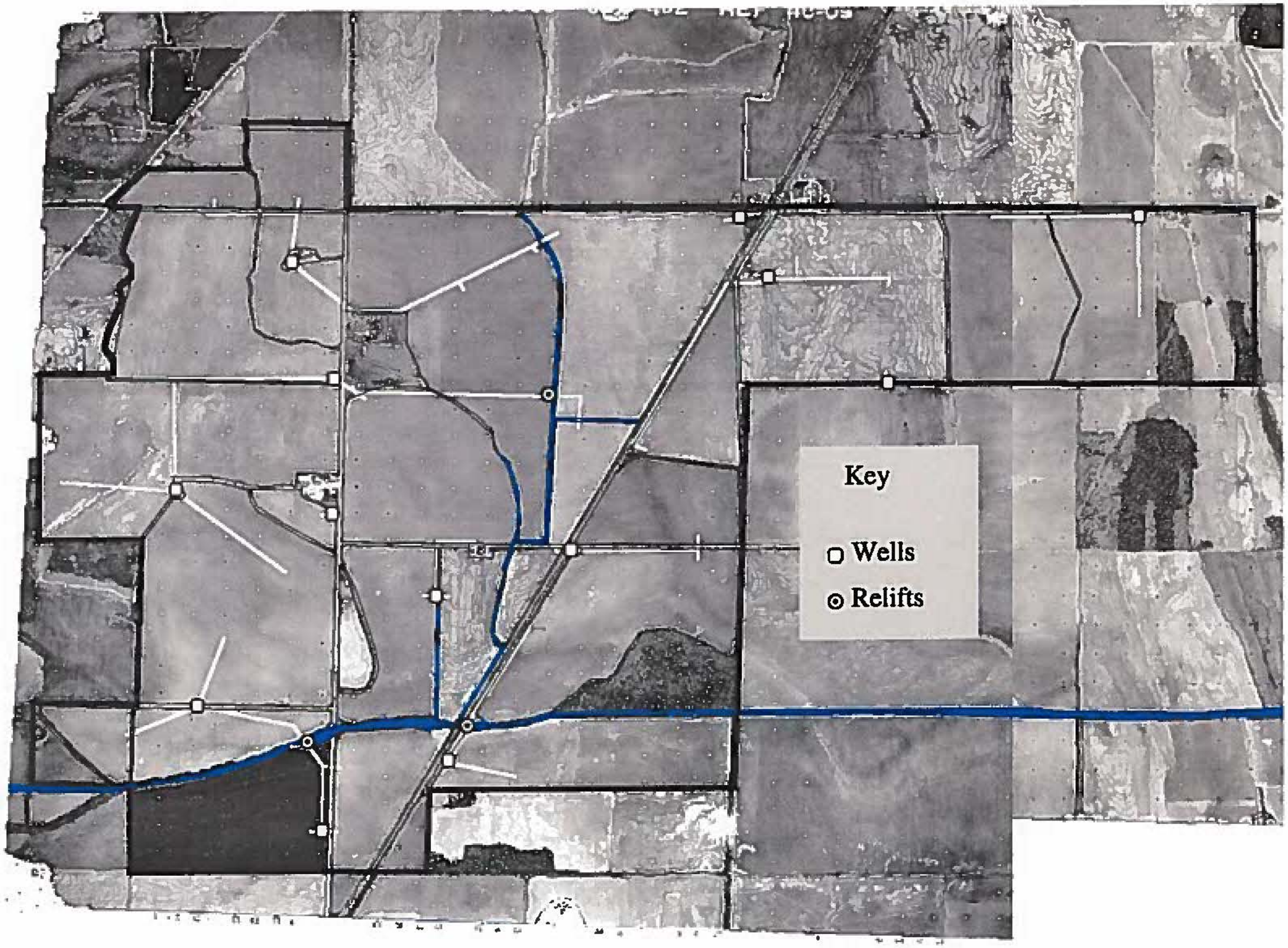


Figure 2. Fields, boundaries, and water sources.

MATERIALS AND METHODS

GPS/GIS System

The technical phase of Project 810 began in early June of 1998. GPS/GIS (Global Positioning Systems/Geographic Information Systems) data gathering hardware and software were purchased pursuant to the recommendations of expert staff, and a research specialist was hired to operate these essential tools for the project. Hardware included the Trimble©AGR 132 DGPS (Trimble Navigation/Differential GPS) unit, which offered real-time DGPS data collection as opposed to post-processed data collection, and which was field proven for accuracy and durability.

Current GPS technology is an electronic range finder that can accurately gauge its distance from any of the 24 operating concentrically-spaced government GPS satellites that are within its line of site. The range finder or GPS unit must receive at least four satellite beacons to accurately triangulate its position. There are additional elements that can cause interference or dilution of precision (DOP), but the unit evaluates these constantly and a DOP number is added to the GPS data provided to the operator. Generally, if this DOP number is below 6.0 the data are considered to be within accuracy parameters for an adequate GPS fix, but for the purposes of this project an upper limit of 4.0 was used and most often the actual DOP was well below 2.0.

If these technical elements were the only sources of precision error, then the standard GPS unit could produce meter accuracy at all times, but to complicate the system and to insure control, the government added error to the system called SA or specific availability. In essence, they manipulate the signals to produce inaccuracy. The effect that SA has on GPS fixes causes the positional fix to move constantly for up to 30 meters in the XY plane. For many years, the method used to circumvent the effects of SA was to establish a base station on an accurately known point and then to produce correctional data from this base station and apply this correctional information to data collected from nearby (100km-150km) the base station at a later time. This method is called post-processing and is still an accurate and commonly used solution to SA. Differential GPS or DGPS can be the product of post-processing, or taken a step further, the correctional data can now be broadcast and received via navigational beacons, radio carrier waves, or communication satellite transmissions, and the correctional data incorporated directly into the real-time data emitted by the receiver. This was the method that our chosen DGPS unit used to collect and simultaneously correct positional data to within one meter of actual. The government no longer adds SA to the GPS signal.

Geolink©(Baker Georesearch, 1996) collection software was chosen for background mapping, feature table building, and grid creation and numbering for the project. This software takes the DGPS data and allows the second by second point data to be tabulated as point and line features such as wells, roads, field boundaries, and soil samples. Internal DOS programs allow Geolink© to convert standard aerial photos or maps to geo-registered background photos and maps. The software also has a grid generator that allows large areas to be overlaid by geo-registered numbered grids of most sizes or configurations. All of these mapping and display features can then be translated into many different GIS (Global Information System) formats, including Arcview© (ESRI Corp.,1998), which was our GIS of choice.

Geographic information systems or GIS are computer-based tools for mapping and analyzing things that exist and events that happen on, above, or below the surface of the earth. GIS technology integrates common database operations such as query and statistical analysis with the unique visualization and geographic analysis offered by maps (W.H. Baker, personal communication, 2000). Arcview© 3.0 with four extensions: Spatial analyst, Image analyst, 3D analyst, and Tracking analyst was the GIS software used. The system was later upgraded to Arcview© 3.1 and then to Arcview©

3.2 as they became available.

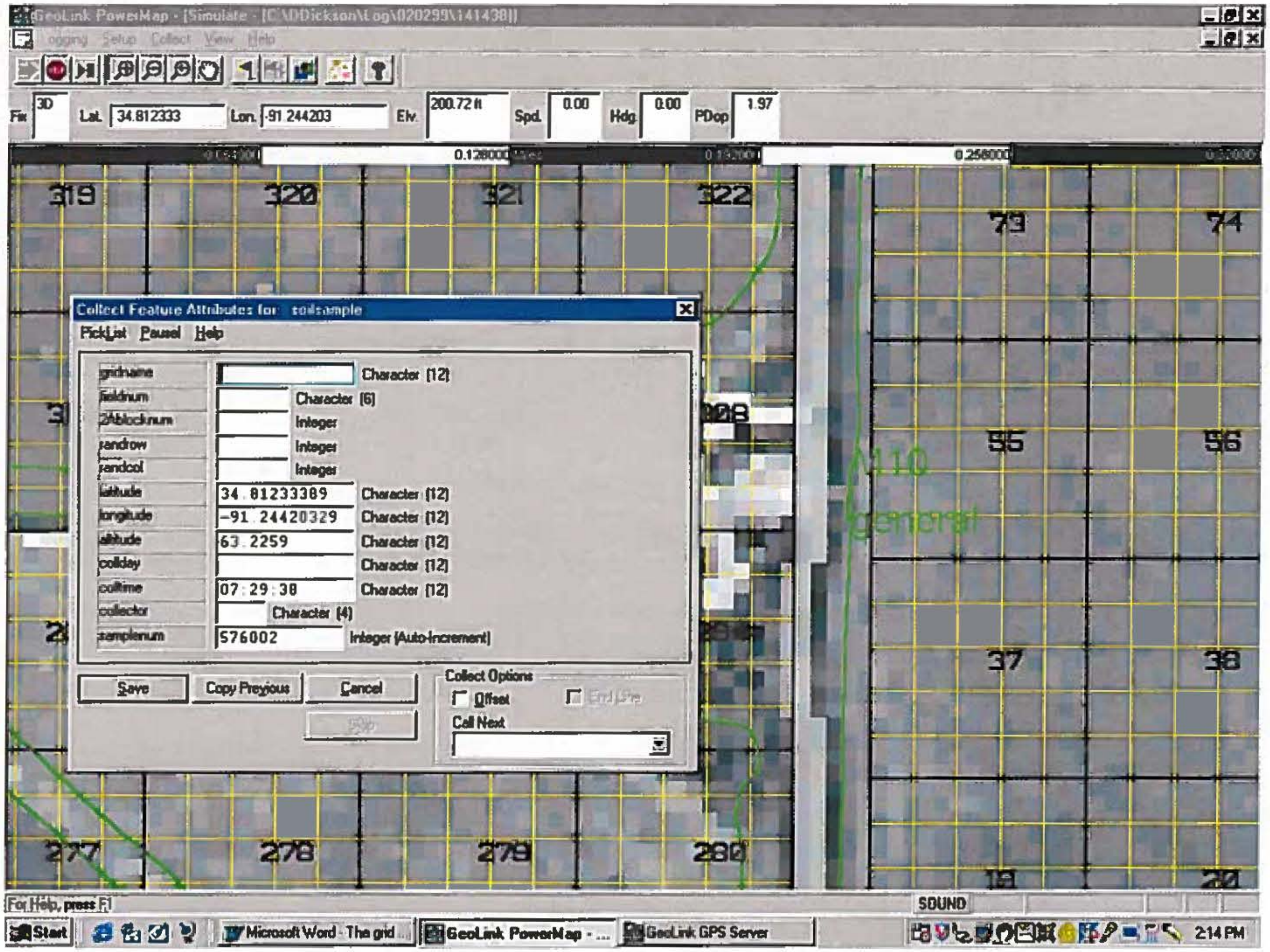
Memory, storage capability, field battery life, and processor speed were criteria used to select a notebook computer for the project. Gateway's 9100SE was purchased. Next, a mobile platform was needed. Four-wheel drive was assumed to be a minimum for travel across cultivated fields. A 4WD all-terrain vehicle or ATV was tested under all of the conditions that might be encountered, and found to be adequate.

The data collection system then, consisted of the DGPS unit, hard mounted to the rear cargo rack of the ATV with its antenna mounted on a staff above the operator's head at precisely 2 meters from the ground to allow offset accuracy and to limit interference with the operator. The DGPS unit was powered by a 12V jack from the ATV battery, and the unit's data feed was connected to the serial port of the notebook computer. The computer was mounted in a cushioned weather-protective box on the front cargo rack of the ATV and powered by its own battery power (two lithium-ion units), which afforded 7 to 8 hours of constant use before recharging. The computer was not powered from the ATV's battery source to insure that any possible mechanical malfunction of the ATV could not cause loss of data from the computer. The collection, translation, mapping and GIS software were loaded into the notebook computer, doubling as a field data collection unit and desktop analytical unit for the first six months of the project.

The DGPS unit was configured for the locale and for the correctional beacon frequencies for both Northwest Arkansas, where prototypical testing was done, and the Delta region around Brinkley, where the demonstration farm was located. Ports on the computer were configured to receive the type of data and format that the DGPS unit produced. DGPS signal configuration was completed and location point data began to be received. Using two United States Geological Survey known reference points on campus, the accuracy of the DGPS unit was gauged and found to be within the ± 1-meter range. The last configuration needed then was to allow the Geolink© software to be able to receive and read data in the correct format through the correct port.

Attempts to make the system components communicate with each other were initially unsuccessful. The problems seemed to lie within the DOS commands internal to the Geolink© software, which were written with Motorola GPS hardware as a base. Features (points, lines, and polygons) and feature tables (descriptive attributes of the features) could not be configured without receiving error messages that were fatal to the Geolink© program. The software was used in test fields with good DGPS results as long as no attributes were configured, but this only provided point logs. After much interaction with the vendor, attribute and feature tables were developed and tested for use in collecting data by feature/attribute on the Main Agricultural Research Farm at the University of Arkansas in Fayetteville (hence-UA Farm). Tables were formatted properly for the information collected. The features were then programmed to be accessed with what was known as "hot keys." By pushing a single key 0 through 5 on the laptop (0 for buildings, 1 for field boundaries, 2 for wells, 3 for poles, 4 for roads, and 5 for soil samples), the desired collection feature and its attribute table of contents could be accessed for ease of collection.

Maps and aerial photos of the UA Farm were acquired and geo-registered using the Geolink© software. Prototypical grids compatible with the EPA grid sampling protocol were constructed for the UA Farm test location using the Geolink© software. Figure 3 shows a typical section of the farm as it appeared on the portable computer screen in the field. The inserted box was the result of pressing "hot key" #5 while stationary over a soil sample point. The operator then inputs additional descriptive data and saves all to the hard drive. All software features like:



Fix 3D Lat. 34.812333 Lon. -91.244203 Elv. 200.72 ft Spd. 0.00 Hdg. 0.00 PDop 1.97

gridname		Character (12)
fieldnum		Character (6)
2Ablocknum		Integer
sandrow		Integer
sandcol		Integer
latitude	34.81233389	Character (12)
longitude	-91.24420329	Character (12)
altitude	63.2259	Character (12)
collday		Character (12)
colltime	07:29:38	Character (12)
collector		Character (4)
samplenum	576002	Integer (Auto-Increment)

☐ Offset ☐ End Pre

Figure 3. Section of grid with attribute collection table (insert).

collecting devices, geo-referenced maps, and grid surfaces were tested using the ATV mobile platform. Procedures were written for the most complicated aspects of the collection process: data gathering, geo-registration of maps/aerial photos, and grid building (Appendix). The experiences at the test location provided good preparation for similar activities at the demonstration project farm.

The Arcview© 3.1 upgraded version solved many of the syntax problems we had experienced with the 3.0 version, like the non-recognition of file names that were more than 8 characters long or of ones that contained spaces, or the loss of a file's path causing the file to be misplaced.

Data Quality Objectives

Soil and water analyses were done so that they would be comparable to those a farmer would receive when he sends in his own samples. The samples analyzed at the AWRC-Water Quality Lab and the Arkansas Soil Test Labs were treated exactly as if a producer had sent in individual samples, with the exception that the water samples were preserved in ice and delivered to the lab the same day they were collected. Each lab maintained its own quality control procedures and reported the data in the same format used for individual producers, except that results for project water samples were reported with Quality Assurance information. Samples were logged-in and tracked to assure sample custody.

The major data quality objective related to completeness. To be satisfactory, analyses were reported for more than 95% of the soil and water samples collected. Eight hundred and seventy-six soil samples (one for each two acres of those fields sampled) were collected and analyzed for routine soil test parameters allowing a GIS database and parameter maps to be constructed. This information was needed to identify fields where the soil had been damaged due to long-term use of poor quality irrigation water. Sixteen water sources were sampled and analyzed four different times for components related to each water's potential to cause saline and calcareous conditions. The water quality data were analyzed by the computer program, WATER© (J.T. Gilmour, 1996), which assessed the potential of each water source to reduce soil productivity and crop production.

Tables 1 and 2 list the various analyses for the water and soil samples, including the methods used, detection limits, and acceptable levels of accuracy and precision for each analyte. The Water Quality Laboratory was responsible for delivering documentation and records of analytical results for the water samples to the investigator. The Soil Test Laboratory was responsible for delivering documentation and records of analytical results for the soil samples to the investigator.

The laboratory reports to the investigator included a report date, numerical reports of the concentrations and units of measurement, dates when the samples were received and analyzed, laboratory Quality Control data, method of analysis, and sample custody information. All pertinent sample label information was duplicated on the Sample Custody Form (Appendix) which was delivered along with the samples to the labs and became permanent records at the labs. Bound field notebooks containing all records of sample collections were also permanent records.

Table 1. Data quality objectives for water samples[†]

Parameter	Source/Method	Units	MDL[‡]	%RSD	%Recovery
Hardness	EPA 130.2	mg/L	none	10	+/-10
pH	EPA 150.1	$-\log(H^+)$	0.010	10	+/-10
Conductivity 25°C	EPA 120.1	µS/cm	1.000	10	+/-10
Calcium	EPA 200.7	mg/L	0.010	10	+/-10
Magnesium	EPA 200.7	mg/L	0.001	10	+/-10
Sodium	EPA 200.7	mg/L	0.002	10	+/-10
Total Alkalinity	EPA 310.1	mg/L	none	10	+/-10
HCO_3 Alkalinity	EPA 310.1	mg/L	none	10	+/-10
Chloride	EPA 300.0	mg/L	0.010	10	+/-10
Nitrate-N	EPA 300.0	mg/L	0.005	10	+/-10
Sulfate	EPA 300.0	mg/L	0.010	10	+/-10

[†] All parameters are critical.

[‡] Method detection limit.

