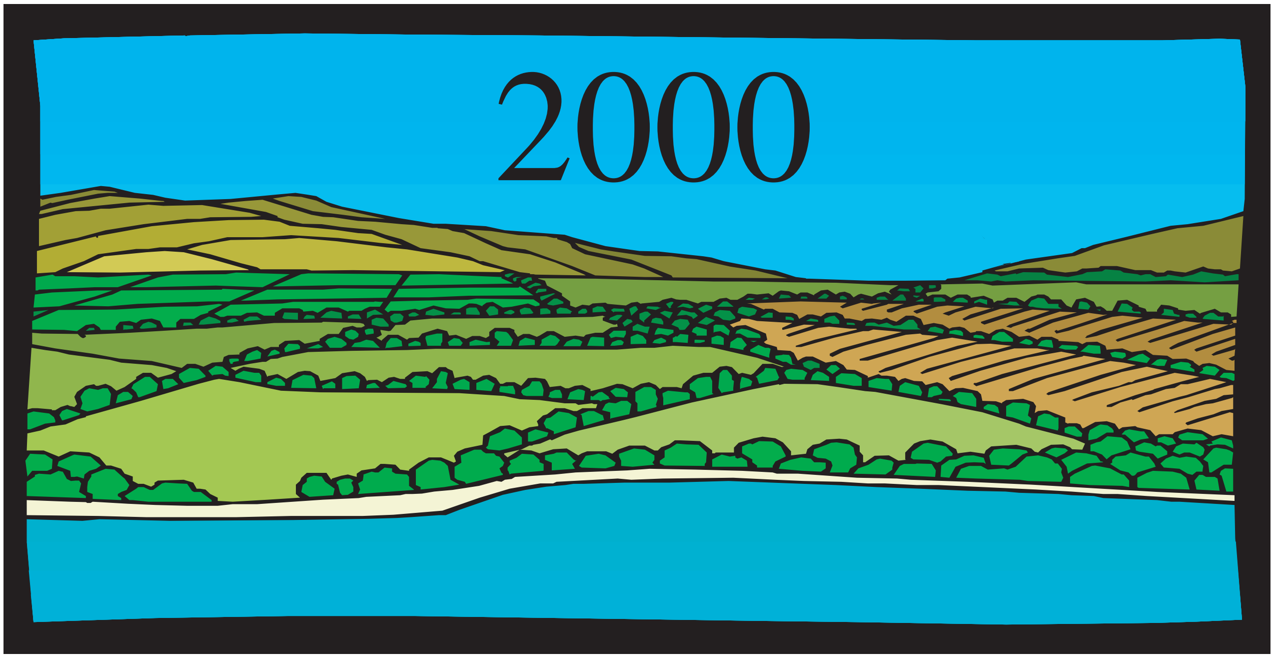
FAPRI
Environmental Projects



FAPRI-UMC Report #02-01

FAPRI
At the University of Missouri
Food and Agricultural
Policy Research Institute

College of
Agriculture,
Food and
Natural
Resources

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FAPRI
Environmental Projects 2000

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Table of Contents

List of Figures

List of Figures (continued)

Summary

Two facts of life exist in production agriculture. One, all types of livestock production generate animal waste that must be dealt with. Two, for profitable crop production, plants must receive adequate nutrients and pests must be controlled. In many respects, these two facts are at the heart of the challenge of the agriculture/environment interface.

Since 1995, the Food and Agricultural Policy Research Institute at the University of Missouri (FAPRI) has been providing analytical support in several areas around the state as communities try to come to grips with various water quality issues thought to derive from production agriculture's two underlying facts of life.

This report provides a summary of the lessons learned as the unit has looked at and worked with these communities. It also discusses the specific projects underway in the unit, again focusing on issues directly related to the interface problem. Full reports on most of these analyses are available from FAPRI.

Based on information and analysis of the farms and watersheds discussed in this report, as well as earlier analysis efforts by FAPRI, the following lessons have been learned about the agriculture/environment interface.

There is a direct relationship between animal waste application rates, the number of acres on which the waste is applied, and the extent to which the nutrients contained in the waste leave the field or watershed, but factors such as soil type, slope, and climate also play key roles.

If current animal waste application rates are maintained, phosphorus buildup in the soil has the potential to cause groundwater concerns in some parts of the state. This is a particular issue in the karst regions.

- The hog operations examined have either adequate acreage for waste disposal or have waste handling systems that will minimize phosphorus build-up in the soil, at least in the short run. Lagoon systems minimize the short-run problems, but ultimately the dispersal of phosphorus retained in the lagoon must be dealt with.
- Conservation tillage practices have produced great strides in reducing sediment erosion rates in the state but they have resulted in a shift to greater chemical control of weeds which has, in turn, led to a higher degree of concern over chemicals in the environment.
- In addition to application rate, timing and the soil type and slope are factors contributing to the extent to which crop chemicals leave the field to which they are applied.
- The acreage allocation among crops grown in a watershed is directly related to the amount of agricultural chemicals that appear at the watershed outlet. Agricultural policy affects the shift between crops.

Policies designed to deal with the interaction of agriculture and the environment must consider a number of factors ranging from soil characteristics to topography, from climate to economics. They must also recognize the balance that exists between these many factors. The soil erosion/crop chemical challenge is a classic example. The economics of dealing with animal waste in a large versus a medium-sized livestock operation is another.

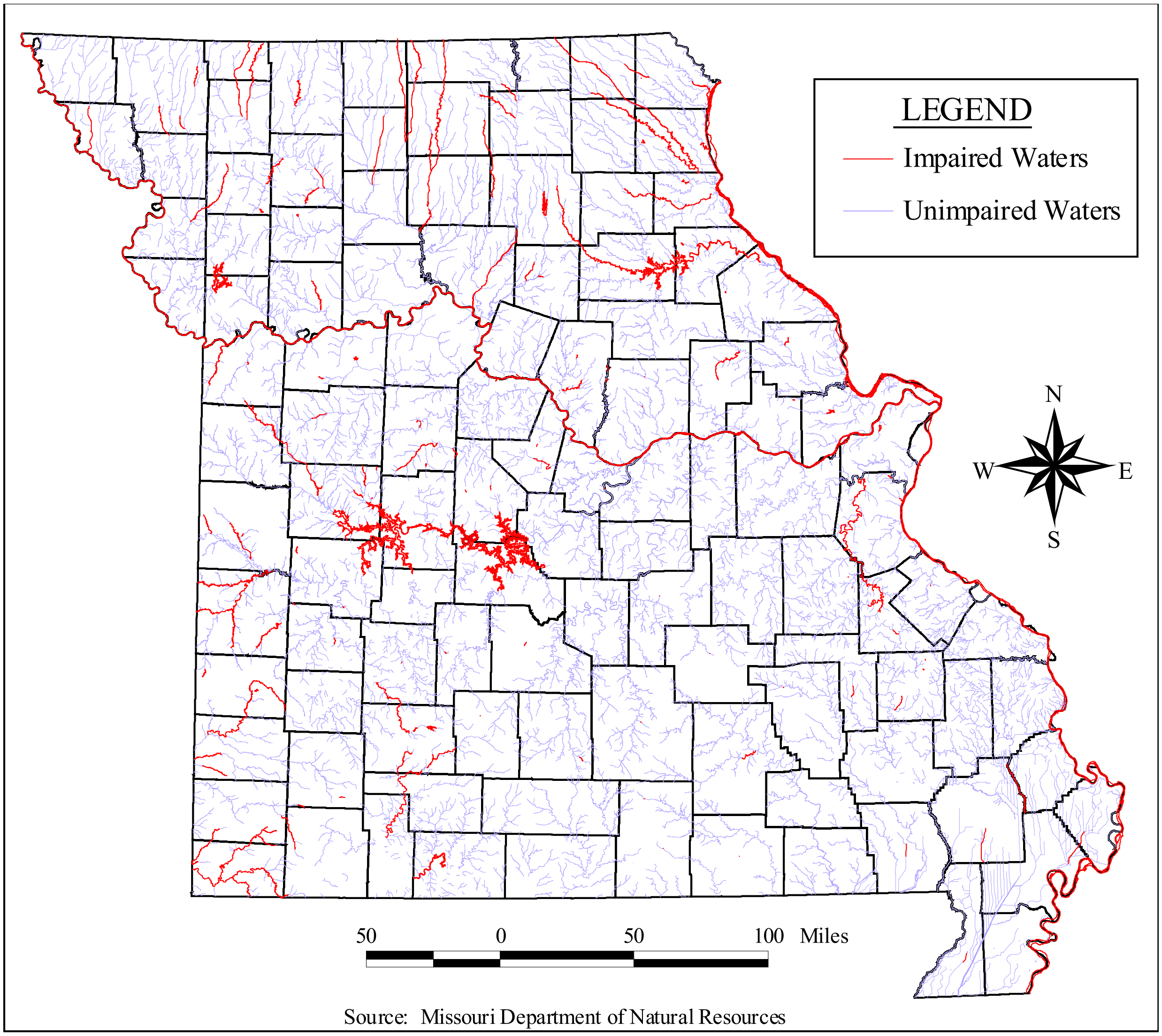
The combination of studies here, as well as the underlying analytical systems involved, can be directly used to evaluate current and alternative production practices while recognizing the crop and livestock production facts of life.

Introduction

The last century has seen tremendous change in the character of agriculture in the United States. We have gone from a predominately rural country with most of the population living and working on diversified farms to larger specialized farms with only 2% of the population on farms. This specialization led to livestock farms with limited cropland for recycling manure nutrients and crop farms with rotations that provided little soil residue cover.

Missouri has also faced concerns with nutrient loads in streams and lakes that have been viewed as fairly pristine in the past. These nutrients tend to be identified with livestock production and animal waste. For many years, nitrogen was the main nutrient of concern. In recent years, however, phosphorus has risen as a potential long-term problem. Phosphorus has very different properties than nitrogen, necessitating very different management practices. The Missouri Department of Natural Resources (MDNR) has placed impaired surface waters in Missouri on its 303(d) list, a list of state and national impaired water bodies that do not meet the standards for their intended use (Figure 1).

In the 1980s, Missouri ranked number one in water caused soil erosion. To address this, Missouri designated a portion of monies from the Park and



Source: Missouri Department of Natural Resources

Figure 1. Location of streams on Missouri's 303(d) list.

Soils sales tax for soil erosion control. Coupled with federal programs, these monies have enabled great strides in reducing erosion rates.

If left uncontrolled, weeds compete with crops for moisture and nutrients and have a negative impact on yields. As producers shifted from traditional tillage systems toward no-tillage systems, the use of older, cheaper pesticides with long residuals for season long weed control increased. This, in turn, resulted in occurrences of pesticides entering water bodies at levels exceeding U. S. Environmental Protection Agency (EPA) established standards. These standards are known as Maximum Contamination Levels or MCLs.