Table 2. Data quality objectives for soil samples[†]

Parameter	Extract	Source/Method	Units	MDL[‡]	%RSD	%Recovery
pH	water	ASA p. 99	-log(H^+)	none	10	+/-10
Conductivity	water	ASA p.167	µS/cm	none	10	+/-10
Potassium	Mehlich 3	S&M Bull#374 p.9	mg/L	5	10	+/-10
Calcium	Mehlich 3	S&M Bull#374 p.9	mg/L	5	10	+/-10
Magnesium	Mehlich 3	S&M Bull#374 p.9	mg/L	5	10	+/-10
Sodium	Mehlich 3	S&M Bull#374 p.9	mg/L	5	10	+/-10
Chloride	water	Labconco	mg/L	1.8	10	+/-10
Nitrate-N	water	S&M Bull#374 p.25	mg/L	2.8	10	+/-10
Phosphorus	Mehlich 3	S&M Bull#374 p.6	mg/L	5	10	+/-10
Org. Matter	none	S&M Bull#289 p.35	%OM	none	10	+/-10

[†] All parameters are critical.
[‡] Method detection limit.

For water sampling, the quality of data from the AWRC-WQL was assured by a system of internal checks. These included equipment checks, reagent checks, and laboratory performance checks. The results of these checks were recorded to verify the operation of the QC system and to monitor any changes that occur. All non-valid data were discarded. If there had been a discrepancy in sampling due to the instruments not working properly, the data would have been evaluated by the project director for validity. All chemical analyses were checked for precision by the analysis of duplicate laboratory samples. The frequency of duplicate analysis was approximately one in ten samples. At least one duplicate analysis was done each day a parameter is run. The results of the analyses were recorded and filed with the QA officer. All chemical analyses were checked for accuracy by the analyses of spiked samples. The frequency of spiked samples analyses was approximately one in 20 samples. These spiked samples were prepared by the addition of a known amount of the substance to an aliquot of the duplicate sample. The results were recorded on the spike sample sheet and control charts and filed with the QA officer. Performance samples from an outside source were analyzed biannually. Either samples from EPA or commercially prepared samples were used. The analyst performed the analysis without knowing the expected value. These checks, spiked samples, etc. were the responsibility of the AWRC-Water Quality Laboratory.

For soil sampling, the Arkansas Soil Test Laboratory was responsible for quality control procedures and reporting for the soil samples. The performance of laboratory procedures was checked with duplicate samples and internal standards. Internal standards were soil samples produced by the lab using reference solutions to verify their analyses. All analyses were checked for precision by inclusion of duplicate field samples at the rate of approximately 10 percent. At least one duplicate analysis was done each day a parameter was run if the total samples numbered under 10. The results of the analyses were recorded on the control charts. All analyses were checked for accuracy by the inclusion of standard samples at the rate of approximately 10 percent. If there was an instrument breakdown, the lab technician audited the process. If the technicians were authorized to make repairs, they did. Otherwise the appropriate vendor was contacted for service work.

DGPS Site Characterization

The first DGPS data were collected on the demonstration farm in early October of 1998. The road data were used in geo-referencing USGS maps and Arkansas Highway Department aerial photos of the demonstration farm. Well locations were collected as geographic points as the well water samples were collected. The well and distribution line locations were later used to divide the demonstration farm into areas served by good, fair and poor quality irrigation water sources.

In early November of 1998, field boundaries were collected as lines using the ATV. These data were later used to reference soil samples as to their field location. All of this DGPS data was translated into Arcview© 3.0 format at the end of each session. The early data collected at the demonstration farm were presented to the farm owner on December 10th, 1998.

Water Samples

Water samples were collected from the wells and relifts on the demonstration farm on 11 June, 9 July, 6 August, and 1 September of 1998. The sample containers and control samples, an ice chest for preservation, and custody paperwork (Appendix) were obtained from AWRC Water Quality Laboratory. On June 11th, the first water samples were collected at all of the wells and relifts on the demonstration farm. Great care was taken to obtain good samples. Each well was either pumping at the time or was started and run for a full five minutes before the sample was taken. The spigots that were used were allowed to run for 30 seconds before flushing the sample bottles three times, and then the sample bottle was completely filled to eliminate any possible air space, sealed, labeled, and stored in ice for transport. This procedure was repeated for each of the thirteen well water sources sampled, and also for the three surface waters sources sampled. Irrigation intersections where well waters were mixed were also sampled. All samples were returned to the custody of the AWRC-Water Quality Lab the same day they were taken. This process was repeated for the three additional sampling sessions. All water samples were tested for concentrations of calcium, magnesium, sodium, bicarbonate, chloride, and sulfate ions in meq/L. Electrical conductivity (EC) of the waters was measured and the sodium adsorption ratio (SAR) calculated from concentration data.

The computer model named WATER used the data obtained for the sixteen irrigation water sources as input. WATER, was based on research conducted by Ferguson and Gilmour (1981). An outcome of that research was an algorithm that could be used to estimate the potential for an irrigation water to lime a soil cropped to rice and soybeans. Input variables included (Appendix): field size, pump capacity, soil texture, initial soil pH, crop rotation, annual rice irrigation depth, soybean irrigation, and water quality parameters (pH, EC, calcium, magnesium, sodium, bicarbonate, chloride and sulfate).

In order to compare the water sources on the demonstration farm, a typical rice production scenario was used: 70 acre field, 1200 GPM pump, silt loam soil, initial soil pH 6, rice-soybean-soybean crop rotation, 24 inch rice irrigation depth and soybeans were irrigated. The mean water quality data from each field also served as input. The computer model calculated sodium adsorption ratio (SAR) and would provide a warning "If SAR > 10, then a sodic soil will develop causing a loss of soil structure." If the chloride concentration was >3 meq/L, the computer model would give a warning of "If chloride >3 meq/L, chloride damage to rice seedlings and soybeans is possible." Finally, the computer model estimated pH in the upper parts of the field and in flow areas for 6 and 12 years of irrigation based on the research of Ferguson and Gilmour (1981). A warning would be issued regarding soil pH as follows: "If soil pH>7 and the soil is a silt loam, zinc deficiency in rice seedlings is expected."

Soil Samples

Soil sampling was begun on the demonstration farm in late February of 1999. Fields M1, M2, M11, M12, L4, and L5 were sampled at this time. The top six inches of soil was sampled, or to the plow pan (~4 inches) if one was present. Numbered two-acre squares, 90 meters on a side, were created using the Geolink© grid generator and laid out in rectangular grids over the background aerial photos so that they covered all of the cultivated areas on the demonstration farm. These 90 by 90-meter squares were then sub-divided into 25 equal 18 by18-meter squares or sub-grids. One of the sub-grids in each grid was randomly chosen for composite sampling, using a random number generator to choose the row and column number, from one to five in each case. With the field computer as a guide, the operator drove the ATV to a point within the selected sub-grid of each numbered grid square. An assistant on a second ATV collected eight sample plugs approximately one meter apart around this point, mixed them in a bucket, and then took a representative sample of the mixture that became the actual soil sample. While the assistant gathered the sample, the operator entered the necessary reference data into the attribute table for that specific sample site. The sample boxes were labeled with pre-determined Arkansas Soil Testing and Research Lab numbers that were also entered into the soil sample feature table. As the samples were taken, their precise locations were recorded (latitude, longitude, and altitude to eight decimals) along with the field ID, grid name and number, and the randomly selected row and column numbers of the sub-grids. The identical numbers were used to allow for digital integration of the soil sample analyses with the collection files/locations. After collection, the samples were boxed in numerical order, sealed against tampering, and logged into custody (Appendix). The boxes were stored inside a dry barn until the sampling session was completed, and then all of the samples from the session were transported and delivered into the custody of the Arkansas Soil Testing and Research Lab in Marianna. During this sampling session an accident occurred involving the laptop computer and the DGPS cable causing two to three days of lost time and limiting the session to 200 samples. Further sampling was postponed until mid-May to limit interference with the producer's preparations for planting.

Fortunately, the computer was essentially undamaged and the cables were replaceable, though not readily so. As a result, back-up cables were purchased and a tether installed to protect the system from a similar mishap. Additionally, all of the data which were at that time contained solely on the notebook computer's hard drive, were backed up on an Imation Superdisc© exterior drive. In early 1999, a powerful desktop computer was purchased to allow for more data storage, quicker operations, and a more complete back-up capability. The laptop was relegated to data collection, and could also be linked to the project desktop to back-up files from both computers and enhance project security using Laplink©.

The next and final soil sampling session on the demonstration farm was for three days in mid-May of 1999, and included Fields M3 through 10, M16, M18, L1, and L2. The session was uneventful and garnered nearly 700 soil samples. The samples were maintained in custody as before and transferred to the Arkansas Soil Testing and Research Lab's custody the afternoon of May 14th.

All of the soil samples were tested for soil test sodium, phosphorus, potassium, calcium, magnesium, sulfur, iron, manganese, copper, zinc, nitrates, and boron. The soil pH was measured as was the electrical conductivity (EC), and the cation exchange capacity (CEC) was estimated for each sample. The analyses of all of the nearly 900 samples were completed within 30 days and downloaded directly from the soil test lab website in digital form.

The Exchangeable Sodium Percentage (ESP) was calculated using the results of the soil sample analyses; specifically the sodium present in pounds/acre divided by the cation exchange capacity (CEC), with each converted into centimoles per kilogram of soil. The value can be expressed as a fraction or decimal, or multiplied by 100 and then expressed as a percentage. This value relates to the portion of the CEC that is occupied by sodium. The results of these calculations then became a new column in the soil sample analysis table.

Data Manipulation and Presentation

The soil sample analyses were digitally joined to the collection point data in Arcview® shapefiles. This data set was easily accessed visually by creating interpolated surfaces for each parameter in Arcview using inverse distance weighting (IDW). The IDW interpolator assumes that each input point has a local influence that diminishes with distance. A specific number of points, or all points within a given radius (parameter size set by the operator), influence the output value of each cell between known point values. This method assumes that the variable being mapped decreases in influence with distance from its sampled location. The surfaces were visually analyzed for trends and relationships with parameters like irrigation supply points, levee contours and yield extremes. Combinations of variables were viewed as well to assess whether any of the variables were dependent upon one another. All of these surfaces were viewed for each individual field as well as across the entire demonstration farm.

Soil erosion was calculated for each field using the three cropping systems in practice on the farm: rice, soybeans, and soybean-wheat double crop. USGS topographical maps were used to confirm field slopes that were determined using elevations from actual DGPS fixes. The Revised Universal Soil Loss Equation Handbook (USDA-NRCS, 1995) and its standardized forms and graphs were used to predict soil erosion across the demonstration farm on a field by field basis.

Runoff and peak discharge were estimated using collected data and the USDA Engineering Field Manual (USGS-SCS, 1989). The manual uses a geographic rainfall distribution constant, the area of the field, a tabulated runoff curve number for the specified cropping practice, the slope of the field, and the length of the longest slope to determine the time of concentration for major rainfall events. This time of concentration is then used in a model along with rainfall and event frequency to determine the peak discharge of runoff and the calculated runoff for major 2, 5, and 10 year rainfall events.

The remaining fraction of each of the tested soil samples was returned and was tested for water holding capacity. This information was added to the project database.

Yield Data

The 1998 and 1999 yield data was collected in JDMap/GREENSTAR© by the farm manager during harvest. The data are dependent on the operator's expertise in JDMap© program design and proper calibration of the pressure plate that gauged the yield by the pressure that the flow placed on the plate each second. These data, then, were downloaded and converted into a database format using a custom program designed to eliminate outliers (0's and improbably high values) and to combine 100 consecutive yield values and apply that averaged yield value to the specified midpoint of those 100 sites (J. Smartt, personal communication, 2000). This method produced approximately ten point sources of yield per acre, and eliminated turnaround values that approached zero over harvested ground and unreasonably high yield values caused by the rough terrain and resultant jostling of the pressure plate. These data were then used to produce a yield surface over the 9 rice fields where yield data was collected in 1998 and the 8 rice fields where data were collected in 1999. In 1999, a yield surface for soybeans also was produced. The yield at the precise points where the soil samples were taken was quantified and applied to those positions in the applied sample table. The yield data were then graphed on scatter charts versus selected soil parameters.

Where a relationship between yield and some soil property was thought to occur, the SAS JMP© program using the fit Y by X platform for linear regression was used.

Economic Analysis

The assessment of constructing a reservoir, the size of which would vary according to the needs of the producer/owner, was evaluated from an economic standpoint. The vehicle for this surface reservoir assessment was the modified ARORA© model which uses weather, farm, and field data, along with economic data related to soybean and rice production in order to simulate the income and expenses associated with off-stream reservoirs of various capacities.

When executed in optimization mode, the program operates in a manner which will identify the reservoir size which will result in the maximum present worth of simulated net income for the number of years specified. When executed in non-optimization mode, the model identifies yearly costs and returns for a reservoir of a specified capacity. The modified ARORA© model incorporated algorithms to simulate reservoir and soil water balances, water dispersion and recapture, rice and soybean production costs, crop yields and profits, and other processes related to reservoir performance. Input data for the program was read from two separate files. The first contained weather data for 30 years for the geographic area around Brinkley in Monroe county (Weather files for the major agricultural areas of eastern Arkansas were available). The second file (Appendix) contained many agricultural and economic variables which allowed the simulation to be fine tuned for this particular area and adjusted to investigate the impact of numerous factors on optimal reservoir size and performance.

The basic structure of the model remained unchanged from the original ARORA© model as presented by Edwards and Ferguson (1990). Some minor changes to the order in which events unfolded were required in order to support the program enhancements. These enhancements included the simultaneous simulation of water use by both soybeans and rice, the dynamic reallocation of rice acreage to soybeans when insufficient water for rice production is detected, the recovery of excess runoff and tail water, the ability to specify multiple wells, lift pumps and irrigation pumps, and the ability to calculate the cost and returns for flooding the harvested rice fields for duck hunting.

Several sizes of impoundment were studied from 280 to 1120 acre-feet, and were cost-assessed for the information of the operator and the owner. These varied in size to satisfy the minimal irrigation requirements (rice only/southern half) to the maximum irrigation requirements rice and soybeans/southwestern two-thirds). A summary of the economics of each of the various reservoir plans is provided in the Appendix.

RESULTS AND DISCUSSION

Water and Soil Resources

It is important to know the soils on a farm to determine the importance of soil properties on crop yields as compared to other factors such as irrigation water quality, cropping system and level of management. Soil series are presented in Figure 4. Forty-nine percent of the soils at the demonstration farm were Grubbs silt loam that has medium natural fertility, very slow permeability and high available water capacity. Thirty-three percent of the soils at the demonstration farm were Jackport silty clay loam that has medium natural fertility, very slow permeability and high available water capacity. Fifteen percent of the soils at the demonstration farm were Crowley silt loam that has medium natural fertility, very slow permeability and high available water capacity. Two percent of the soils at the demonstration farm were Dundee silt loam that has high natural fertility, moderately slow permeability and high available water capacity. One percent of the soils at the demonstration farm was Foley silt loam that has medium natural fertility, very slow permeability and moderate available water capacity. **Thus, most of the soils on the demonstration farm were similar and were not expected to cause large differences in crop production.**

Irrigation water quality was found to be very different in different areas of the farm. Irrigation waters were divided into three groups based on water quality: good, fair and poor. The areas of the demonstration farm served by these groups are presented in Figure 5. The good quality irrigation waters were located in the north central to northwest area of the farm and served 32% of the total farm acreage. The fair quality irrigation waters were located in the west central to northeast area of the farm and served 26% of the total farm acreage. The poor quality irrigation waters were located in the south central to southwest area of the farm and served 42% of the total farm acreage.

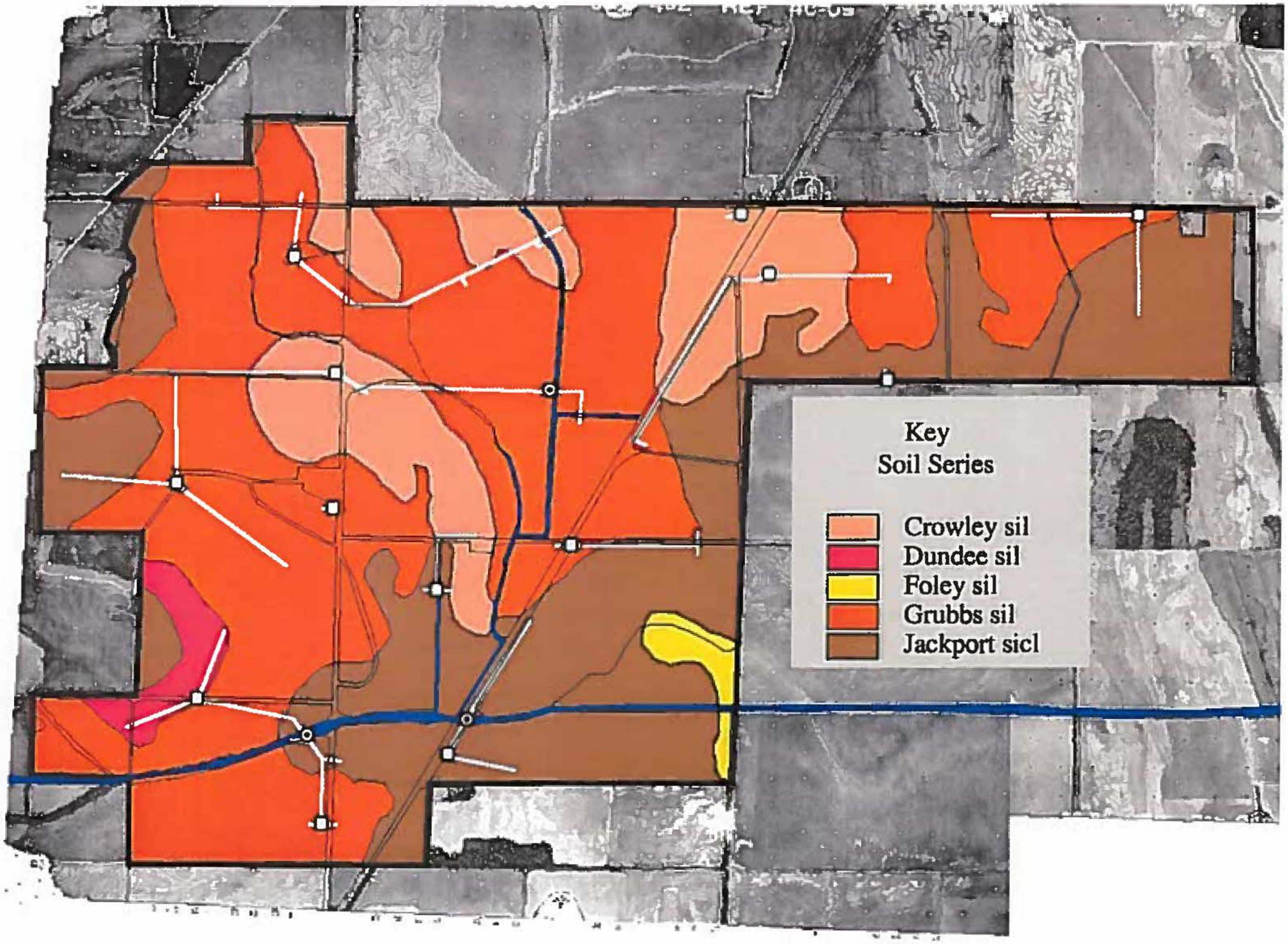


Figure 4. Soil series underlying fields, wells, lines, and relifts.