Through a cooperative effort between EPA, Missouri Department of Natural Resources (MDNR), and the Natural Resource Conservation Service (NRCS), the Food and Agriculture Policy Research Institute (FAPRI) at the University of Missouri was commissioned to undertake an ongoing analytical effort focused on selected impaired waters in Missouri. The goal of the analysis is to evaluate current and alternative management practices identified by local stakeholders that would lead to reduced nutrient, sediment, and pesticide losses. FAPRI's role was to bring the same level of objective analysis to environmental issues that it brings to the U.S. commodity policy analysis.

This report presents some of the projects in progress or recently completed by FAPRI's environmental analysis group. Analyses were conducted at the field, farm, and watershed level to analyze the impact of current management practices on the water quality of surface runoff, streams, and reservoirs. The analyses focus on the nutrient, pesticide (namely triazines such as atrazine and cyanazine), and sediment loadings carried off the fields and entering the streams and reservoirs. Currently, they do not address problems caused by failing lagoons or septic tanks, manure piles located too close to a stream, or contamination caused by point sources. The studies have been selected to address the short- and long-term concerns relative to their drinking water sources as expressed by the rural communities and agencies in the indicated areas.

The methodology adopted in these studies relies on mathematical computer simulation models that calculate nutrient and pesticide loads at the edge of a field, outlet of a farm, or watershed. The environmental models used in these studies are the Environmental Policy Integrated Climate (EPIC) model for field level analyses, the Agricultural Policy Environmental eXtender (APEX) model for farm or small watershed level analyses, and the Soil and Water Assessment Tool (SWAT) for watershed level analyses (Figure 2). These models simulate many of the physical processes that impact soil nutrient accumulation and water quality. The complexity of these models required FAPRI to build a team of interdisciplinary analysts.

The purpose of using a model is to establish water quality baseline characteristics resulting from current management practices when there is no or limited monitoring data, and to determine the contributions from different areas to water quality parameters of concern. Furthermore, these models are used to evaluate the potential changes in the environment if farmers adopt alternative management practices. As more factors are found to affect water quality, these models are useful to describe and analyze increasingly complex systems. The evaluation of current and proposed management practices is then based on the calculated values of water, sediments, and chemical yields on a daily, monthly, or annual basis. In short, a quantitative analysis is provided that will, hopefully, take much of this debate to a different plane.

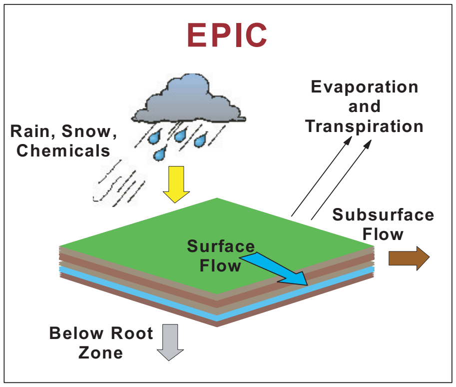
These models require considerable inputs. Some are readily available with the use of the Geographic Information System (GIS) technology (soils, slopes, land uses) and some, being specific to each area, are not readily available through public data sources (crop rotations, crop management practices, manure management practices, grazing practices).

Local panels of farmers help determine the inputs to these models. This cannot be stressed too strongly. Local producers have provided the production practices and other input information throughout this report. The goals of an environmental analysis at a field, farm, or watershed level vary.

- Field level analyses examine a single farming system on a single field under defined conditions (soil map unit, crop rotation, pesticide and nutrient management, tillage practices, livestock management). The evaluation is based on the calculated crop yields, erosion rates, and nutrient and pesticide movement within the field (edge of field analysis). The analysis can be combined with a farm level economic analysis to project the economic and environmental ramifications of current and proposed management practices.

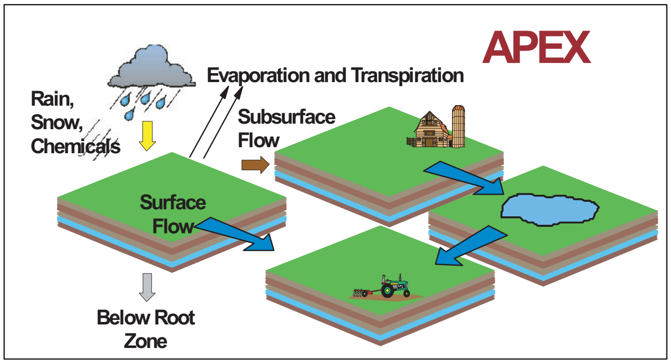
Field Level: Environmental Policy Integrated Climate model

Processes included in EPIC include:



- Weather (simulated or actual)
- Hydrology, evapotranspiration, runoff, percolation
- Erosion (wind and water)
- Crop growth (N & P uptake, stresses, yields, N-fixation)
- Fertilization (application, runoff, leaching, mineralization, denitrification, volatilization, nitrification)
- Tillage
- Irrigation and furrow diking
- Drainage
- Pesticide (application, movement, degradation)
- Grazing
- Manure application
- Crop rotations, inter-cropping, weed competition

Farm Level: Agricultural Policy Environmental eXtender model



APEX includes all EPIC processes, plus:

- Ponds and reservoirs
- Grazing management
- Buffer strips and grassed waterways
- Subsurface flow between subbasins
- GIS interface under development

Watershed Level: Soil and Water Assessment Tool

SWAT includes most EPIC processes, plus:

- Instream degradation of chemicals
- Ponds and reservoirs
- Lake water quality
- Ability to combine watersheds to simulate river basins
- GIS interfaces
- Fecal coliform modeling under development

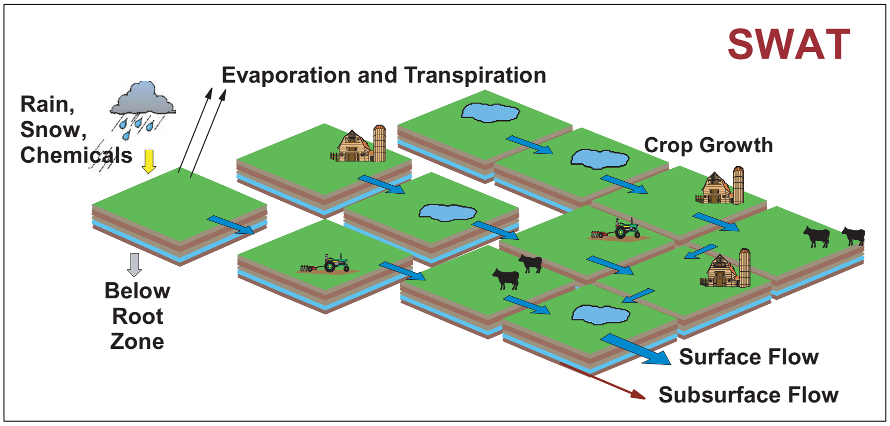


Figure 2. Environmental models used in analyses performed at the Food and Agricultural Policy Research Institute.

- Farm level analyses intend to evaluate the interaction of different management practices in adjacent fields controlled by the same manager. The fields can have distinct soil map units and/or management practices, such as a pasture next to a row crop field. This level of analysis can be used to evaluate the potential benefit of a buffer strip or a riparian zone. Farm level environmental analyses are often combined with a farm level economic analysis, in which the crop revenues are calculated as a function of crop yields generated from the environmental model, to project the economic implications of current and proposed management practices. To perform an analysis that is indicative of farms in a specific area, a “representative” farm is developed.
- Watershed level analyses intend to evaluate the combined environmental impacts of various agricultural and non-agricultural land uses within a watershed. The watershed is divided into nearly homogeneous subbasin units that have a distinct land use, soil map unit, and management. The analysis of subbasin results indicates areas in the watershed that may contribute most to nutrient, pesticide, and sediment problems in the receiving stream or lake. Economics are not currently addressed at this level.

The representative farm methodology includes a series of steps starting with the identification of a particular type of farm to be simulated, both financially and environmentally. The geographic area the farm is to represent is determined and a knowledgeable local facilitator is identified. The facilitator has the responsibility of identifying the size of the farm and selecting the farm panel members. As off-farm income is not considered, one basic premise is that the farm be able to financially support a single family. With size determined and panel members identified, the panel is convened to develop the hypothetical farm in a consensus building process. Typically, one of the panel members is a custom pesticide applicator or certified crop advisor who aids in developing pesticide and nutrient management practices for the farm. A critical factor in this methodology is that the farm being developed by the panel is not any individual panel member’s farm, but a farm that is indicative of the whole panel. Data on farm management (crop rotations, tillage type and dates, pesticide and nutrient application rates and dates) is entered into the models and validated with the panel. Once the farm is validated, it becomes the baseline against which alternative policy scenarios can be compared for their financial and environmental impacts. The alternatives are almost always locally derived to address the issue at hand.

The determination of these inputs by the farm panels is essential for the validation of the models. The members, the facilitator, and FAPRI determine together the current agricultural practices. Additional watershed inputs come from other agencies, mainly the NRCS, the Farm Service Agency (FSA), the local Soil and Water Conservation District (SWCD), and the Missouri Agricultural Statistics Service (MASS). Agreement on these practices and other parameters as being representative of the area is a key factor in the acceptance of the results. The models are then used to determine how these practices contribute to environmental conditions on the farm or in the watershed and how changes might affect the water quality of surface runoff, streams, and reservoirs.

This report is divided in two sections. The first section presents farm level analyses of various animal feeding operations. These include contract broiler representative farms in Lawrence and Barry Counties, and Newton and MacDonald counties, a Montgomery County 160-sow representative hog farm, and a northeast Missouri (Audrain, Marion, Monroe, and Shelby Counties) 1,500-sow representative hog farm. The management and environmental fate of nutrients, both commercial fertilizer and manure (liquid and solid), is the primary concern of these studies. This includes land applications of animal manure for nutrient recycling of nitrogen and phosphorus. These analyses are conducted on a farm level with the APEX model.

The second section presents watershed level analyses and is geared more toward crop operations. These include the Monroe City Route J watershed, the Miami Creek watershed, and the Long Branch Lake watershed. The primary concern is the potential presence of pesticides, nutrients, and sediments in a stream or reservoir that is a primary source of drinking water. These analyses are conducted on a watershed level with SWAT. In the Monroe City Route J and the Miami Creek watersheds, a more focused analysis was conducted on a field level with the EPIC model to address the environmental fate of pesticides.

Figure 3 shows the location of FAPRI's previous and current projects studies and related farm level economic analyses.