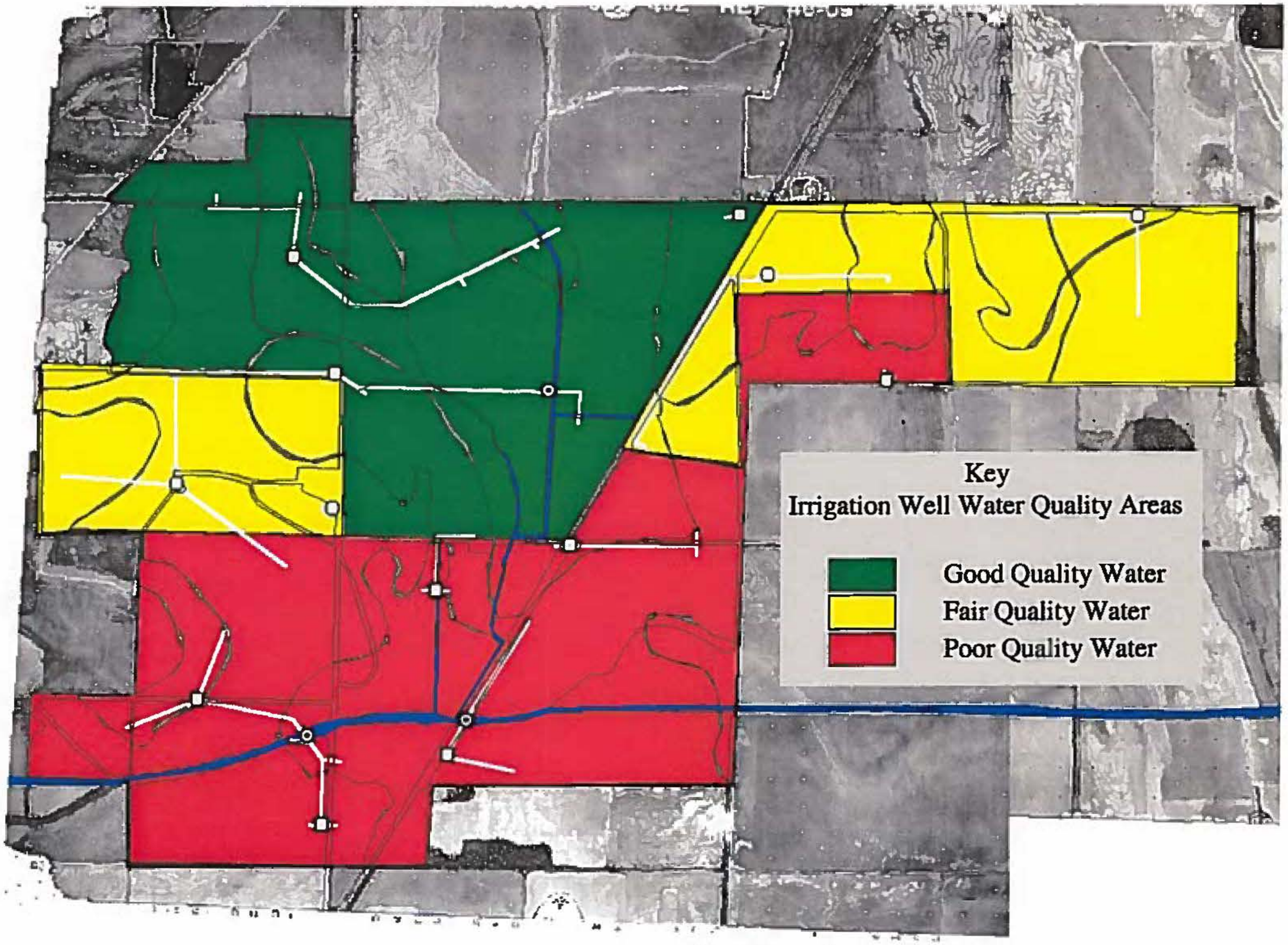


Figure 5. Areas served by the three well water quality groups.

In the good water quality area Grubbs, Crowley and Jackport soils accounted for 66, 29 and 5% of the area, respectively. In the fair water quality area, Jackport, Grubbs and Crowley soils accounted for 44, 40 and 16% of the area, respectively. In the poor water quality area, Jackport, Grubbs, Dundee, Crowley and Foley soils accounted for 49, 40, 5, 4 and <2% of the area, respectively. Thus, there was shift across the farm from Grubbs and Crowley soils to Jackport and Grubbs soils as water quality became poorer. The Monroe County Soil Survey (Maxwell et al., 1978) indicates no differences among soils for soybean production, but does indicate that Grubbs is a slightly less productive soil for rice production than Jackport or Crowley soils. **Thus, soil differences in the three water quality areas were likely not as important as water quality differences themselves.**

Table 3 presents background information on the irrigation water sources. Well depth ranged from 120 to 160 feet according to the farm manager. This is within the range of depths for water in the Quaternary aquifer. Well capacities ranged from about 500 to 1400 gallons per minute. The sampling schedule is also presented in Table 3. Most wells were sampled three to four times.

Irrigation water quality is defined herein as the chemistry of the irrigation water and the impact of that chemistry on crop growth and yield. Concentrations of calcium, magnesium and sodium were used to calculate sodium adsorption ratio (SAR) which is a measure of the tendency of the irrigation water to create a sodic soil condition. Sodic soils are dispersed and not a good growth medium for upland crops. Concentrations of calcium and bicarbonate were used to estimate the liming potential of the irrigation water. The higher the concentrations of calcium and bicarbonate, the more lime that will be deposited on the soil from the irrigation water. These lime deposits lead to soil pH increases in the upper parts of fields and in irrigation water flow areas. Soil pH increases are not harmful to soybean, but can lead to zinc deficiencies in rice on silt loam soils.

Chloride in the irrigation waters was used as a measure of chloride toxicity potential. Chloride has been shown to be specifically toxic to rice and to some soybean varieties. If chloride concentrates in the root zone, damage to these crops is possible. Electrical conductivity (EC) was used as a general measure of the total salt load in the irrigation waters. As electrical conductivity increases, crop damage due to saline soil conditions is more likely.

Table 3. General information on water sources.

Identifier	Type	Depth	Flow Rate	Sample Dates
		feet	gallons/minute	
		Good Water Quality		
M1	well	160[†]	1000[†]	6/11, 8/5
M2	well	120	1800	6/11, 7/9, 9/1
M3	well	130	1800	6/11, 7/9, 8/5, 9/1
MRN	surface		600	8/5
		Fair Water Quality		
L1	well	140	1000	6/18, 7/9, 8/5, 9/1
L2	well	130	1000	6/11, 8/5, 9/1
LRE	surface		600	6/11, 7/9, 8/5
M4	well	120	500	6/11, 7/9, 8/5, 9/1
M5	well	140	1100	6/18, 8/5
MRS	surface		600	7/9, 8/5
		Poor Water Quality		
L3	well	120	1000	6/11, 8/5, 9/1
L4	well	130	900	6/11, 7/9, 8/5, 9/1
L5	well	120	600	6/18, 7/9, 8/5, 9/1
M6	well	120	500	6/11, 8/5, 9/1
M7	well	130	1200	6/11, 7/9, 8/5, 9/1
M8	well	130	1400	6/11, 7/9, 8/5, 9/1

[†] data obtained from farmer.

Table 4 presents mean water quality analyses and calculations based on those analyses for the 16 irrigation water sources, while Table 5 presents an interpretation of the water quality data based on information in Tacker et al. (1994). No consistent trends in water quality were found from one sampling time to another – thus, means are presented in Table 4. Irrigation waters with an SAR greater that about 10 can causes sodic soils to develop. **No irrigation waters had SAR values greater than 10 and, so, these irrigation waters were considered to have a low potential to cause sodic soil conditions.**

Table 4. Mean water quality analyses for irrigation water sources.

Identifier	Calcium	Magnesium	Sodium	Bicarbonate	Chloride	Sulfate	SAR	Electrical Conductivity
	meq/L						%	µS /cm
Good Water Quality								
M1	5.5	2.8	3.5	8.6	2.5	0.3	1.7	1180
M2	3.7	2.1	1.5	5.8	1.2	0.5	0.9	810
M3	3.9	2.1	2.4	6.2	1.9	2.4	1.4	900
MRN	2.4	1.4	1.1	3.7	1.0	0.2	0.8	550
Fair Water Quality								
L1	5.8	3.0	4.6	8.8	4.4	0.3	2.2	1240
L2	5.5	2.9	6.0	9.0	4.4	0.3	2.9	1300
M4	5.2	2.8	4.4	7.1	4.7	0.3	2.2	1200
LRE	3.8	3.5	6.9	4.9	7.5	0.5	3.5	1460
M5	4.3	2.5	3.3	6.4	3.5	0.4	1.8	1110
MRS	3.5	3.0	5.0	5.1	5.5	0.4	2.8	1150
Poor Water Quality								
L3	6.2	3.2	8.7	7.7	8.1	0.1	4.0	1610
L4	6.0	3.7	7.7	7.5	9.0	0.4	3.6	1740
L5	7.6	4.2	6.9	8.5	7.8	1.4	2.8	1640
M6	7.1	4.1	6.3	8.3	7.4	0.9	2.7	1560
M7	7.2	4.0	7.9	8.7	7.7	2.1	3.4	1700
M8	6.3	3.5	9.2	8.4	8.8	0.7	4.2	1920

Table 5. Interpretation of mean water quality analyses for irrigation water sources.

Identifier	SAR>10	Chloride > 3 meq/L	EC > 1200 µS /cm	Calcium > 3 meq/L and Bicarbonate > 5 meq/L	
			Good Water Quality		
M1	no[†]	no	no	yes[‡]	M2
no	no	no	yes		
M3	no	no	no	yes	
MRN	no	no	no	yes	
			Fair Water Quality		
L1	no	yes	yes	yes	
L2	no	yes	yes	yes	
LRE	no	yes	yes	yes/no	
M4	no	yes	yes/no	yes	
M5	no	yes	no	yes	
MRS	no	yes	no	yes	
			Poor Water Quality		
L3	no	yes	yes	yes	
L4	no	yes	yes	yes	
L5	no	yes	yes	yes	
M6	no	yes	yes	yes	
M7	no	yes	yes	yes	
M8	no	yes	yes	yes	

[†] no adverse soil conditions expected.

[‡] adverse soil conditions can develop.

In general, these water sources were expected to cause soil pH increases in the top levees of a field leading to rice nutritional problems in those areas (Tacker et al., 1994). Mean values for calcium for the good, fair and poor groups were 3.9, 4.7, and 6.7 meq/L, respectively. Parallel values for bicarbonate were 6.1, 6.9, and 8.2 meq/L, respectively. **Thus, the potential for these waters to increase soil pH in flow areas and upper levees increased from the good to the**

fair to the poor quality irrigation waters. The surface waters (MRN, LRE and MRS) had lower calcium and bicarbonate concentrations which suggested that calcium carbonate (lime) had precipitated on the soils being irrigated before returning to the surface water source.

The electrical conductivity of the good quality irrigation waters was below 1200 µS/cm. **Development of soil salinity sufficient to damage rice (EC > 1200 µS/cm) are not likely in soils irrigated with the good quality waters.** The fair quality irrigation waters had poorer water quality than the good group with respect to chloride concentrations and electrical conductivity. Chloride concentrations ranged from 3.5 to 7.5 meq/L with a mean of 5.0 meq/L. Electrical conductivity ranged from 1110 to 1460 µS /cm with a mean of 1240 µS /cm. **Thus, the fair quality waters would be expected to increase soil chloride and overall soil salinity to levels that could damage rice (Tacker et al., 1994).** The chloride concentrations in the poor quality irrigation waters ranged from 7.4 to 9.0 meq/L with a mean of 8.1 meq/L. These waters could reduce rice seedling stands as well as rice and soybean yields in cases where the chloride remains or concentrates in the crop root zones. **The electrical conductivity of the poor quality waters ranged from 1560 to 1920 µS /cm with a mean of 1700 µS /cm that could cause salinity damage to rice should the soluble salts remain in the root zone.**

The general impact of salinity on the rice was evaluated using unpublished data from the USDA Salinity Laboratory in Riverside, California (L. Zeng and M.C. Shannon, unpublished data, 2000). The unpublished data were used to develop a polynomial relationship between rice grain yield (y) and EC (x) in dS/m ($y = 35.5 - 5.93x + 0.253x^2$, $r^2 = 0.98$). **The yield decreases predicted for the good, fair and poor water quality areas were 13, 20 and 25%, respectively.** These data were used in the economic analysis.

Grid Soil Samples

Where soil test pH is greater than 6.5 and the soil is a silt loam, zinc deficiency in rice can occur (Slaton et al., 1994). Soil test pH values for the demonstration farm are presented in Figure 6. **The results clearly show that long-term use of these irrigation waters containing high concentrations of calcium and bicarbonate can increase soil pH.** Eighty-four percent of the sampled area had a soil pH greater than 6.5, while 45% of the sampled area had soil pH greater than 7.0. Only 14% of the sampled area had a soil pH greater than 7.5.

The impact of the irrigation waters on soil pH paralleled the good, fair and poor water quality categories. The good quality water area had soil pH greater than 6.5, 7.0 and 7.5 on 79, 26 and 5% of the sampled area, respectively. The fair quality water area had soil pH greater than 6.5, 7.0 and 7.5 on 80, 48 and 19% of the sampled area, respectively. The poor quality water area had soil pH greater than 6.5, 7.0 and 7.5 on 92, 68 and 22% of the sampled area, respectively.

If irrigation with the wells in the poor water quality area is discontinued, soil pH in the poor water quality area is expected to gradually increase. This is because the water in the creek at the south border of the demonstration farm would be the new water source. The creek water contains lower concentrations of calcium and bicarbonate (Table 4) which means that it is less likely to lime the soil than the well waters.

Where soil test electrical conductivity (EC) values are less than 150 µS/cm soils are considered non-saline (Slaton et al., 1994). Soil test EC was less than 150 µS /cm over the sampled area even though irrigation waters contained high levels of soluble salts (Figure 7). **Low soil EC in areas where saline waters are used is common as the soluble salts in the irrigation waters are leached from the surface soil by rainfall. It is not anticipated that converting to a better quality water in the poor water quality area will lower soil EC due to the leaching effect.**

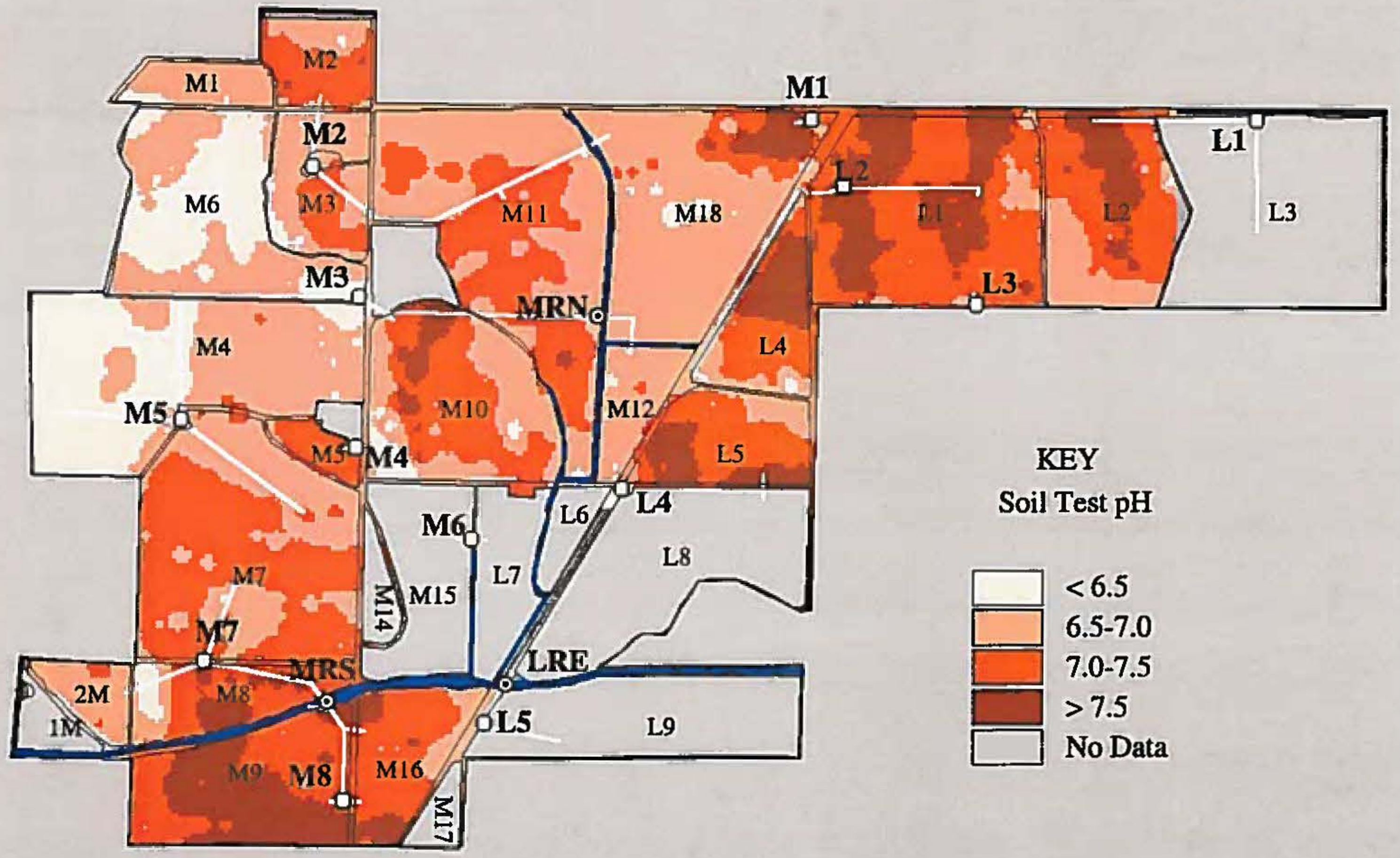


Figure 6. Soil test pH at the demonstration farm. Larger, bolded symbols (e.g. **M1**) are water sources and regular symbols (e.g. M1) are field IDs.

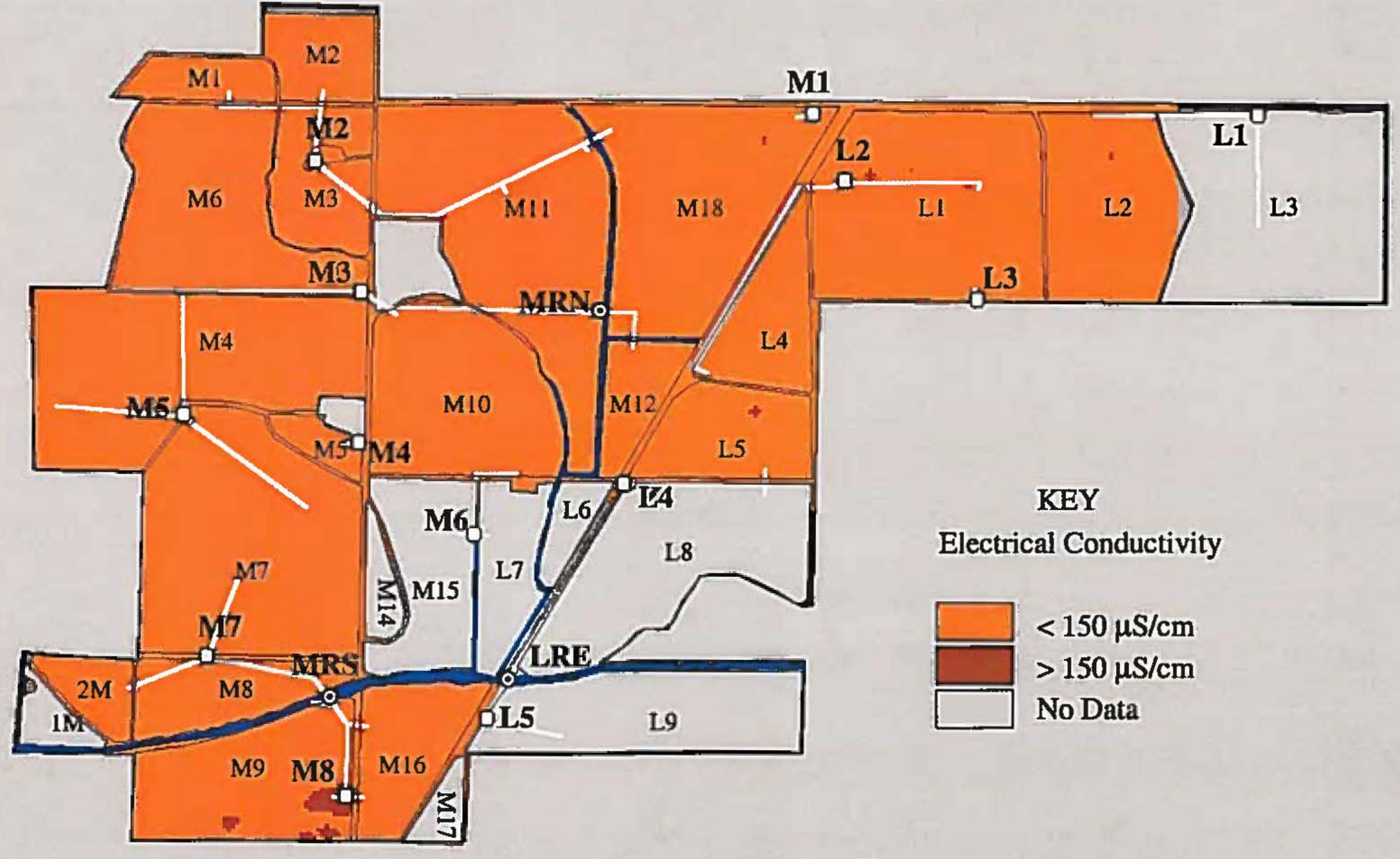


Figure 7. Soil test electrical conductivity (EC) at the demonstration farm. Larger, bolded symbols (e.g. **M1**) are water sources and regular symbols (e.g. M1) are field IDs.

Sodic soils are defined as those with an exchangeable sodium percentage (ESP) that will lead to deterioration of soil structure. An ESP of 10% was chosen as the ESP above which sodic soils develop for this project. Slaton et al. (1994) chose a SAR of 8% for this value. Figure 8 presents exchangeable sodium percentage (ESP) for the sampled area. **All values of ESP were below 10%, which suggests that these irrigation waters are not creating a sodic soil condition.** Since irrigation water SAR (Table 4) will be approximately equal to soil ESP, these results were expected as SAR values were well below 10%.

Soil test pH and phosphorus (P) combine to predict where P deficiencies in rice might occur (N. Slaton, personal communication, 2000). If soil test pH is greater than 6.5 and soil test P is less than 30 lb P/acre, rice response to phosphorus fertilization is likely to occur. Figure 9 presents the results for the sampled soils. Forty-six percent of the sampled area was found to be potentially P deficient. The good, fair and poor water quality areas were 51, 38 and 43% potentially P deficient, respectively. **Thus, nearly half of the demonstration farm would likely benefit from P fertilization. The P fertilization would also reduce potential for erosion as P fertilization is known to enhance rice seedling growth.**

Soil test P and potassium (K) values are also important to maximize rice crop production (Slaton et al., 1994). Phosphorus is especially important in producing early crop biomass that protects the soils from erosion. Figures 10 and 11 present soil test P and K data for the demonstration farm. The mean value for soil test P was 34 lb P/acre which is slightly above the minimum needed for rice production (30 lb P/acre). The mean values for soil test P in the good, fair and poor water quality areas were 29, 39 and 38 lb P/acre, respectively. **Substantial areas of the farm do need additional P fertilization as 55% of the farm was below the minimum level.**

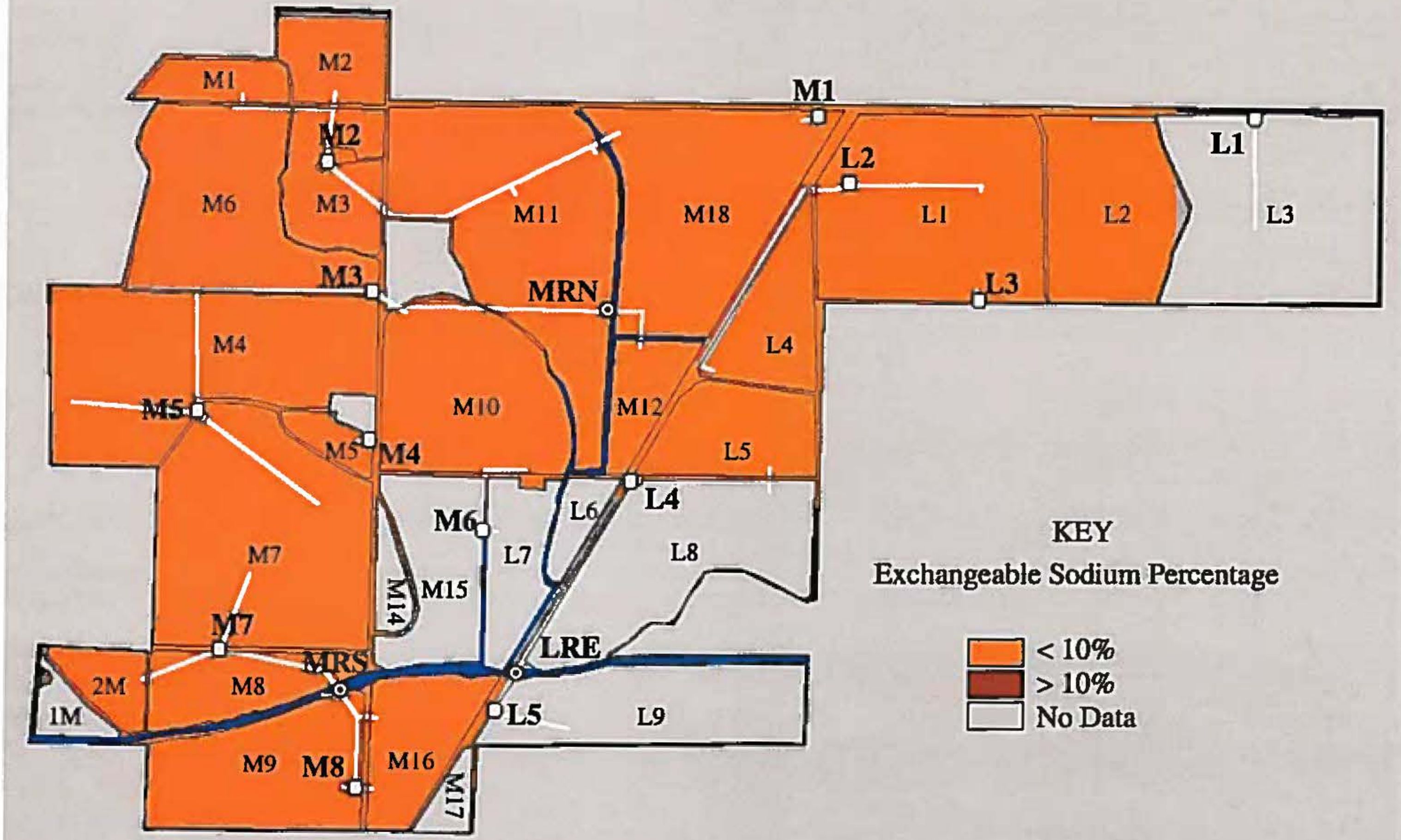


Figure 8. Exchangeable sodium percentage (ESP) calculated from Soil Test parameters at the demonstration farm. Larger, bolded symbols (e.g. **M1**) are water sources and regular symbols (e.g. M1) are field IDs.

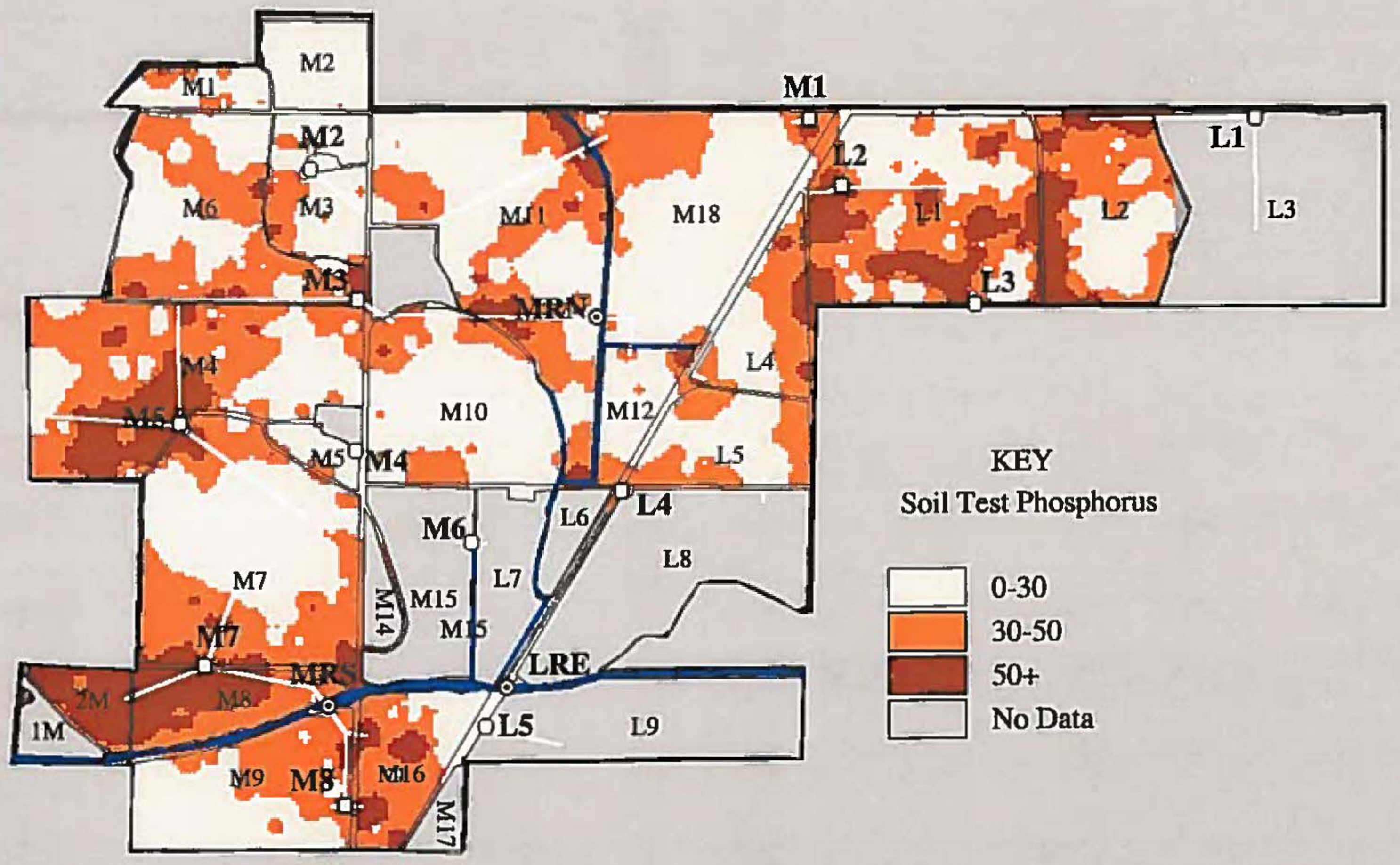


Figure 10. Soil test phosphorus in lb P/acre at the demonstration farm. Larger, bolded symbols (e.g. **M1**) are water sources and regular symbols (e.g. M1) are field IDs.

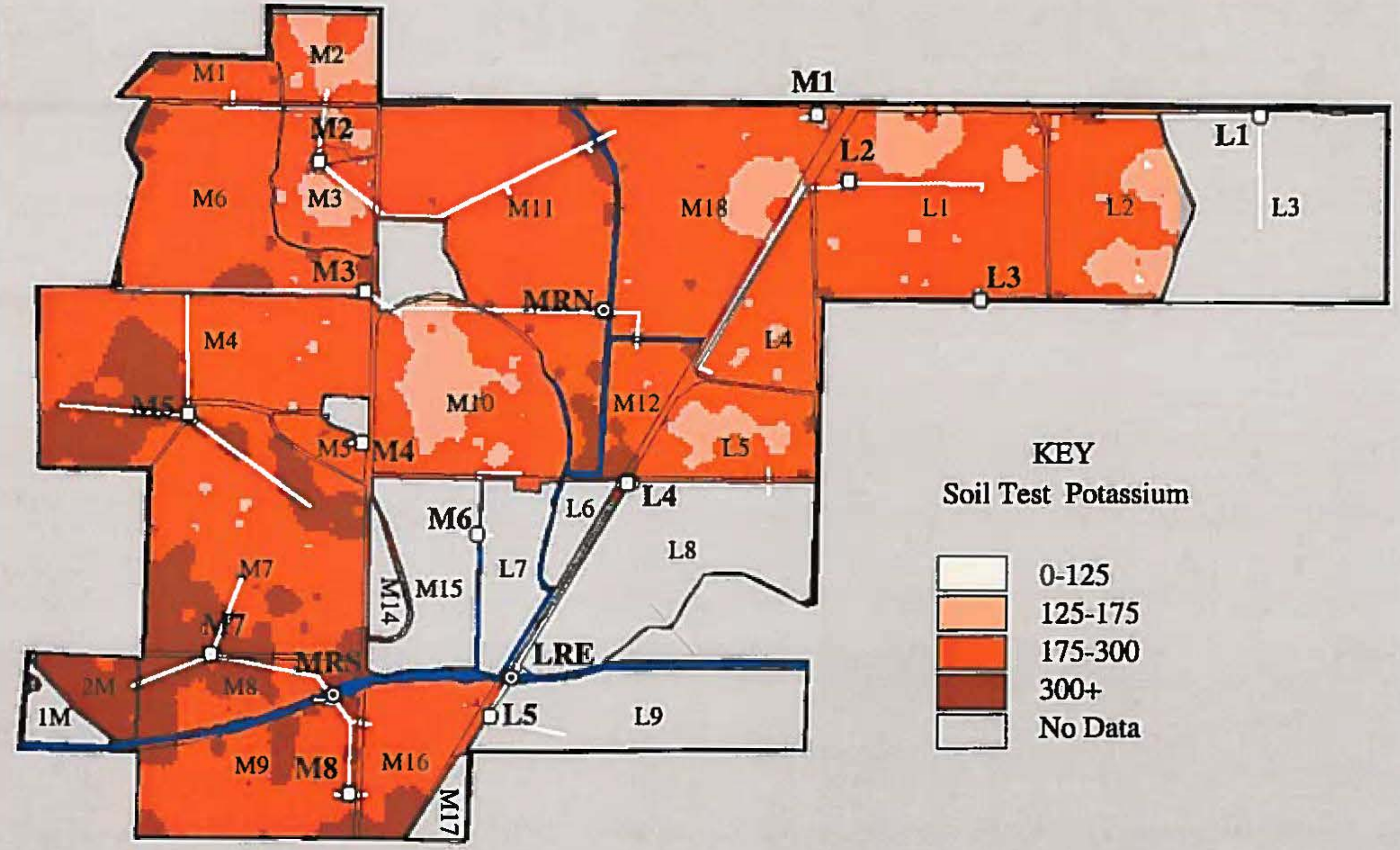


Figure 11. Soil test potassium in lb K/acre at the demonstration farm. Larger, bolded symbols (e.g. **M1**) are water sources and regular symbols (e.g. M1) are field IDs.