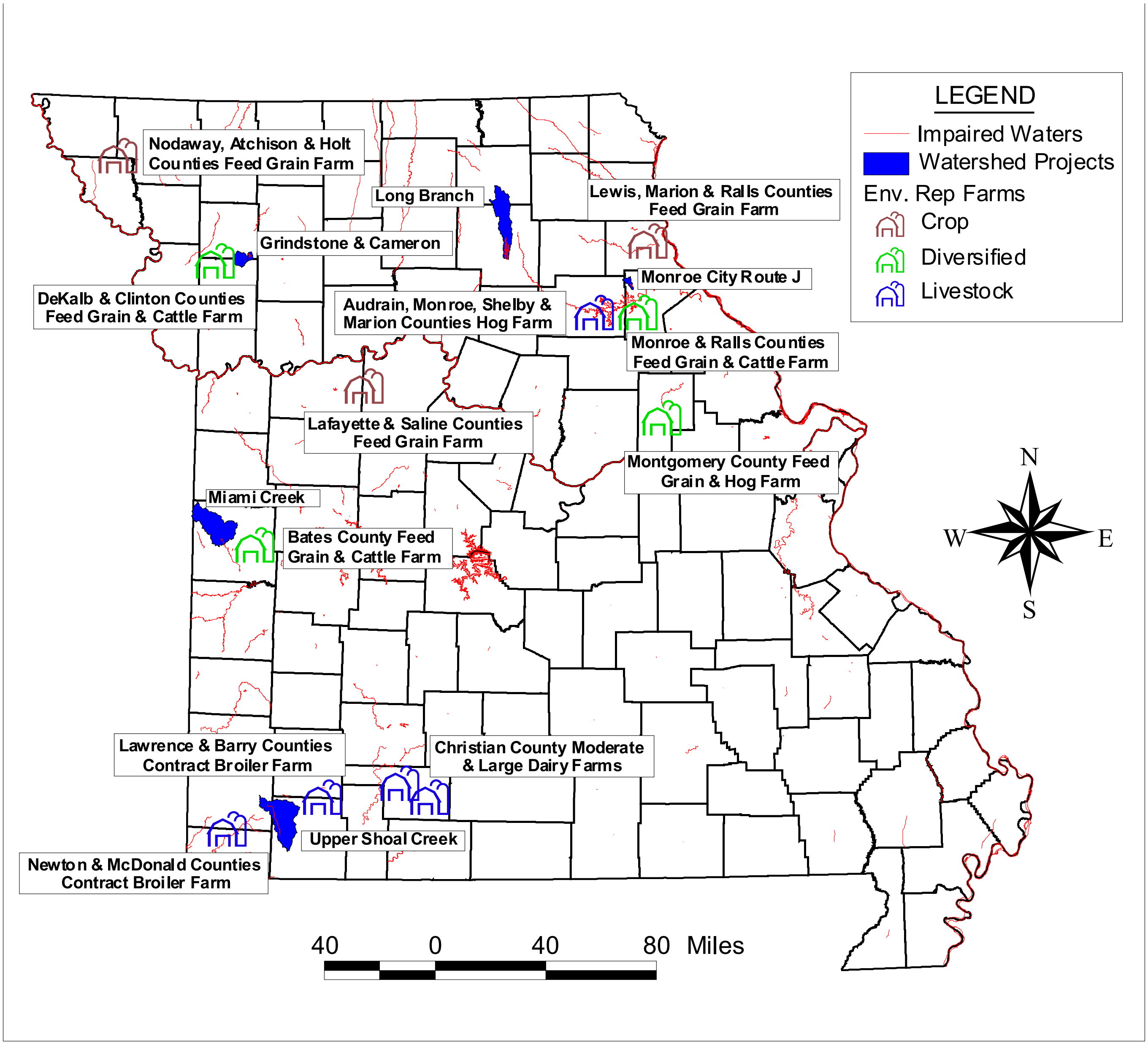


Figure 3. Location of all FAPRI eviornmental projects in Missouri in relation to streams on Missouri's 303(d) list.

Lawrence and Barry Counties Representative Contract Broiler Farm

Farm Description

In late 1998, FAPRI started modeling a representative poultry farm located in the Ozark Highland Major Land Resource Area (MLRA 116) in southwest Missouri. The representative farm site modeled in this analysis consists of 130 acres in fescue pasture and seed production. Three fields make up the farm: one 30 acre field (number 2) and two 50 acre fields (numbers 3 and 5) (Figure 4). Fields number 1, 4, and 6 are part of other farms but were modeled as part of the watershed in this study. The farm also has 50 cow-calf pairs that graze the pastures in non-seed years.

Concern

The management of nutrients derived from the continued application of poultry litter and how these nutrients will impact the environment is the main concern of this study

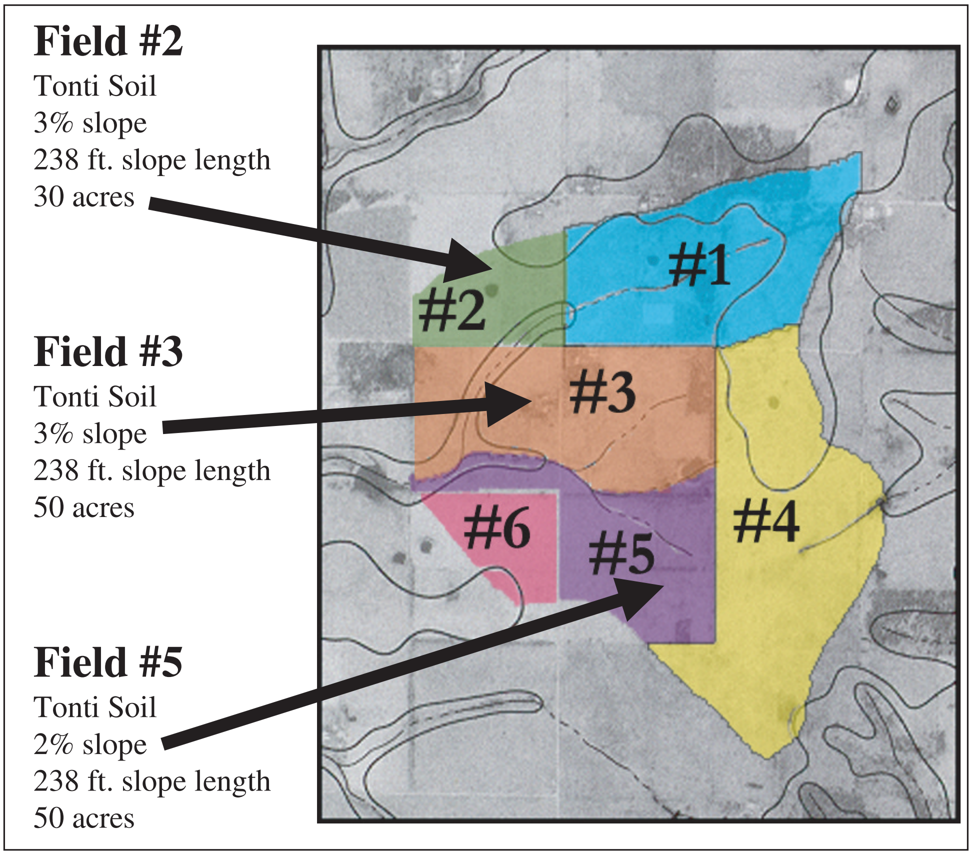


Figure 4. Arrangement of fields modeled for the Lawrence and Barry Counties Representative Contract Broiler Farm.

Objectives

The objectives of this study include to

- determine the effects of current litter management practices on nutrient buildup (particularly soluble phosphorus) in the farm's soil and the likelihood of runoff of these nutrients and
- evaluate the effects of alternative litter management practices and crops on these same buildup and runoff variables.

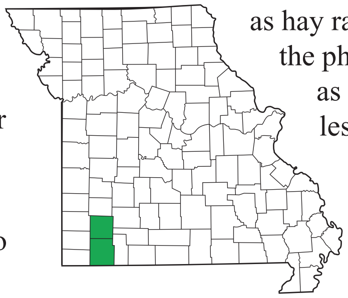
Land Management

The baseline (current) management for this farm includes utilizing the 30-acre field for fescue hay and grazing it from September 1–March 1. The two 50-acre fields are grazed at a rate of 2.8 ac/head every other year beginning October 1 following seed harvest and stubble baling. During non-seed years, grazing usually starts by April 1. A yearly application of 2 t/ac of poultry litter is made in March.

Six alternative management scenarios developed by the producer panel were examined.

- Fescue/legume pasture grazing system with year-round grazing at 2.8 ac/hd. 30 lbs/ac supplemental nitrogen is applied to the pasture but no litter is applied. Under this option the producer would be required to find an alternative off-farm use for the poultry litter.

- Fescue/legume pasture grazing system, year-round grazing, 2.8 ac/hd stocking rate, 2 t/ac litter application. This alternative doesn't harvest hay or seed. Legumes are overseeded.
- Bermuda grass hay system with a 2 t/ac litter application each fall, no grazing.
- Alfalfa hay system with a 2 t/ac litter application each fall, no grazing.
- Eastern gama grass hay system with a 2 t/ac litter application each fall, no grazing.
- Baseline management but applies litter every other year and 100 lbs/ac nitrogen fertilizer in the non-litter years.



Results

Figure 5 shows the phosphorus accumulation in the upper 6 inches as projected by the model for the baseline and alternatives 1, 5, and 6. After 50 years, the lowest level of phosphorus, 117 lbs/ac, was found with alternative 1 with no poultry litter applied. In comparison, the baseline phosphorus accumulation climbed from an initial level of 164 lbs/ac to 228 lbs/ac after 50 years. The results from the first five alternatives led the farm panel to propose that litter be applied every other year, alternative 6. Alternative 6 results in little phosphorus accumulation in the soil, as well as relatively low phosphorus loadings in runoff and sediment. However, the grower must have adequate land to spread the litter or must export the litter off the farm.

The analyses also show that more phosphorus is removed from a field when the hay is harvested as hay rather than grazed by cattle. Two-thirds of the phosphorus removed by grazing is returned as manure. Not only does grazing remove less phosphorus, it also tends to harvest phosphorus from deeper soil layers and redeposit it on the soil surface.

Conclusions

The current practice of applying 2 t/ac litter in the spring each year to fescue seed plus hay/grazed pasture in two-year rotations will likely lead to increased soluble phosphorus accumulations. Continued buildup of phosphorus in the upper 6 inches of the soil indicates this farm will need to look at alternative management practices that would stabilize or even decrease the phosphorus levels in the soil. In any event, the farm does not have a sufficient base to deal with the phosphorus coming from the broiler house. It needs to roughly double the acreage being used for litter application and harvest the resulting grass or legume growth as hay in order to stabilize the phosphorus loadings in the soil. Alternatively, the litter could leave the farm and be used elsewhere.

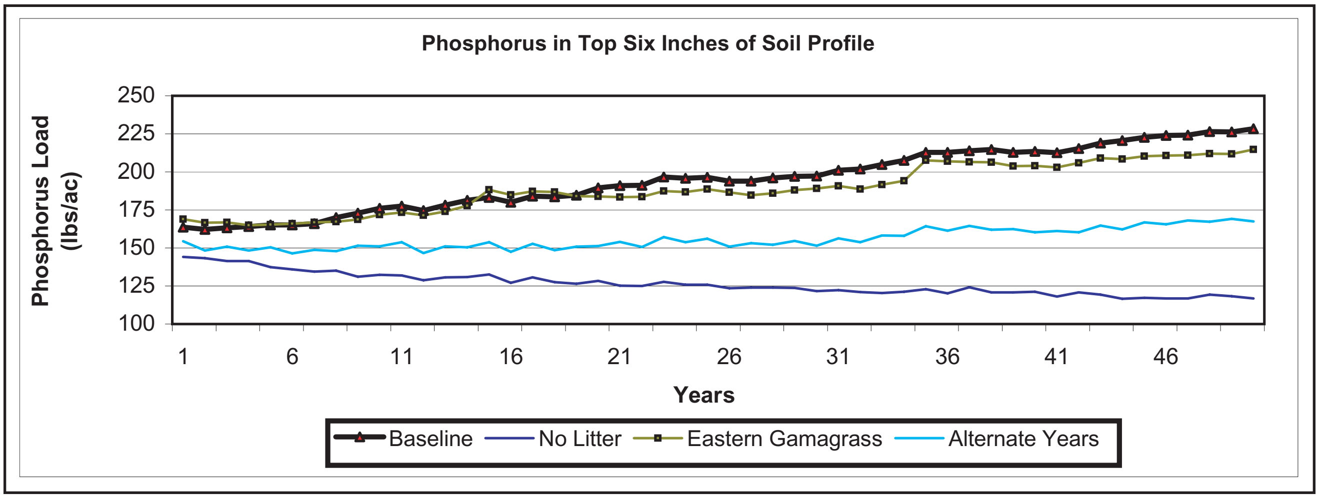
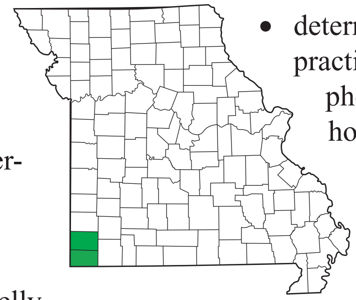


Figure 5. Estimated phosphorus buildup in the upper 6 inches of the soil profile under four management scenarios on the Lawrence and Barry Counties Representative Contract Broiler Farm.

Newton and McDonald Counties Representative Contract Broiler Farm

Farm Description

In early 1999, FAPRI started modeling another representative poultry farm located in the Ozark Highland Major Land Resource Area (MLRA 116) in southwestern Missouri. The representative farm site modeled in this analysis consists of 200 acres of clover/tall fescue pasture, which is split into five 40-acre fields. The farm also has 50 cow-calf pairs in a rotational grazing system. The farm is modeled on each of five different soils. Three, Tonti silt loam, Hoberg silt loam, and Nixa very gravelly silt loam are fragipan soils—a soil type with a nearly impermeable layer at depths ranging from near the surface to a few inches deep. Two, Clarksville very gravelly silt loam and Crackerneck very gravelly silt loam, are fairly porous, rocky soils.



One reason particular attention was paid to the potential variety of soil types that might occur on this farm is the different leaching characteristics each displays. First consider the gravelly soils relative to the other soil types. The gravelly soils tend to allow phosphorus and other nutrients to move quickly through the top few inches of the soil and into the lower layers, often to depths below the plant's root system. Consequently, when looking at the phosphorus levels in the top 6 inches of soil, one sees very little phosphorus buildup but relatively high levels of percolation. Conversely, in soils without the gravel content, the phosphorus tends to stay in the soil.

The second soil property of concern is the fragipan layer. Fragipan is a layer of very dense—almost rock-like—soil. Within the soil profile it appears as a very hard impermeable layer, but when removed from the soil it tends to be fairly fragile or break apart easily. This fragipan will tend to keep water from moving below the fragipan layer, thus trapping the phosphorus in the higher soil levels. Consequently, the fragipan soils tend to display higher phosphorus accumulations in the upper layers than non-fragipan soils. The issue is that on the fragipan soils the phosphorus stays or runs off, on the other soils the phosphorus tends to leach away quickly. Both outcomes are likely to be of some concern.

Concern

The management of nutrients derived from the continued application of poultry litter and how these nutrients will impact the environment is the main concern of this study.

Objectives

The objectives of this study include to

- determine the effects of current litter management practices on nutrient buildup (particularly soluble phosphorus) in the farm's soil and the likelihood of runoff of these nutrients, and
- evaluate the effects of alternative litter management practices and crops on these same buildup and runoff variables.

Land Management

The baseline (current) management for this farm includes utilizing four of the five 40-acre fields for rotational grazing by the cow-calf pairs. The remaining 40-acre field is harvested for hay annually then returned to the grazing cycle. In March, an annual application of 2 t/ac of poultry litter is made on all the fields.

The representative farm panel suggested five alternative management scenarios.

- Bermuda grass hay/grazing system on 20 acres of the original 40 acre field harvested for hay with 2 t/ac litter plus 100 lbs/ac of nitrogen applied annually. The remainder of the farm is operated like the baseline.
- Caucasian bluestem hay/grazing system on 20 acres of the original 40 acre field harvested for hay with 2 t/ac litter applied annually in March in addition to 100 lbs/ac of nitrogen. The remainder of the farm is operated like the baseline.
- An intensive grazing system with litter applied at 2 t/ac annually in the spring on a clover/tall fescue pasture, grazing rotated every 7 days over all five 40-acre fields at a stocking rate of 300 yearlings/field for the period April 1 to August 15.

- Same as alternative 3 except matua brome grass is grown. Litter is applied every second year and 80 lbs/ac of nitrogen is applied in non-litter years.
- Same as alternative 4 except litter is applied every third year and 80 lbs/ac of nitrogen is applied in non-litter years.

Results

Baseline and alternatives 1–3, all with a 2 t/ac litter application annually, showed the highest phosphorus accumulations, around 86–87 lbs/ac from the initial soil phosphorus level of 70 lbs/ac. All four of these scenarios were very similar, except that 20 acres in alternatives 1 and 2 were put into a different hay system (grass species), and the stocking rate in alternative 3 went from 50 cow-calf pairs to 300 yearlings/field. There is no accumulation of phosphorus using alternative 5, which applied litter every third year. Alternative 4, with litter applied every second year, resulted in only slight phosphorus buildup from current levels and accumulated phosphorus at 74 lbs/ac after 50 years of the simulation.

The leaching of phosphorus due to the more gravely soil map units in this analysis is the primary reason for less phosphorus buildup than the Lawrence and Barry counties farm. Figure 6 shows the comparison of the baseline to alternative 5 by each soil map unit. In both scenarios, Crackerneck soil allows the phosphorus to leach below the surface 6 inches to lower layers and beyond, due to the gravelly well-drained soil profile. As a result, phosphorus would not accumulate in the upper 6 inches of these soils. Phosphorus is accumulating, however, in the Hoberg, Nixa, and Tonti soils, due to the shallow soil horizons above the dense and restrictive fragipan, and the increased presence of soil particles to which phosphorus can bond. The Clarksville soil has little if any soil phosphorus accumulation.

Conclusions

The current practice of applying 2 t/ac litter in the spring each year to clover/tall fescue pasture will likely lead to higher soluble phosphorus accumulations in the upper 6 inches of soil except for the Crackerneck and Clarksville soils.

Alternatives 4 and 5, with less frequent litter application, show reduced potential water quality impairments for both groups of soils.

For alternatives 4 and 5 to work, the grower must have adequate land area to spread the litter or export the litter off the farm to some other site. The increased market area necessary to recycle the phosphorus will increase litter hauling costs.

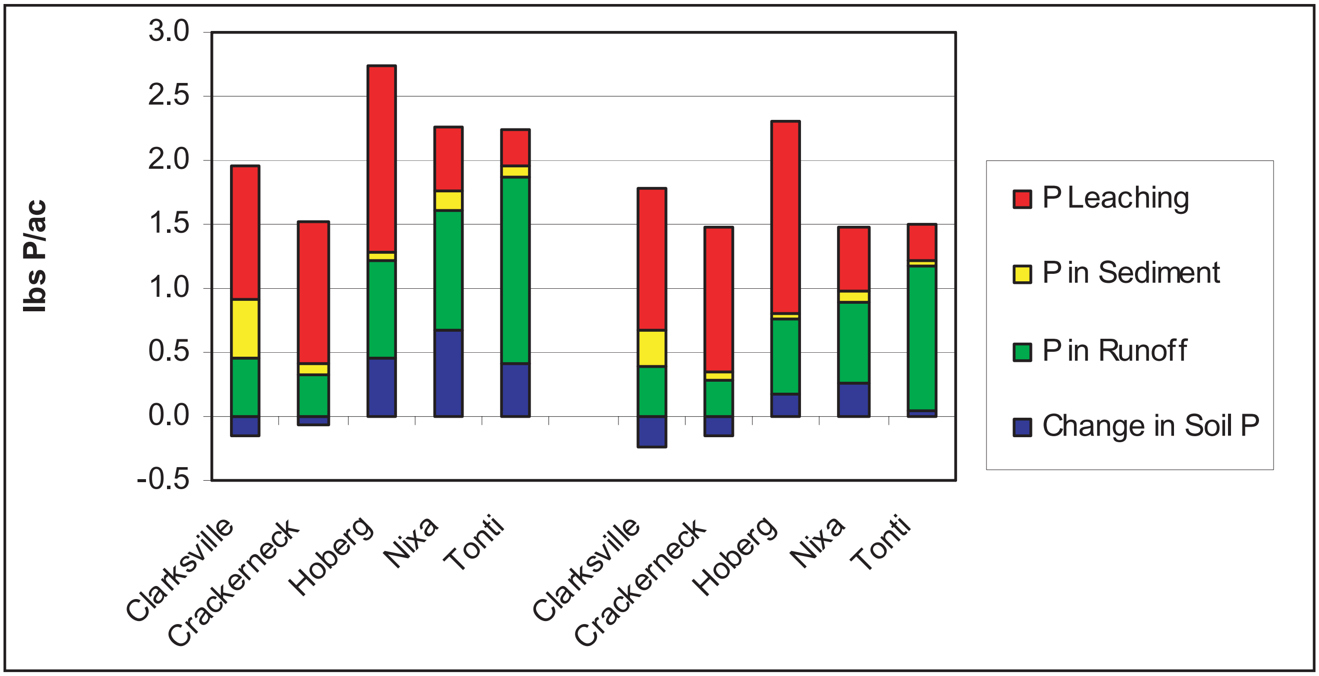
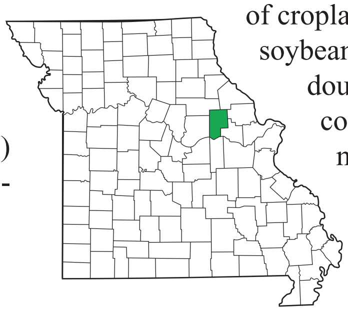


Figure 6. Comparison of phosphorus movements by soil map unit for all management scenarios on the Newton and McDonald Counties Representative Contract Broiler Farm.