Soil test P was less than 30 lb P/acre in 66, 46 and 46% of the soils tested in the good, fair and poor water quality areas, respectively.

The mean value for soil test K was 245 lb K/acre which is above that needed for optimum rice production. The mean soil test K values for the good, fair and poor water quality areas were 230, 235 and 265 lb K/acre, respectively. Soil test K was greater than 125 lb K/acre in virtually all fields tested. Soil test K was greater than 175 lb K/acre in 84, 83 and 92% of the fields in the good, fair and poor water quality areas, respectively. **No K fertilizer component is currently recommended for rice if soil test K is above 175 lb K/acre, thus, soil test K does not appear to be limiting crop growth on this farm.** In fact, soil test K was greater than 300 lb K/acre in 9, 15 and 32% of the fields in the good, fair and poor water quality areas, respectively.

The remaining grid soil sample data can be found in the Appendix, although these data were not useful in making interpretations relating to crop growth.

Erosion and Runoff

Table 6 presents the estimates of annual erosion by soil series and cropping system. **All soil erosion estimates were small with rice being the crop allowing the least erosion and the Jackport and Dundee soils being the least likely to erode. Because the erosion estimates were small and similar among soils, no special management for an individual soil or field was recommended. Increasing the number of times that rice is in the rotation near the creek at the lower end of the demonstration farm was noted as a method to reduce eroded soil entering surface water.**

Runoff for two, five and ten year storms also was estimated. **Soil Series had little effect on the runoff estimates (<10%). Cropping system had a larger effect.** For a two-year storm (4.25 inches of rainfall), runoff for rice, soybean and soybean/wheat cropping systems was about 70, 75 and 60% of the rainfall, respectively (note: the soy/wheat double crop contains no fallow season). For a five-year storm (5.25 inches of rainfall), runoff for rice, soybean and soybean/wheat cropping systems was about 70, 80 and 65% of the rainfall, respectively. For a ten-year storm (6.50 inches of rainfall), runoff for rice, soybean and soybean/wheat cropping systems was about 75, 80 and 70% of the rainfall, respectively. **Thus, the inclusion of the winter crop, wheat, reduces runoff from high intensity storms, some of which occur outside the growing season.**

Table 6. Erosion estimates.

Soil Series	Cropping System	Erosion Estimate
		tons soil/acre/year
Crowley sil	rice	0.4
	soybean	0.9
	soybean/wheat	0.8
Dundee sil	rice	0.4
	soybean	0.8
	soybean/wheat	0.7
Foley sil	rice	0.5
	soybean	1.0
	soybean/wheat	1.0
Grubbs sil	rice	0.5
	soybean	1.0
	soybean/wheat	1.0
Jackport sicl	rice	0.4
	soybean	0.8
	soybean/wheat	0.7

Crop Yields

Figures 12, 13 and 14 present crop yields for selected fields in 1998 and 1999. Rice yields in 1998 were measured for 46% of the demonstration farm and averaged 139 bu/acre. Rice yields in 1999 were measured for 37% of the demonstration farm and averaged 136 bu/acre.

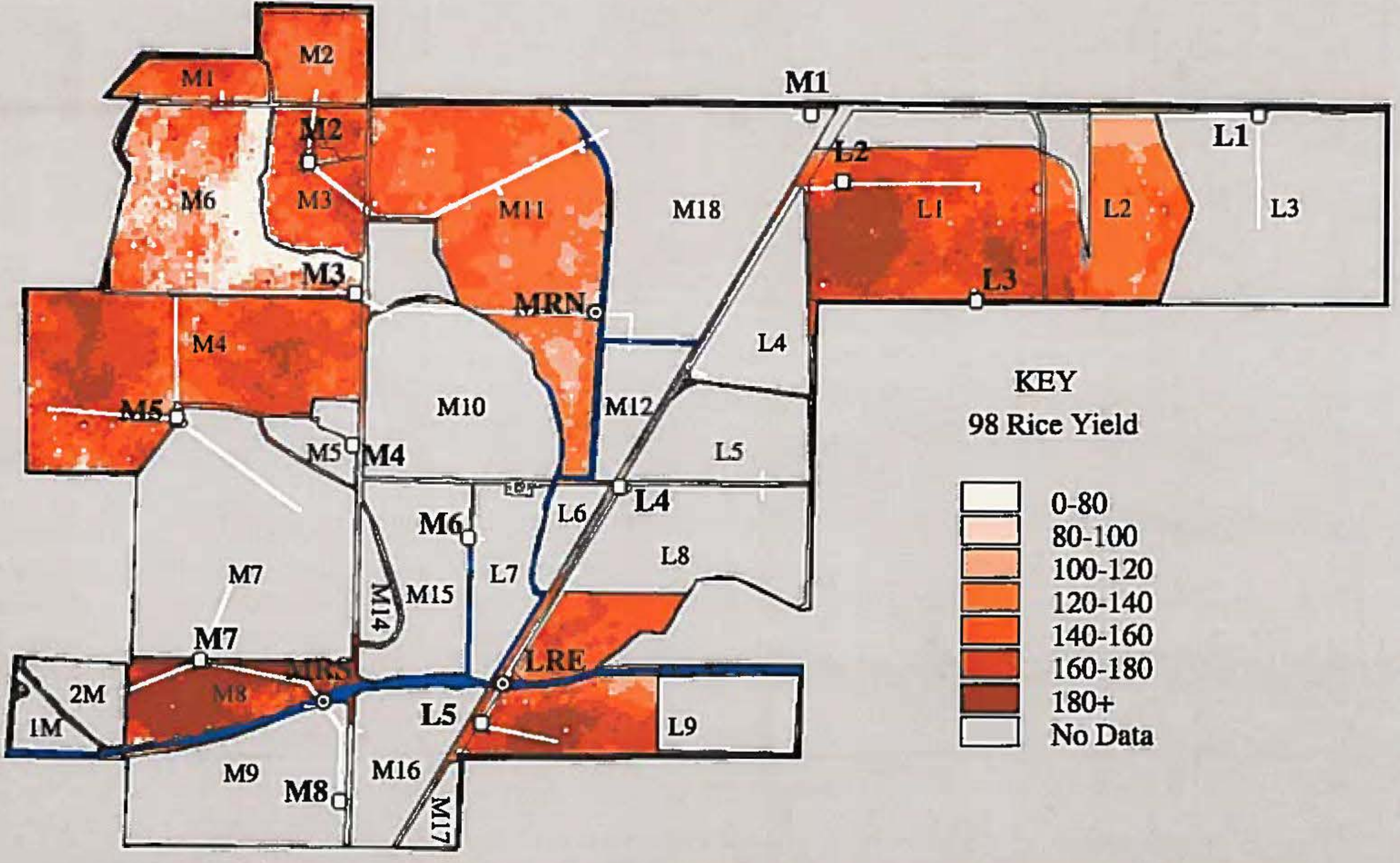


Figure 12. Rice yields by field at the demonstration farm in 1998. Larger, bolded symbols (e.g. **M1**) are water sources and regular symbols (e.g. M1) are field IDs.

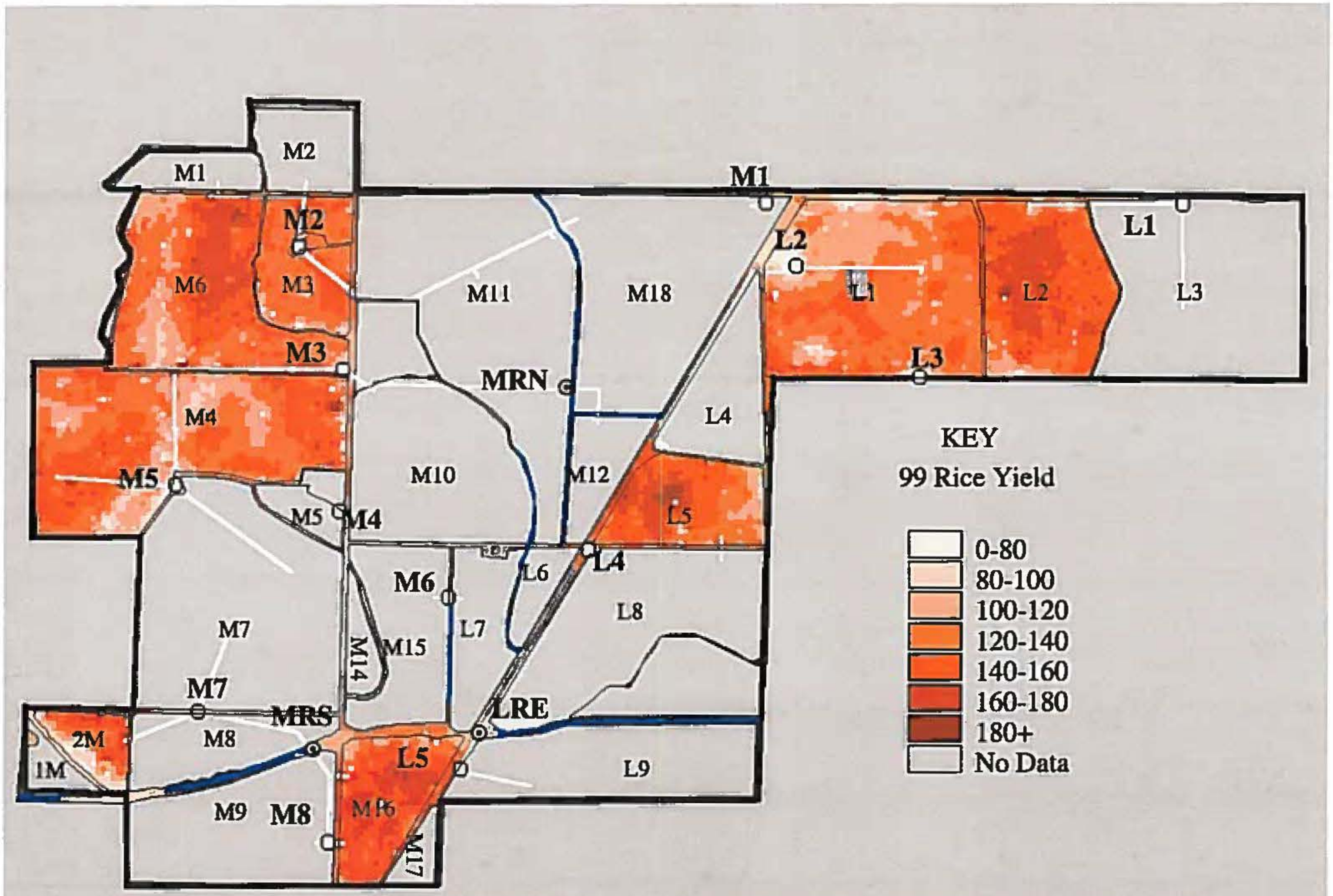


Figure 13. Rice yields by field at the demonstration farm in 1999. Larger, bolded symbols (e.g. **M1**) are water sources and regular symbols (e.g. M1) are field IDs.

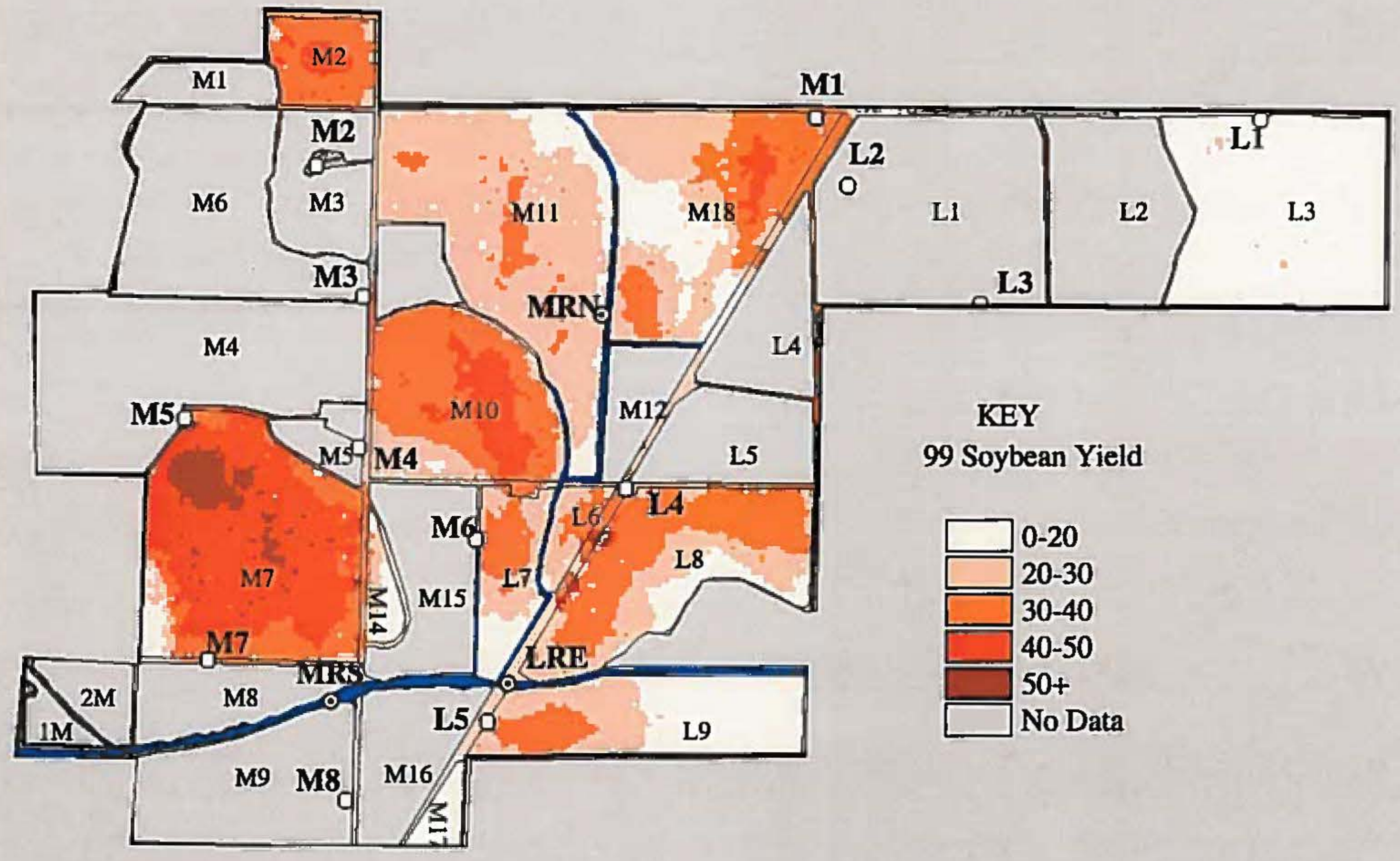


Figure 14. Soybean yields by field at the demonstration farm in 1999. Larger, bolded symbols (e.g. **M1**) are water sources and regular symbols (e.g. M1) are field IDs.

Soybean yields in 1999 were measured for 54% of the demonstration farm and averaged 29 bu/acre.

Water quality did not have a consistent effect on crop yields. In 1998, yields were taken in 64, 69 and 19% of the good, fair and poor water quality areas cropped to rice, respectively. Average rice yields in the good, fair and poor water quality areas were 127, 157 and 175 bu/acre, respectively. In 1999, yields were taken in 28, 69 and 25% of the good, fair and poor water quality areas cropped to rice, respectively. Average rice yields in the good, fair and poor water quality areas were 136, 134 and 143 bu/acre, respectively. **Over both years, rice yields were equal to or higher in the poor water quality area. This was attributed to extensive use of the good quality creek water from relifts LRE and MRS.**

Soybean yields were only available in 1999. In 1999, yields were taken in 74, 37 and 50% of the good, fair and poor water quality areas cropped to soybean, respectively. Average yields in the good, fair and poor water quality areas were 29, 29 and 33 bu/acre, respectively. Thus, soybean yields were not adversely affected in the poor water quality area due to use of creek water for irrigation.

Economic Analysis

The farm operator and the owner evaluated the economic analysis (Appendix 11) and decided that the largest of the proposed reservoirs, at 1120 acre feet, was most feasible. If the reservoir is built, the plan is to start construction as quickly as possible after harvest, and then to fill the reservoir from the creek during the fall and winter months using multiple relifts. The reservoir will be used to gravity feed irrigation water where possible using existing lines and some newly installed lines, and the relifts will be used to recharge the reservoir during the irrigation season as long as the creek water quality remains good. If and when the water in the reservoir becomes depleted to the point where it no longer meets irrigation needs using gravity, then pumps and relifts will be used to distribute the remaining viable reservoir water. It may be necessary to use pumps from the beginning of the irrigation season to reach some of the more remote fields from the reservoir. Only after all of the surface water options have been explored and exhausted, should the fair to poor wells be employed as irrigation water. It is expected that the three good quality wells in the northwestern third of the farm will be employed much as they are currently.