Montgomery County 160-Sow (MDNR Class II) Representative Hog Farm

Farm Description



In late 1999, FAPRI started modeling a MDNR Class II small 160-sow hog farm located in the Central Claypan Major Land Resources Area (MLRA 113) in east central Missouri for the land application of manure/slurry. A specific geographic location but not an actual farm was the source of soil hydrology and field size data for the representative farm for this analysis. The farm consists of 1,228 acres of cropland with three crop rotations: corn-soybean-wheat (C-B-W); corn-soybean-wheat/double crop soybean (C-B-W/DCB); and corn-soybean (C-B) (Figure 7). Fields are modeled to account for physical characteristics of soil map units, slope, drainage ways, and terraces.

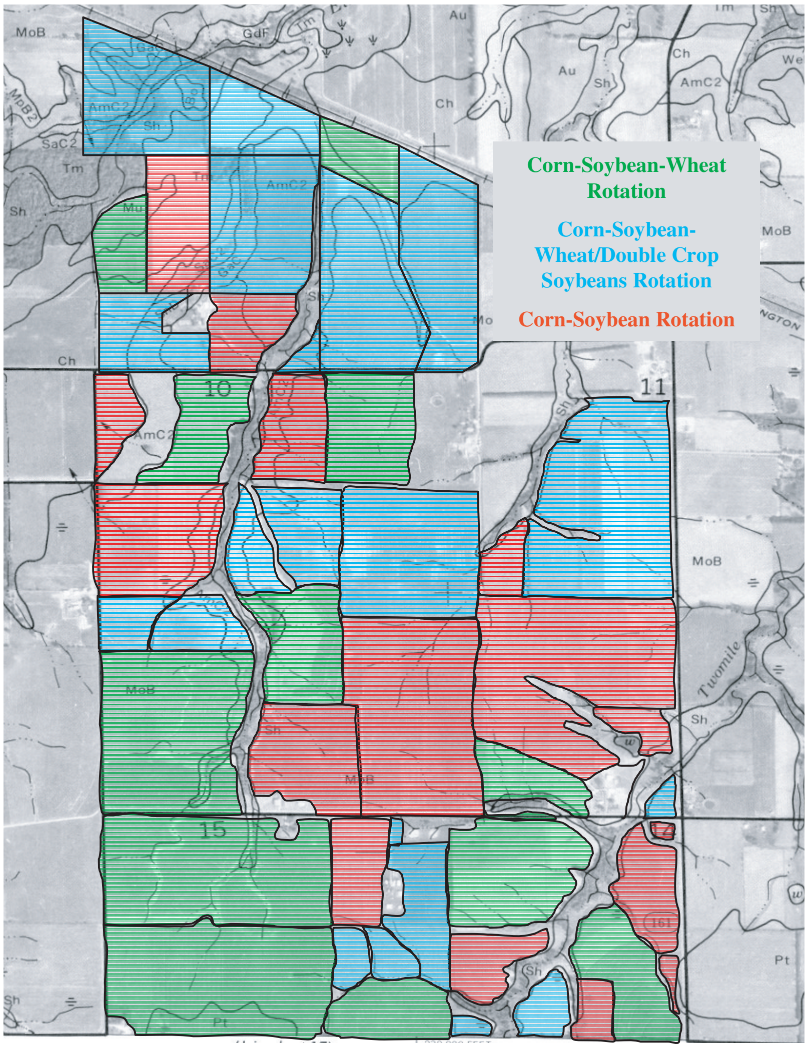


Figure 7. Arrangement of crop rotations modeled for the Montgomery County 160-Sow Representative Hog Farm.

Concern

The management and environmental fate of nutrients, both commercial fertilizer and animal manure (liquid and solid), are the primary concerns of this study. This includes the land application of manure for nutrient recycling of nitrogen and phosphorus.

Objectives

The objectives of this study are to evaluate

- current nutrient management and
- how this size operation could adjust to more stringent phosphorus based regulations.

Land Management

The University of Missouri's recommendations for land application rates of manure were applied to the farm, with the C-B-W rotation receiving the majority of the manure applied to its assigned fields. Figure 8 shows the distribution, by year of rotation, that the fields will receive swine manure slurry from a holding pit.

Preliminary Results

Preliminary results look quite promising for this operation. This is primarily a cash grain farm with a large acreage base on which to spread manure. This farm would be able to handle more restrictive phosphorus based regulations should this be adopted by MDNR.

Two scenarios are presented. The first is the baseline (BL) (current management), which applies 4,800 gallons of slurry per acre from a honey wagon. Second is the University of Missouri-Columbia's (UMC) recommendation, which applies 2,672 gallons of slurry per acre. The latter option requires a considerably larger land base to apply the same quantity of slurry as the baseline option and more time to spread it. Additionally, more precise equipment to apply increasingly smaller quantities of manure is not readily available.

The simulated phosphorus accumulation in the top 6 inches of the soil profile (where future regulations may measure phosphorus) is shown in Figure 9. There is a slow build up of phosphorus at this depth, but the model estimates that the buildup continues to barely below one foot in the soil profile (not shown). As expected by the difference in amounts of slurry applied, the baseline option builds up at nearly twice the rate of the university's recommendation.

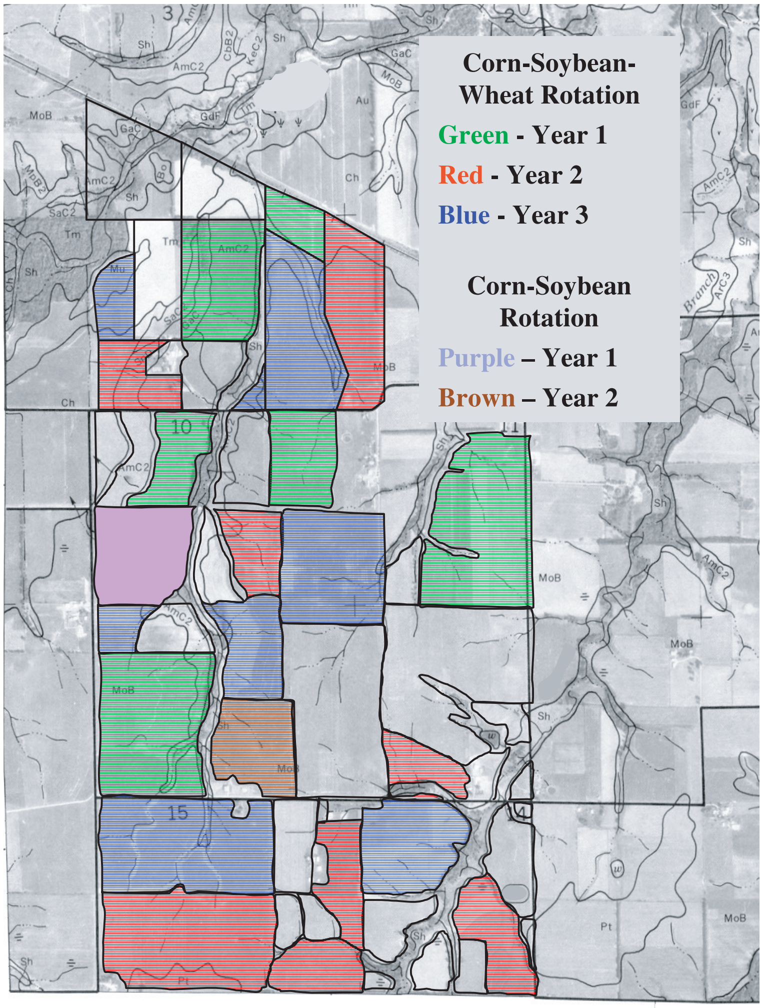


Figure 8. Distribution of manure slurry applications by year on the Montgomery County 160-Sow Representative Hog Farm.

Conclusions

Long-term effects of dealing with phosphorus buildup may require nutrient

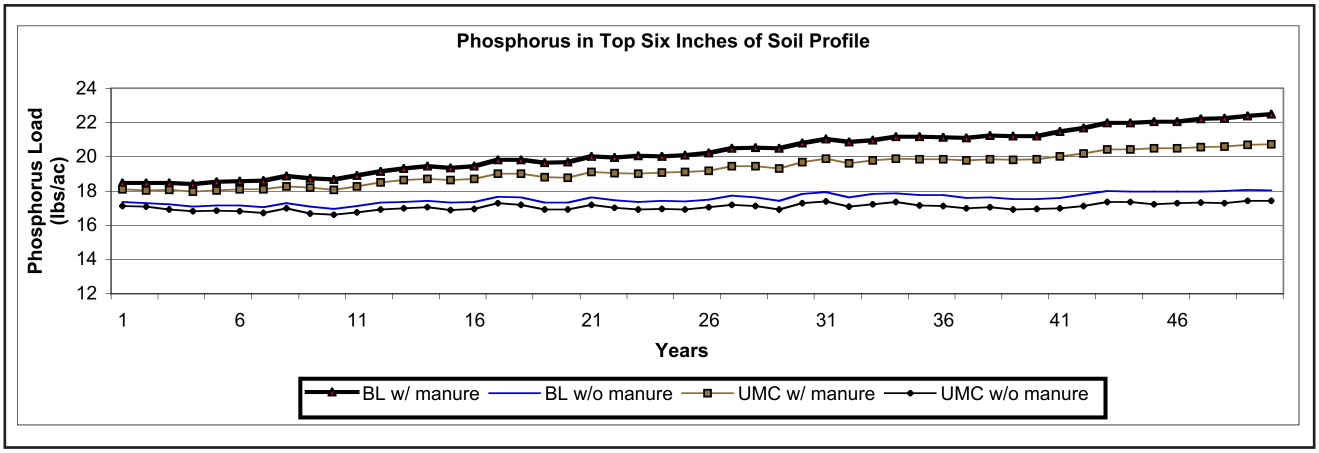


Figure 9. Estimated phosphorus accumulation in the upper 6 inches of the soil profile under four management scenarios on the Montgomery County 160-Sow Representative Hog Farm.

management that allows for longer periods of extraction than the standard 6 inch soil test may lead one to believe. Since the buildup is estimated to be deeper in the soil profile, it will take longer to mine the phosphorus and to reduce the potential for leaching to groundwater or base flow. However, these buildups of phosphorus are considerably less than the broiler farms estimates of phosphorus accumulations in the upper 6 inches of the soil profile. This 160-sow hog farm is not in a crisis management mode and has time and land resources to develop nutrient management plans that will address the issues of more restrictive regulations, should this occur.

The farm has the land base to apply lower rates of slurry, but at an economic cost to the operation in terms of time and increased fuel and repairs due to increased travel time and distance. The producer has a limited window to spread liquid manure when other farm operations are not occupying his time. Additionally, weather constrains the time available to spread slurry. In this model 75% or less of field capacity was considered appropriate for spreading slurry. The number of dry days (by month) needed for spreading manure is given in Table 1. The percentage of years when the total number of dry days were not available during late fall and winter is quite high.

Figure 10 shows the estimated number of dry field days in October for the 17 years in a 50-year simulation that manure would be spread in conjunction with a typical Missouri farm crop rotation. Fifteen dry days are needed in October but 76% of the years (13 out of 17) had 10 or fewer dry days and 18% (3 out of 17) had no dry days available to spread manure.

Table 1. Days Needed to Spread Manure and Percentage of Years Total Number Needed is Not Available.

Month	Days Needed	Years Total Days Not Available (%)
August	15	0
September	6	0
October	15	88
November	8	35
December	7	88
February	5	82

Note: Soil moisture at 75% or less field capacity is considered suitable for spreading manure.

This approach to nutrient management could require expenditures to upgrade equipment to allow manure spreading, planting, and harvesting operations to occur in the window of time available to grow crops.

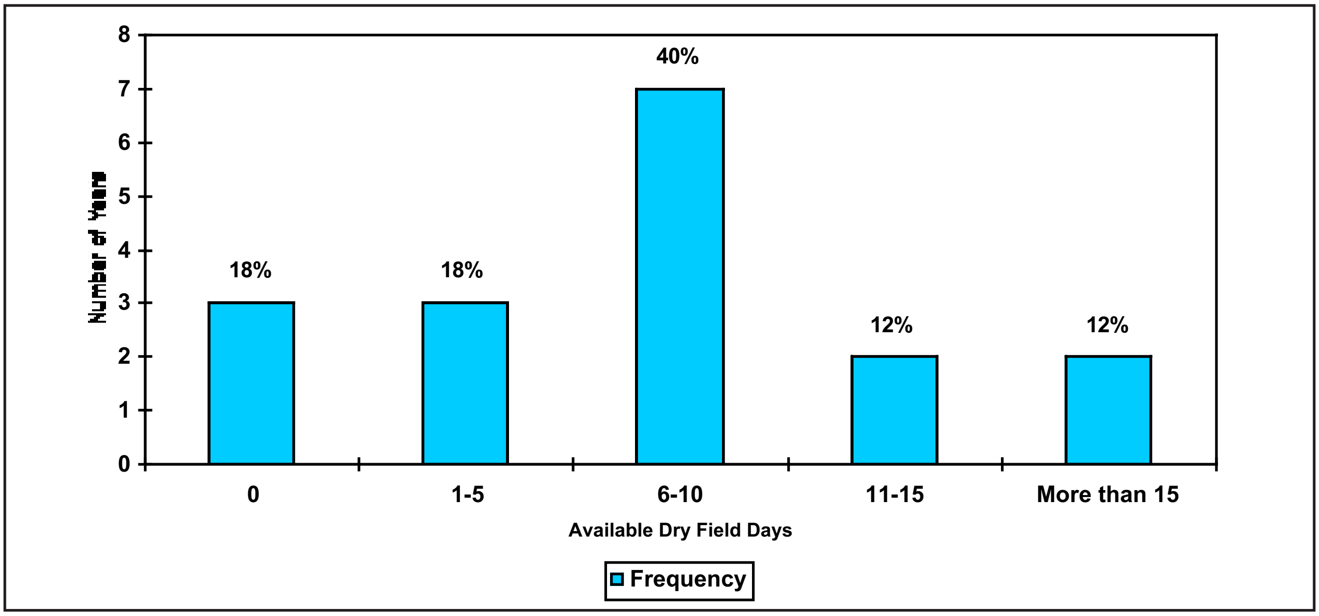


Figure 10. Esimated number of October days a field would be at 75% or less field capacity during the 17 years manure would be spread in a 50-year crop rotation simulation.

Northeast Missouri 1,500-Sow (MDNR Class IB) Representative Hog Farm

Farm Description

In early 2000, FAPRI started modeling a large MDNR Class IB 1,500-sow representative hog farm in the Central Claypan Major Land Resources Area (MLRA 113) in northeast Missouri for the land application of lagoon water. Confined animal feeding operations (CAFO) of this size typically have a large lagoon system to contain treated animal manure, urine, and wash water for future land application. Again, a specific geographic location with fields is modeled to account for physical characteristics of soil map units, slope, drainage ways, and terraces on the representative farm (Figure 11). The farm consists of 980 acres of cropland in a corn-soybean (C-B) rotation.

Concern

The primary concern of this study is the management of the environmental fate of nutrients, both man-made and animal manure (liquid and solid). This includes land applications of manure for nutrient recycling.

Objectives

The objectives of this study are to evaluate

- current nutrient management and
- how this size operation could adjust to more stringent phosphorus based regulations.

Land Management

The baseline representative farm under development will use custom application through a traveling gun at 16,293 gal/ac of lagoon water on fields 2 and 3. The farm's location demonstrates many of the challenges that swine producers in this operation class will face if more restrictive phosphorus-based regulations are adopted by MDNR. To expand the area to which lagoon water is applied requires additional pipelines. Public roads must be crossed to access fields 4 and 5 and streams crossed for access to fields north of fields 6–12. There are extensive containment requirements for lagoon effluent crossing public roads and streams. Utilizing smaller fields and steeper fields with conservation practices, such as terraces or contours, increases costs and application constraints.

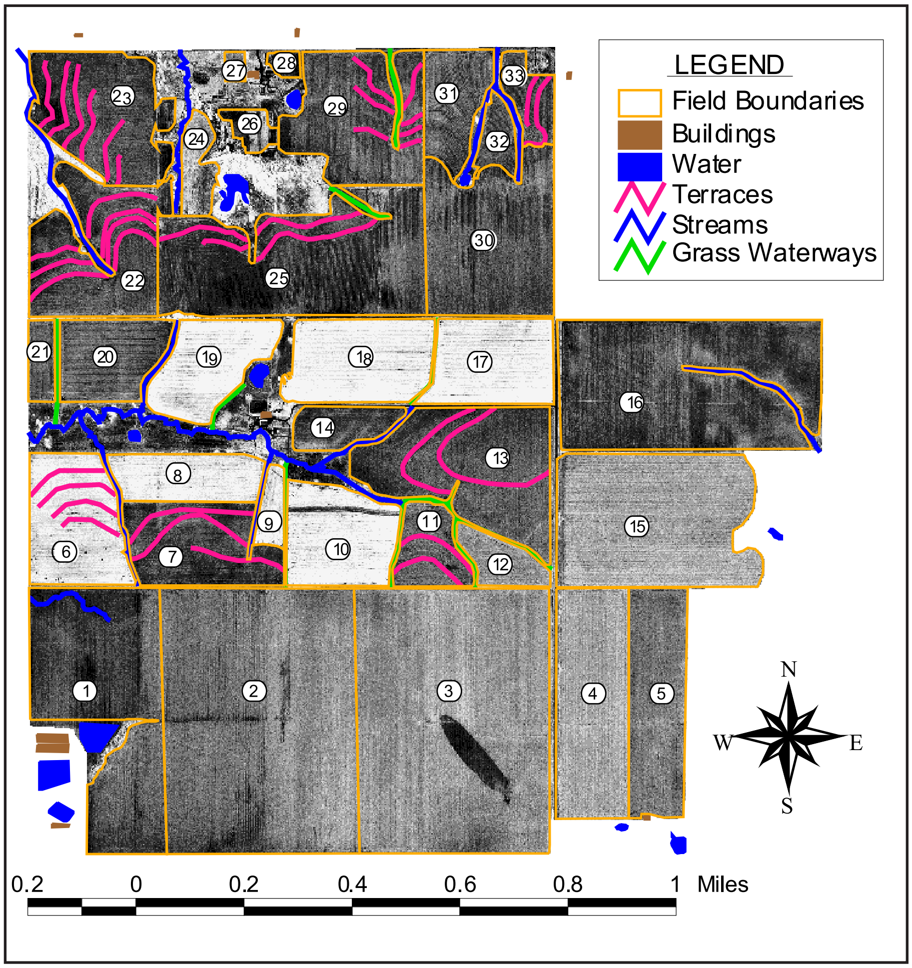


Figure 11. Distribution of fields modeled for the Northeast Missouri 1,500-Sow Representative Hog Farm.

This hog operation is nearly 10 times larger than the 160-sow operation and is primarily concerned with producing pork. Grain production is a secondary, if not a separate, management function. This representative farm has fewer cropland acres than the 160-sow representative farm, leaving fewer acres available to recycle nutrients.

The farming operation is entered into a GIS system where buffer restrictions (setbacks from streams, waterways, public use areas, etc.) can be calculated to demonstrate the loss of spreadable acres. This is an ongoing study and more findings will be released as modeling efforts continue.

Preliminary Results

The results presented are preliminary and subject to change. Because the input data (crop and manure management) has not been finalized with the farm panel, the final results may appear very different if changes are made in the management details.

Current crop management does not apply additional commercial phosphorus to the fields (with or without manure applied). The management on the farm is split between manure applied on fields 2 and 3, and no manure applied on all other fields. Fields 1, 4, and 5 (no manure applied) were compared against fields 2 and 3 with manure applied. The current scenario applies just enough phosphorus through manure to meet plant uptake throughout the 50-year time frame (Figure 12) and there is no phosphorus buildup in the upper 6 inches of soil. Modeling results indicate that there is not an immediate concern with phosphorus in land applications. The model estimates less than 0.5 lb/ac of soluble phosphorus moving with surface water runoff, leaching below the root zone, or moving with sediment.