Crop Yield Versus Soil Test Results

Rice yields in 1998 (Figures 15 to 19), rice yields in 1999 (Figures 20 to 24) and soybean yields in 1999 (Figures 25 to 29) obtained using the yield monitor were plotted versus selected soil test results obtained at the same location in the field. The figures separate the demonstration farm into areas served by the good, fair and poor water quality sources.

Soil pH varied from about 5.5 to nearly 8.0 over the three crop/year combination. No consistent effect on either rice or soybean yield was found. Slaton et al. (1994) suggested that above pH 6.5, zinc deficiencies in rice are possible on silt loam soils. The data in Figures 15 and 20 do not support this hypothesis. Soil test calcium values (Figures 16, 21 and 26) are also presented as soil test calcium should increase as soil pH increases. Again, no relationship to yield was observed. Snyder and Sabbe (1994) suggested that no yield reduction would occur in soybeans if soil pH is above 5.8.

Exchangeable sodium percentages varied from about 1.0 to 7.0 percent. Yield of rice and soybean were not affected over this range of ESP (Figures 17, 22 and 27). Slaton et al. (1994) suggested that ESP less than 8 will not damage rice which agrees with the data presented here.

Soil test phosphorus ranged from slightly less than 20 lb P/acre to nearly 100 lb P/acre, but there were no yield decreases at low soil test P values. Phosphorus fertilization of rice is not recommended on all soils unless soil test P is less than 30 lb P/acre (Slaton et al., 1994), while soil test P values of 40 to 60 lbs P/acre (depending on soil and irrigation) are considered minimums for soybean production (Snyder and Sabbe, 1994). Thus, the lack of adverse response was likely due to adequate soil P in a majority of the fields.

Soil test potassium ranged from about 125 to nearly 500 lb K/acre. K fertilization of rice is not recommended until soil test K falls below 175 lb K/acre, while K fertilization of soybean is recommended as soil test K falls below 220 lb K/acre (depending on soil and irrigation). The majority of soil test K values were well above these minimums and no yield response was noted.

Publications and Presentations

Periodic educational programs on the demonstration project were implemented at University of Arkansas Field Days in the summer of 1999, the Cooperative Extension Agent meeting at the Rice Research Extension Center in 1999, and the 2000 Rice Technical Working Group regional conference in Biloxi, Mississippi. The demonstrations emphasized the importance and the need for all irrigation water sources to be tested, with the goal of improving irrigation water quality by limiting or eliminating poor sources and developing alternatives. The audiences incorporated producers, educators, crop advisors, extension personnel and county agents.

Publications of the projects' findings appeared in the 1998 Rice Research Studies Series (Gilmour et. al., 1998) and the Arkansas Water Resources Center annual conference (Slaton et. al., 1999). Additionally, a link was added to the Cooperative Extension Web Site with a condensed version of this report (Gilmour and Fry, 2000).

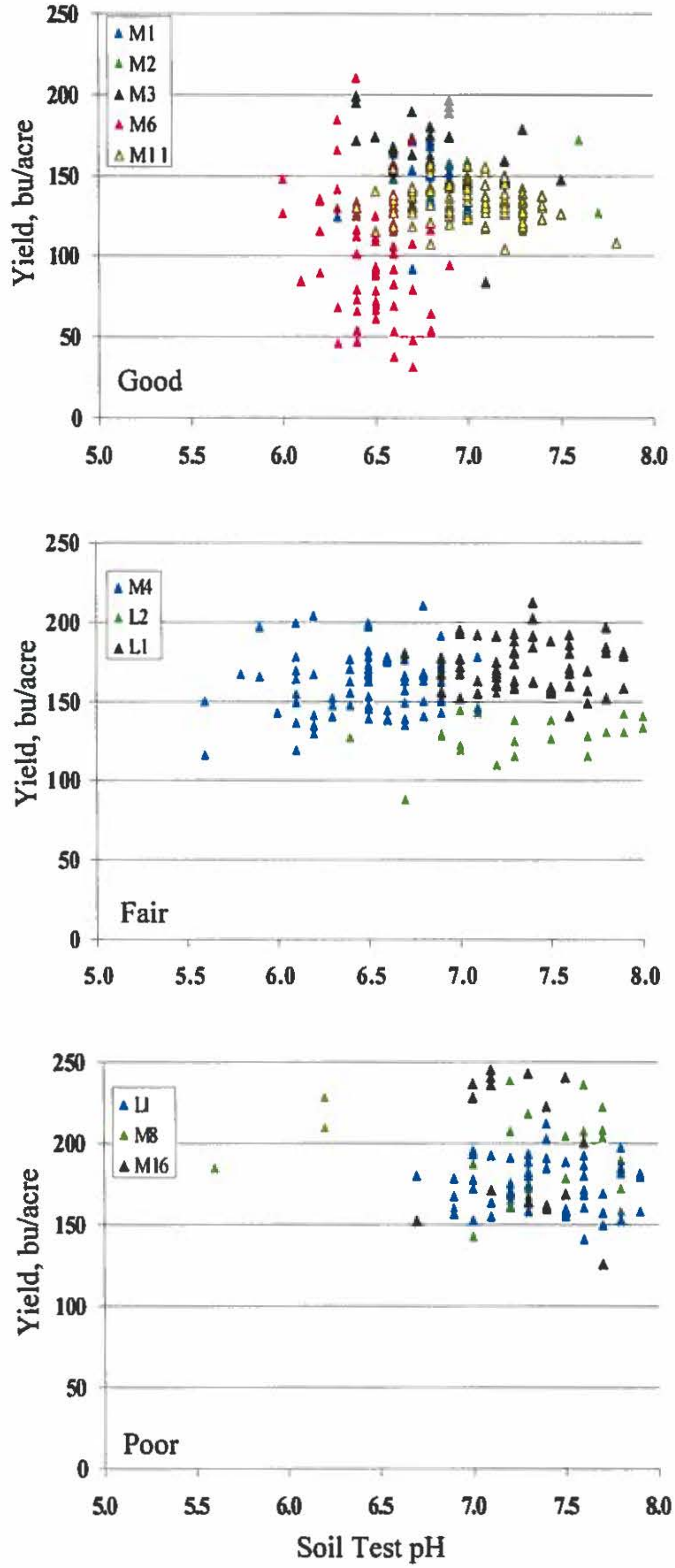


Figure 15. Rice yields versus soil test pH by water quality area in 1998.

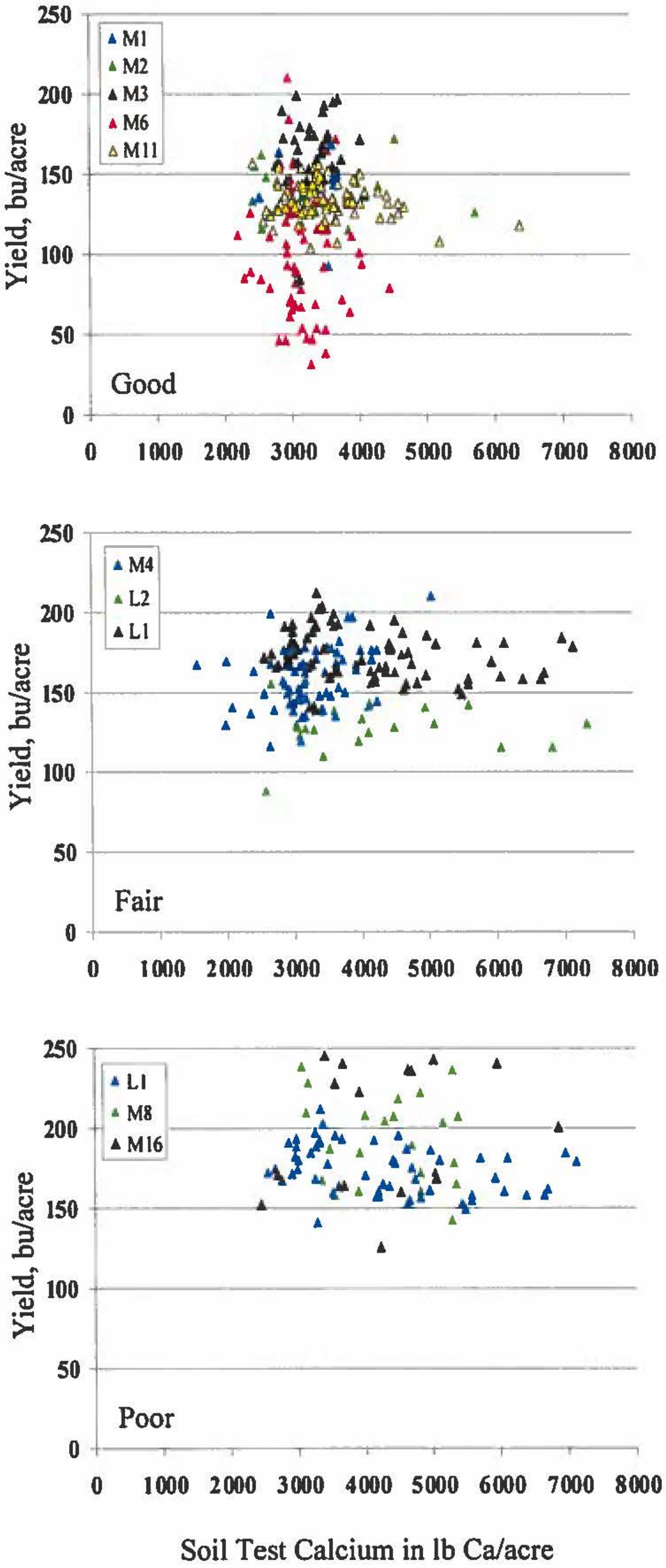


Figure 16. Rice yields versus soil test calcium by water quality area in 1998.

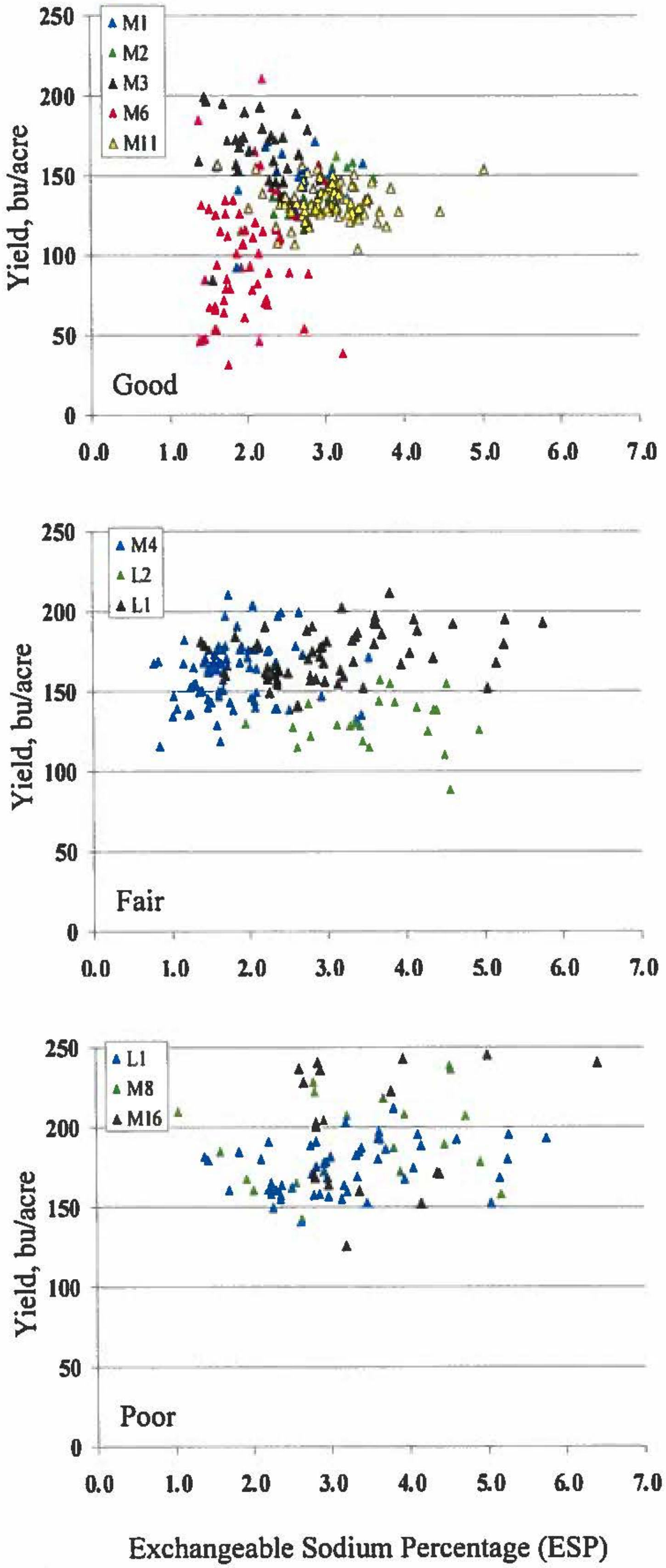


Figure 17. Rice yields versus ESP by water quality area in 1998.

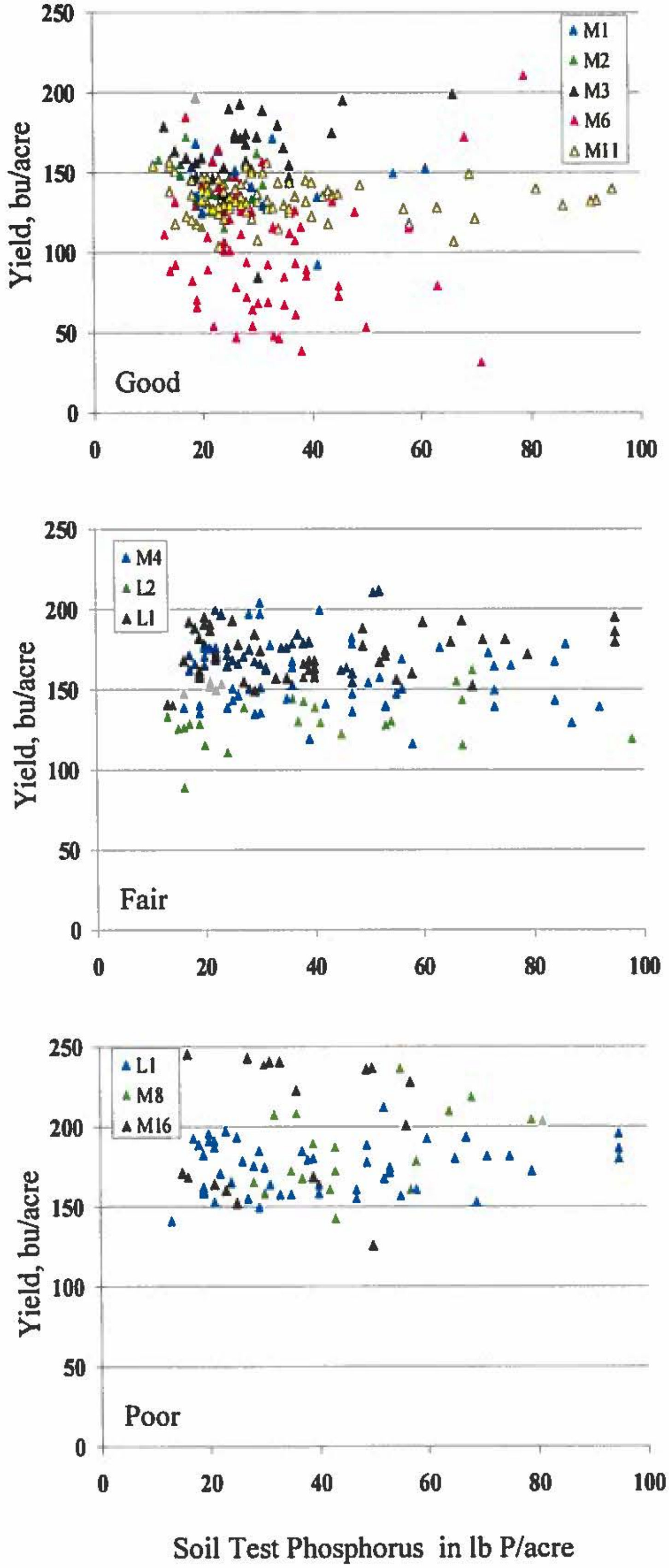


Figure 18. Rice yields versus soil test phosphorus by water quality area in 1998.