Conclusions

Phosphorus movements on this farm are much smaller than in the broiler studies. However, there is a long-term problematic concern with the build up of phosphorus in the lagoon, and the management of this phosphorus will be a problem that will have to be dealt with at a latter date. Because the lagoons are not agitated prior to pumping, which would mix more nutrients into the slurry, most of the phosphorus generated by this hog operation ends up in the bottom of the lagoon. Therefore, minimal phosphorus is being applied. If lagoon agitation were adopted, careful soil testing and nutrient management would be necessary.

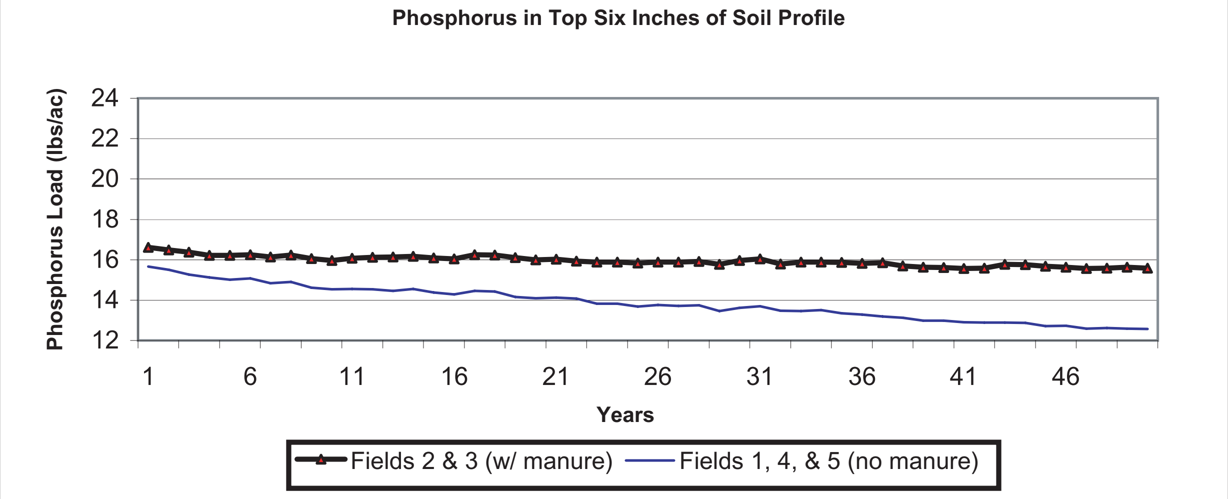
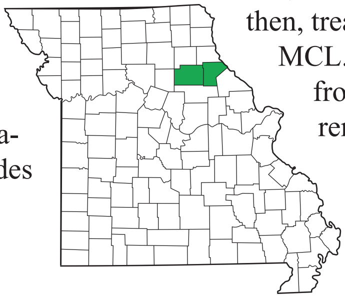


Figure 12. Estimated phosphorus movements in the upper 6 inches of soil under two management scenarios on the Northeast Missouri 1,500-Sow Representative Hog Farm.

Monroe City Route J Watershed

Watershed Description

The Monroe City Route J Watershed is located in northeast Missouri in Ralls and Monroe counties and is part of the Central Claypan Major Land Resource Area 113 (Figure 13). The watershed, encompassing approximately 5000 acres, is primarily agricultural with 65% cropland, 16% grassland, 17% forest, and 2% water.



Feed grain production with some cattle are the primary agricultural operations in the watershed. This study includes farm level and watershed level analyses.

With 95 surface acres, the Route J Reservoir is the largest of Monroe City's three reservoirs. It is used as a drinking water supply and for recreational fishing. The watershed is surrounded by moderately steep to steep wooded slopes.

Concern

High levels of atrazine have been detected in Monroe City's water supply, which also supplies water to three rural districts. On three dates in 1994, treated water exceeded the MCL of 3.0 ppb set by EPA, thereby requiring remedial action. Since then, treated water samples have been below the MCL. However, raw water levels have ranged from 1.5 to 17 ppb, thus the watershed remains on Missouri's 303(d) list in 1998.

Objective

MDNR and EPA commissioned FAPRI to evaluate

- alternative crop production practices that might reduce atrazine runoff, and
- the potential impact of alternative managements on water quality.

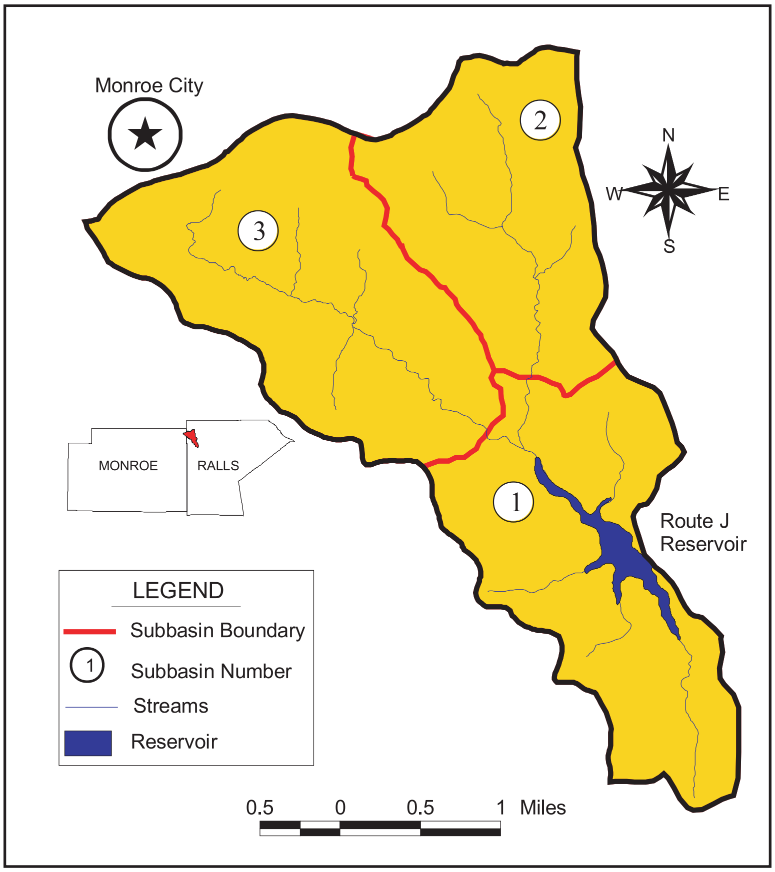


Figure 13. Subbasins in the Monroe City Route J Watershed.

Land Management

Farm level modeling for this analysis started in 1997, with a final report out in 1999. A 1,220-acre representative farm with four crop rotations (corn-soybean-wheat, corn-soybean-soybean, corn-soybean-corn-soybean-wheat, and corn-soybean-wheat-double crop soybean) and four soil map units (Putnam silt loam, 1% slope; Mexico [Adco] silty clay loam, 2% slope; Mexico silty clay loam, eroded, 3% slope; and Leonard silt loam, 5% slope) was modeled. Putnam soils dominated, underlying 55% of the cropland. Alternative pesticide managements proposed by the farm panel involved shifting from cyanazine and atrazine to metolachlor and atrazine.

In 1998, additional information needed for the watershed analysis was gathered from cooperating agencies, including NRCS and FSA. Historical (1993–1997) average crop acreages within the watershed were determined and divided among five common rotations: corn-soybean, corn-soybean-soybean-wheat, corn-soybean-wheat-soybean, corn-soybean-wheat, and corn-

Table 2. Alternatives evaluated in the Route J Watershed.

	Management Scenario	Atrazine (lbs ai/ac)
Baseline	1993-1997 crop history	1.54
1	Revised baseline - Reduced wheat	1.54
2	One-pass - Axiom® and atrazine	1.00
3	Two-pass - Dual II Magnum®; Liberty ATZ® and atrazine	1.06
4	Two-pass - Frontier®; Clarity® and atrazine	1.00

soybean-soybean-wheat-soybean. Soils were similar to the farm level analysis with the addition of an Armstrong loam, eroded, 7% slope soil map unit. Baseline crop management assumed all corn acreage received 1.54 lbs ai/ac of atrazine (Table 2). In alternative 1, crop distributions were updated with 1999 data to reflect reduced wheat acreage driven by falling wheat prices and the U.S. Federal Agriculture Improvement and Reform Act, while pesticide management was held constant.

Alternatives 2–4 involved reducing per acre atrazine application by one-third and delaying application. These three alternatives were a subset of the Atrazine Management and Abatement Project, a cooperative effort between the Monroe City Water Resources and Steering Committee, NRCS, University of Missouri Outreach and Extension, MDNR, and chemical manufacturers.

Results

At the farm level, alternative crop production practices included the elimination of cyanazine and a reduction in the rate of atrazine applied. Reduced application rates resulted in reduced rates of pesticide runoff. However, pesticide runoff was not necessarily greater on steeper slopes (Figure 14). Due to the claypan layer restricting percolation and water ponding on the surface layer, the Putnam soil map unit actually had higher rates of runoff than other soil map units with steeper slopes. Atrazine concentrated on the soil surface or in ponded water was more readily available for runoff in higher concentrations with successive rains.

Other farm level results of interest include

- soil erosion levels are lower than the soil loss tolerance values, although erosion values vary significantly by soil map unit,
- phosphorus losses total approximately 7 lbs/ac, with most moving with sediment, and
- nitrogen losses total approximately 28 lbs/ac, with 40% attached to the sediment and 60% moving in solution with runoff.

At the watershed level, atrazine loss ranged from an average of 15% under baseline conditions to 4% under the two-pass herbicide alternatives (Figure 15). Although each herbicide alternative reduced the amount of atrazine applied per acre by approximately 33%, timing of application had more influence on runoff than did the amount of atrazine applied. The two-pass alternatives, which applied atrazine post-emergence in June, showed the greatest reductions to the reservoir (Figure 16).

Other watershed level results of interest include the following.

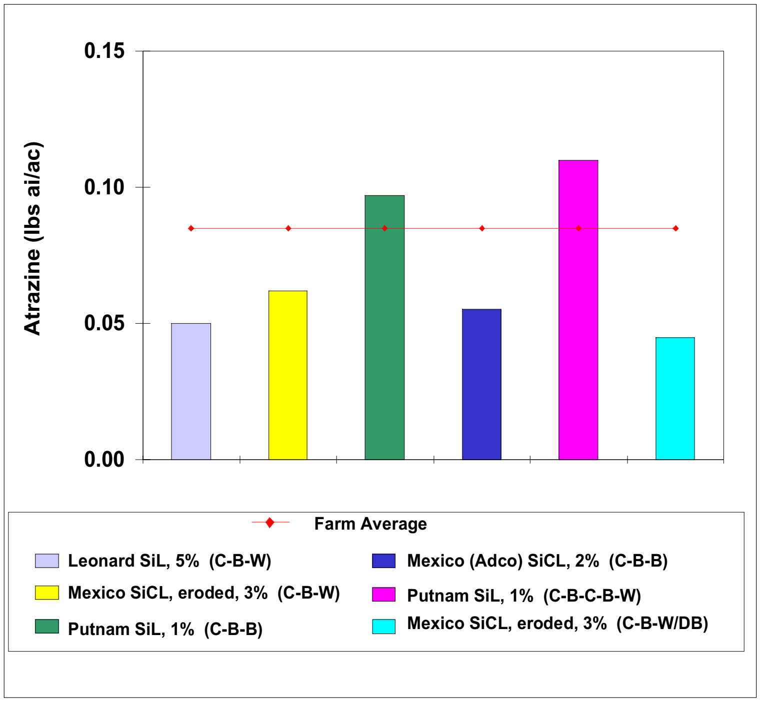


Figure 14. Estimated atrazine runoff by soil mapping unit in the Monroe City Representative Farm.