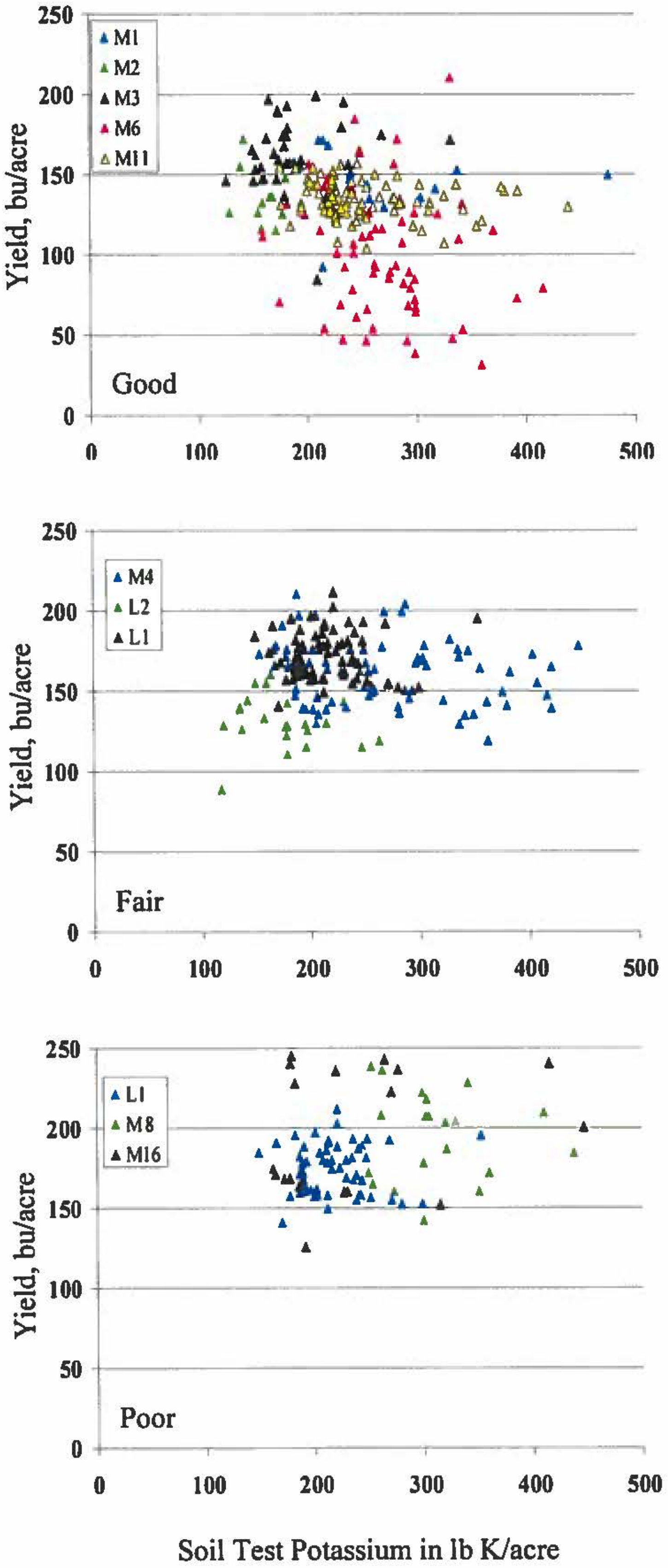


Figure 19. Rice yields versus soil test potassium by water quality area in 1998.

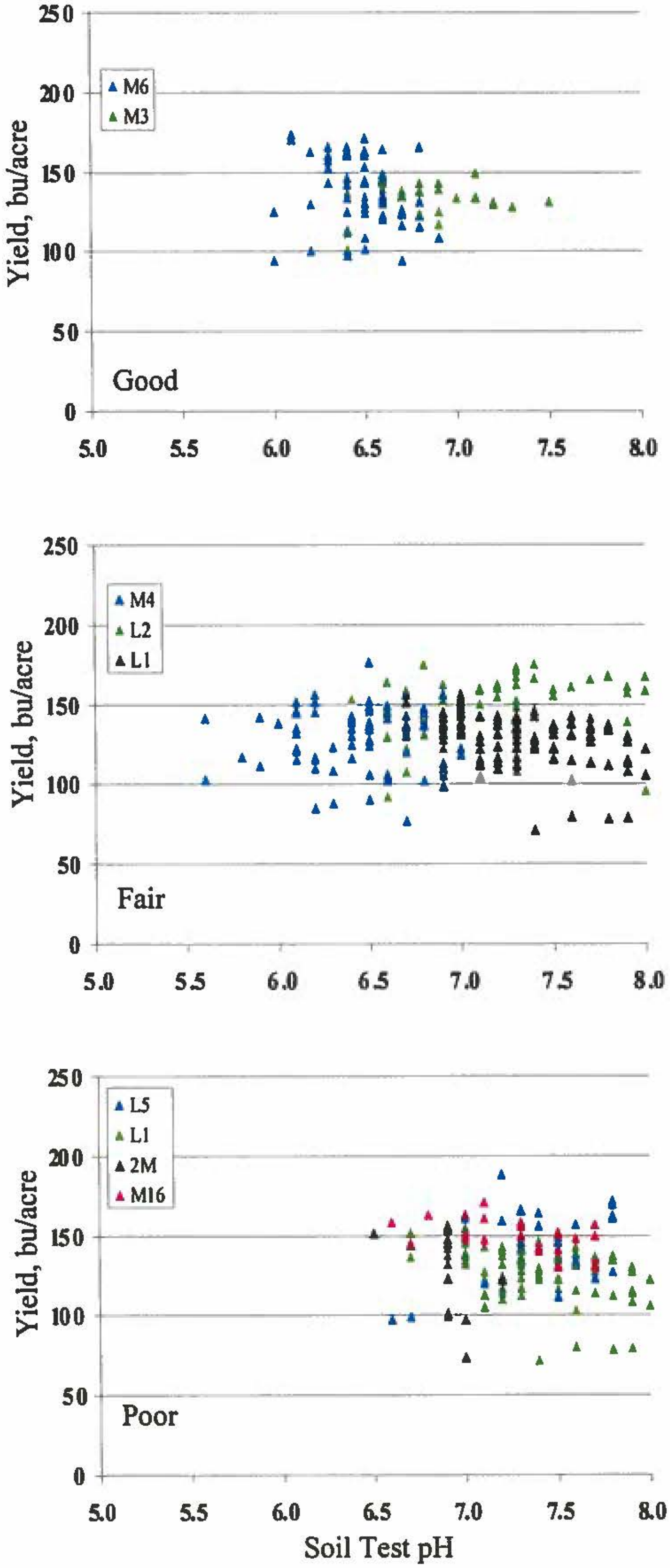


Figure 20. Rice yields versus soil test pH by water quality area in 1999.

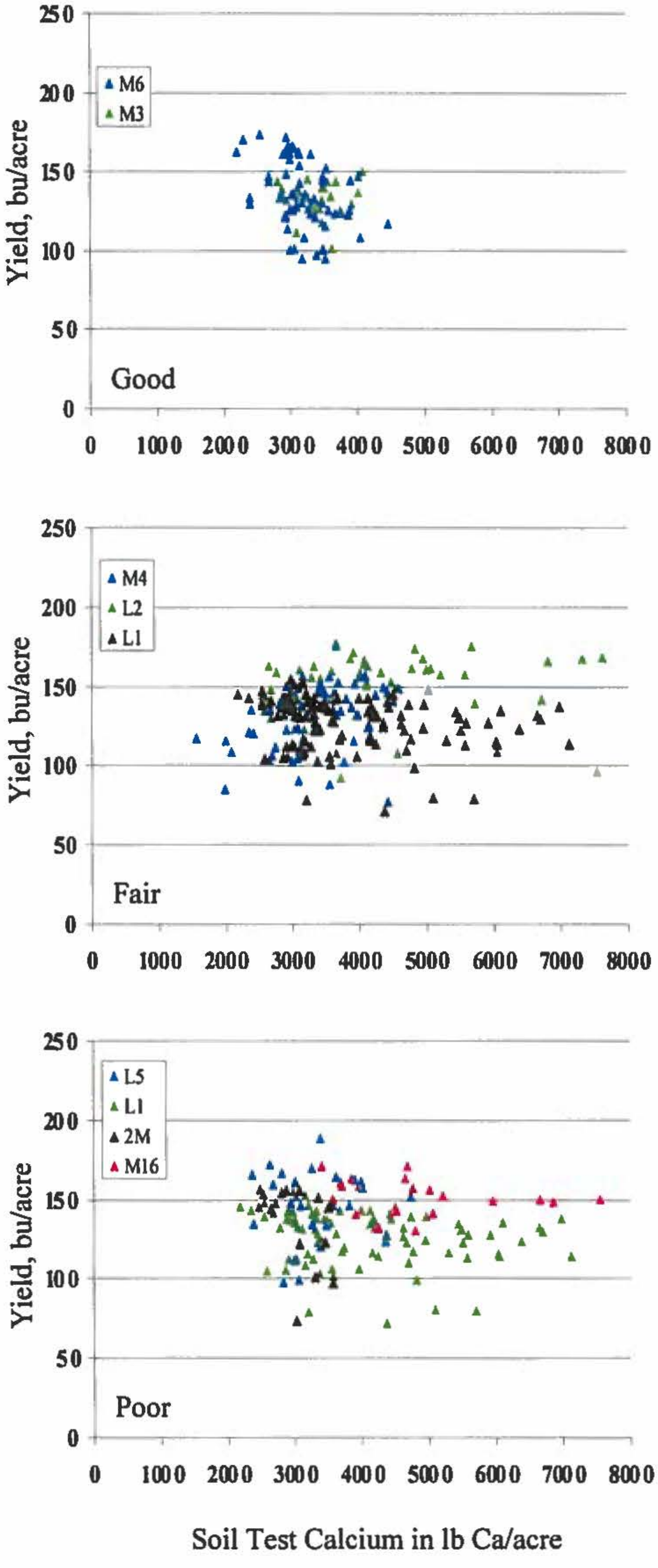


Figure 21. Rice yields versus soil test calcium by water quality area in 1999.

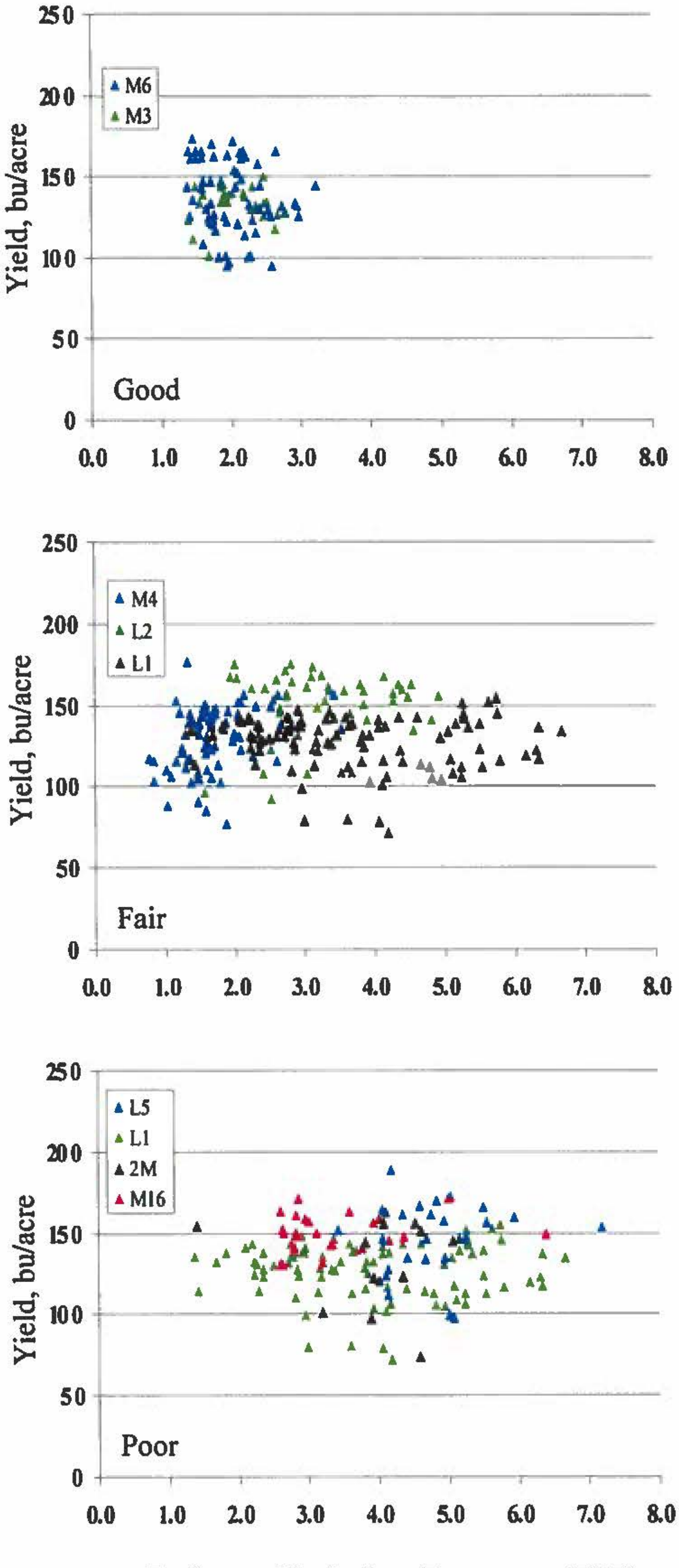


Figure 22. Rice yields versus ESP by water quality area in 1999.

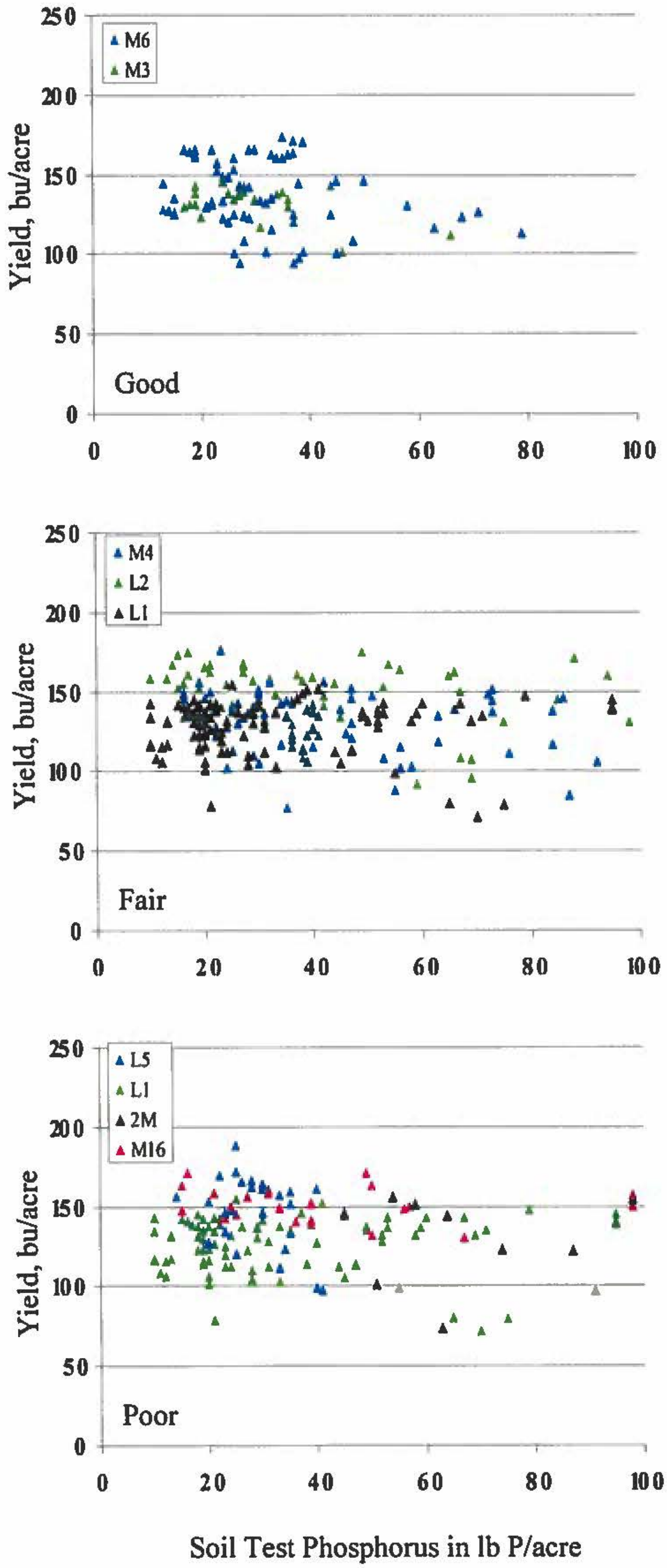


Figure 23. Rice yields versus soil test phosphorus by water quality area in 1999.

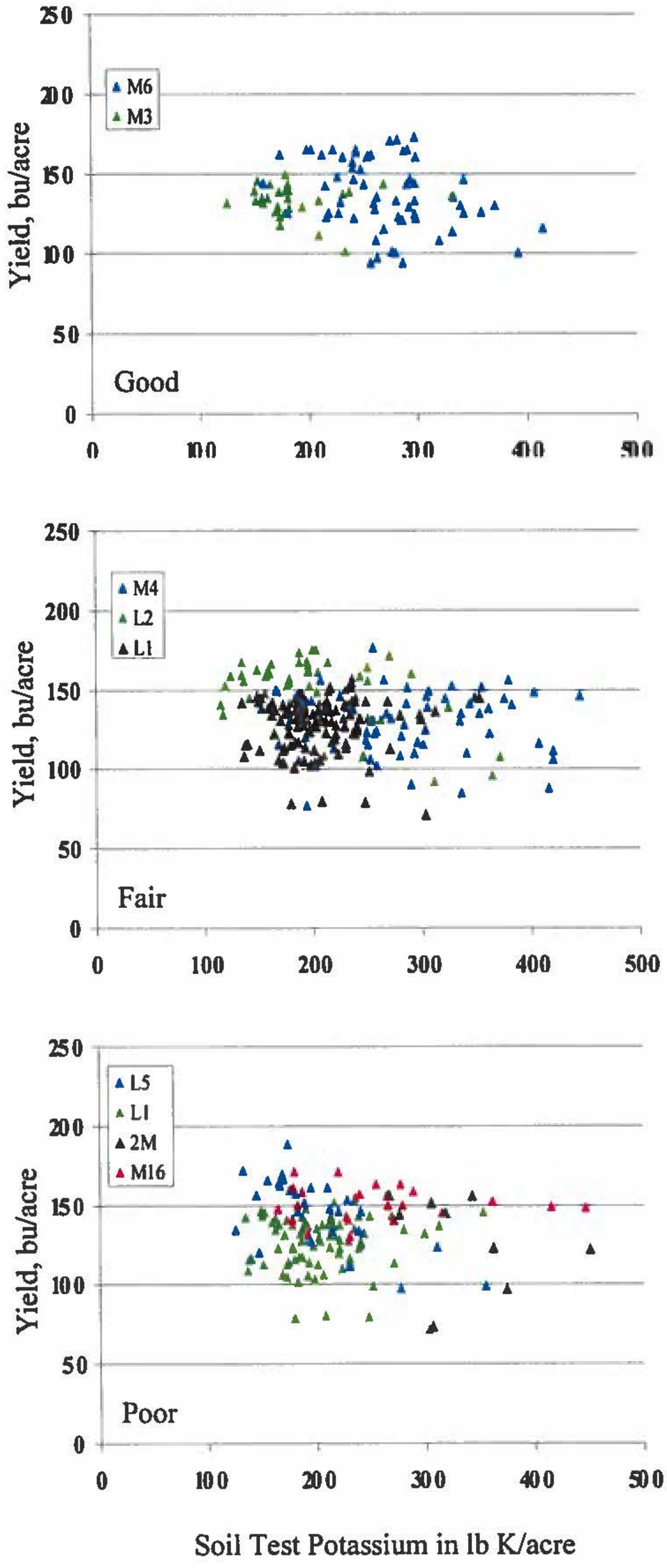


Figure 24. Rice yields versus soil test potassium by water quality area in 1999.

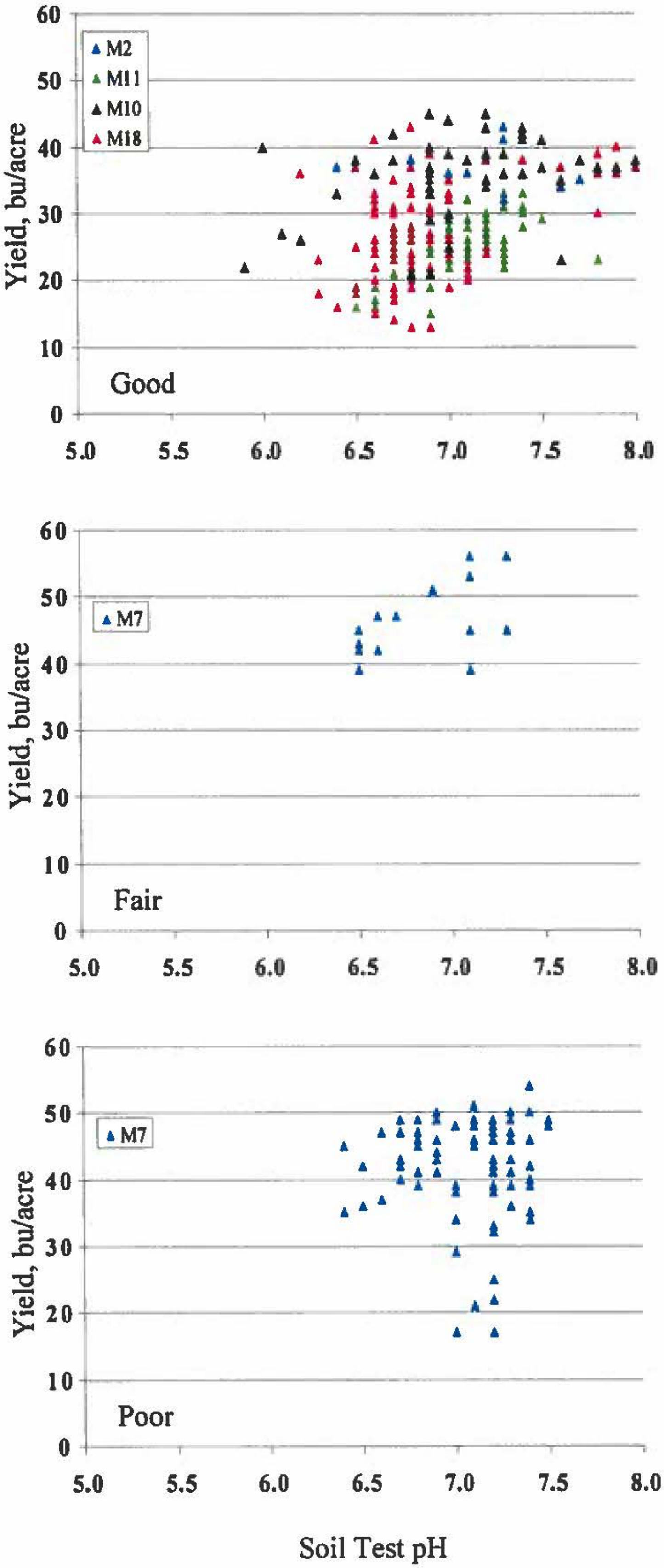


Figure 25. Soybean yields versus soil test pH by water quality area in 1999.

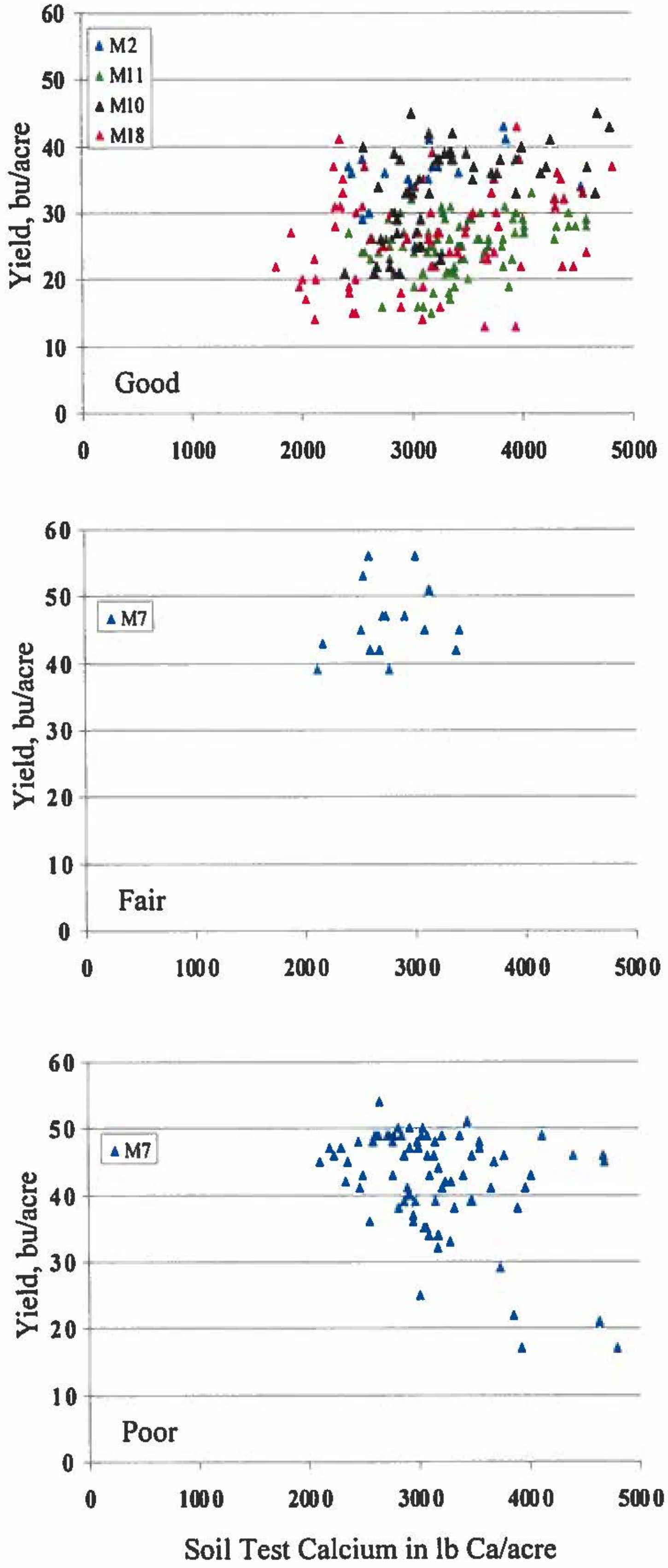


Figure 26. Soybean yields versus soil test calcium by water quality area in 1999.

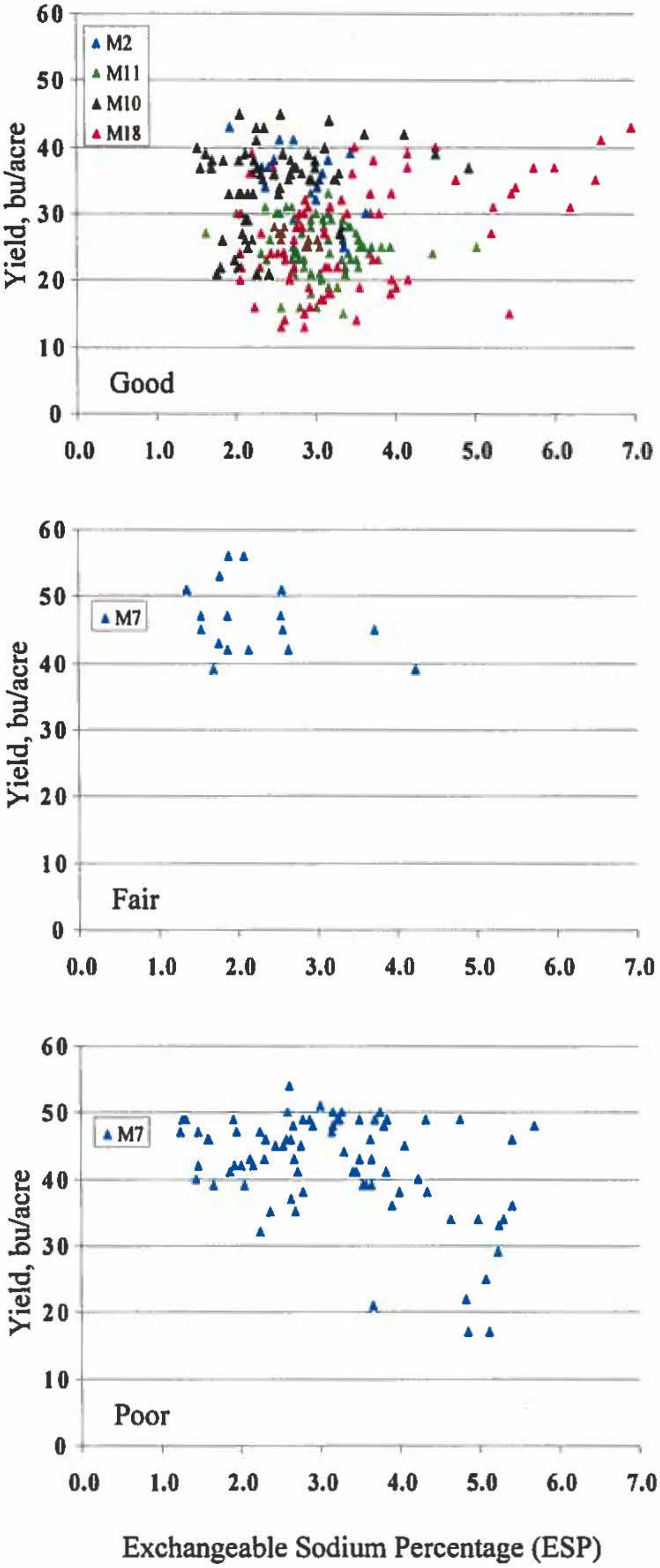


Figure 27. Soybean yields versus ESP by water quality area in 1999.

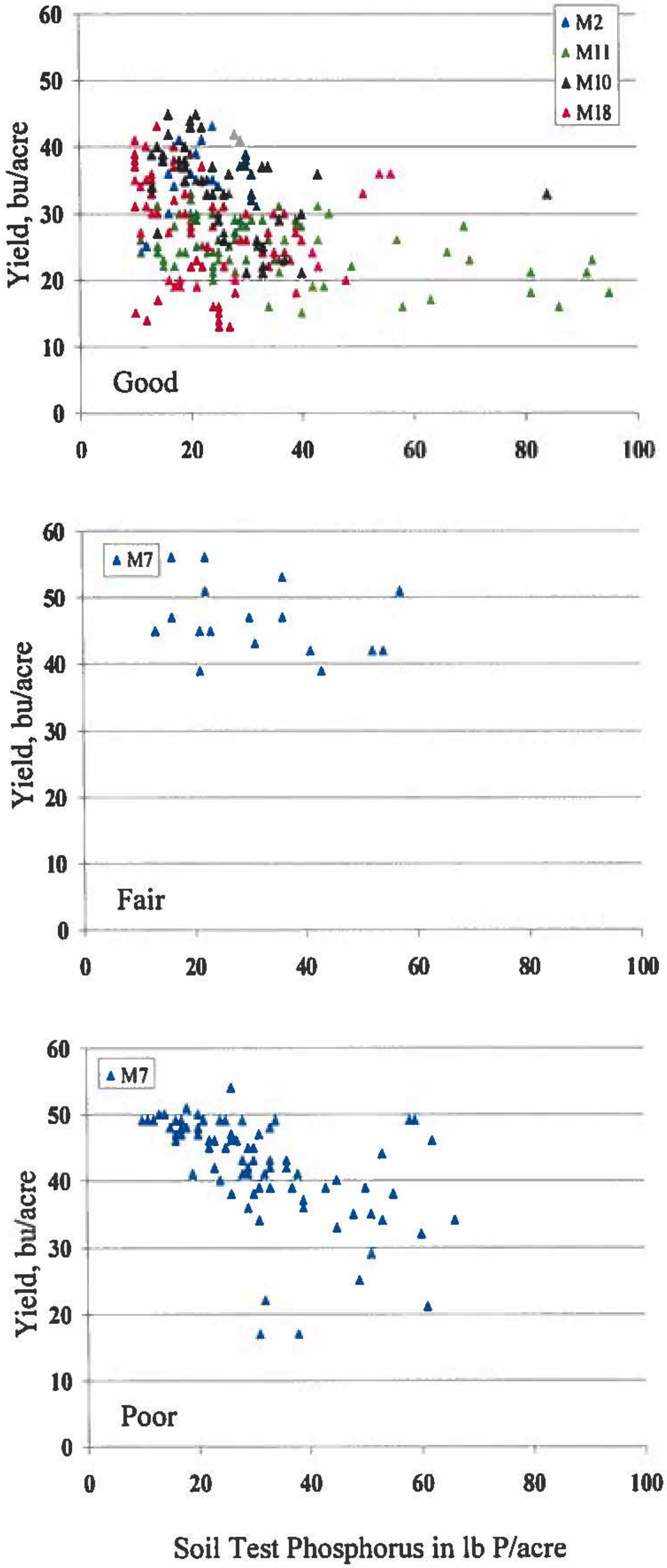


Figure 28. Soybean yields versus soil test phosphorus by water quality area in 1999.

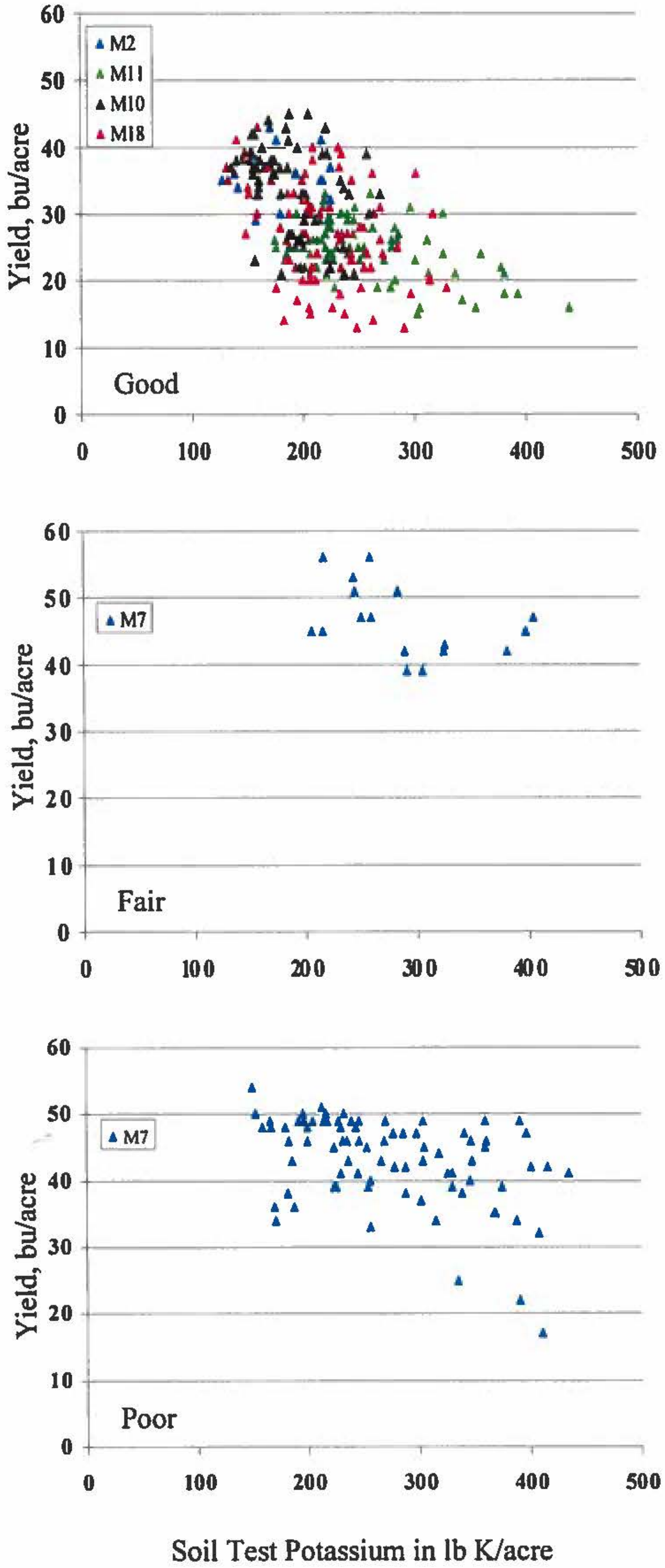


Figure 29. Soybean yields versus soil test potassium by water quality area in 1999.

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APPENDICES

NOTE: These appendices are located on the CD at the back of this publication. It will be necessary to have the appropriate software (in parentheses) to view and print these files. Also available on the enclosed disk are digital copies of this report and the figures included therein to allow for ease of dissemination of this information.

PRINTING INSTRUCTIONS

Print pages 1-9,12-15,17-28,31-36,39,44-45,49-51,67-69
OF THIS REPORT

THEN PRINT

FIGURES 1-14 AND FIGURES 15-29