- Reduced wheat acreage resulted in more corn and soybeans being produced on steeper slopes, this increased erosion rates and atrazine runoff.
- Model results indicate steeper soils are more susceptible to erosion than flatter soils. However, as in the farm level results, flatter soils show higher levels of atrazine in runoff.
- The reservoir had increased sediment deposition under all the alternatives, especially during winter months when wheat would normally be grown on these fields. However, impairment from sheet and rill erosion remained relatively minor. Other potential sediment sources, such as gullies and road ditches, were not examined.

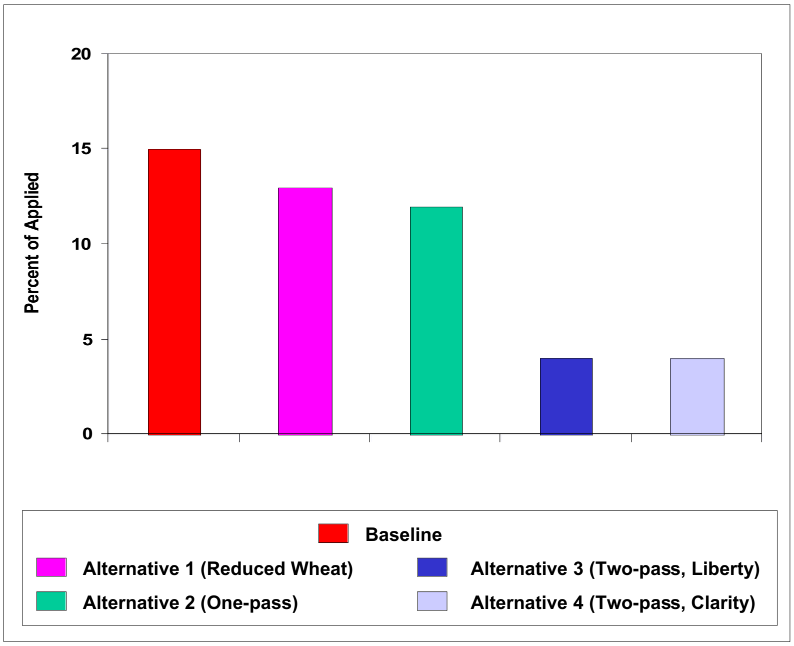


Figure 15. Estimated atrazine loss (percent of applied) under five corn management scenarios in the Monroe City Route J Watershed.

Conclusions

Applying less atrazine per acre resulted in less atrazine runoff. However, at both the farm and watershed levels, soil map units were important determinants in predicting atrazine runoff. Flatter soil map units with a shallow, dense claypan restricting percolation resulted in higher levels of atrazine in runoff than steeper soil map units.

At the watershed level, timing of atrazine application also was critical. Typically, atrazine is applied in May, the month with the highest amount and intensity of rainfall. By delaying application, producers avoid the worst precipitation events in most years. However, later applications may reduce the effectiveness of atrazine. Applied later, more atrazine is intercepted by the crop canopy where it degrades faster (half-life of 5 days compared to 60 days when applied to the soil). The increased degradation was a major contributor to the reduction in atrazine runoff.

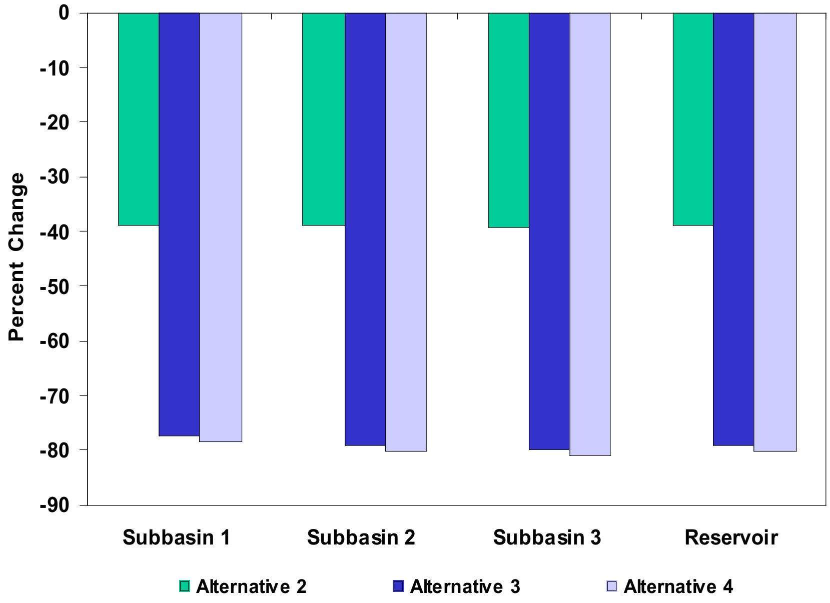
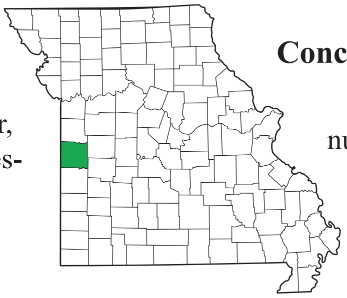


Figure 16. Estimated change in atrazine loading at the subbasin outlets and in the Route J reservoir under the three two-pass application alternatives for the Monroe City Route J Watershed.

Miami Creek Watershed

Watershed Description

The Miami Creek watershed comprises nearly 80,000 acres in Bates County in west central Missouri and is part of the Cherokee Prairie Major Land Resource Area 112 (Figure 17). Downstream recipients include the Marais des Cygnes River, Osage River, and the Harry S. Truman Reservoir. Land use is primarily agricultural with 23 % cropland, 66% grassland, and 11% forest.



It includes several hog, beef, and dairy animal feeding operations. The majority of cattle graze freely on pasture. Typically, cattle have unlimited access to streams and ponds.

Concern

High concentrations of atrazine and nutrients are found in Miami Creek, which is the primary source of drinking water for the city of Butler and five other rural water districts.

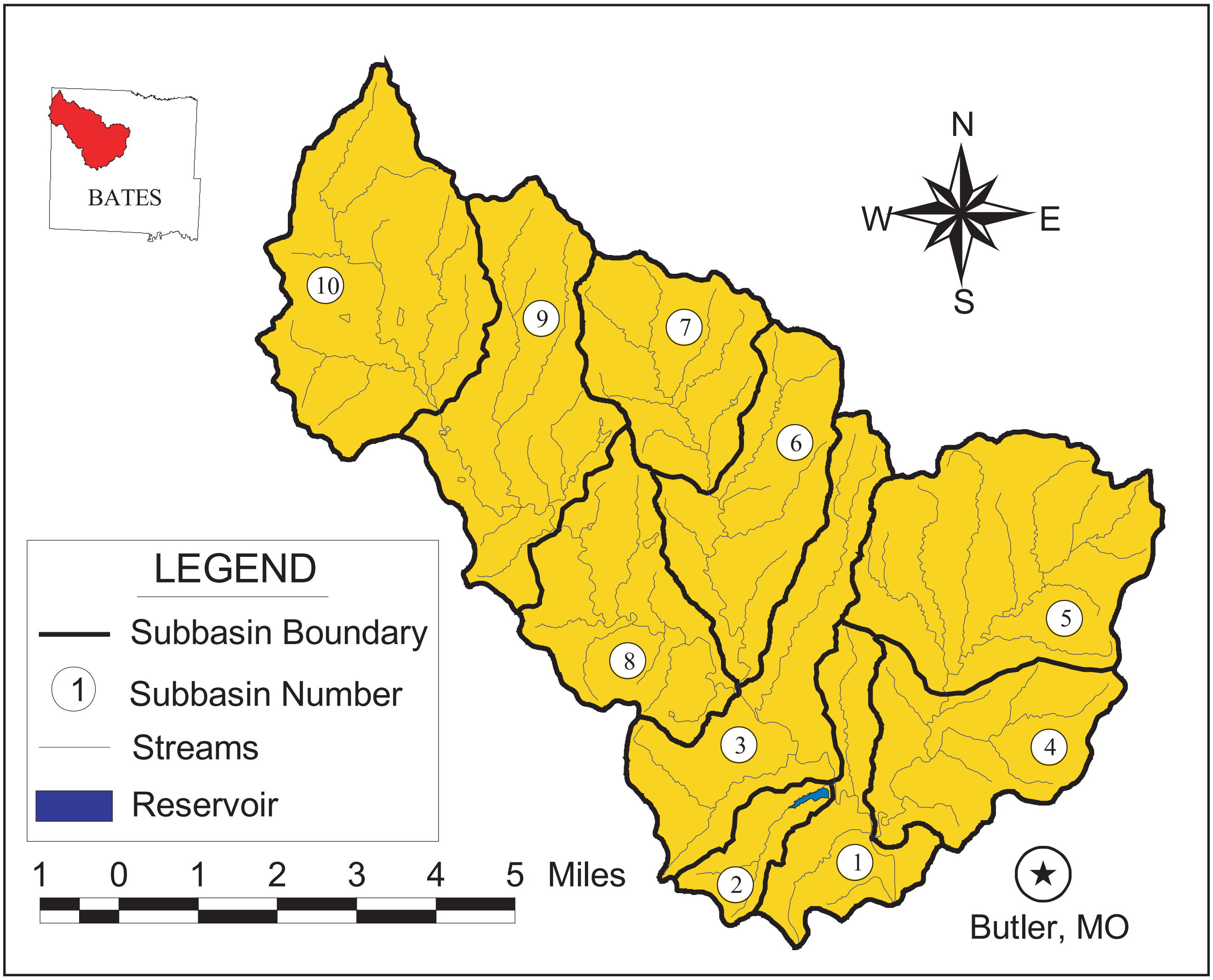


Figure 17. Subbasins in the Miami Creek Watershed.

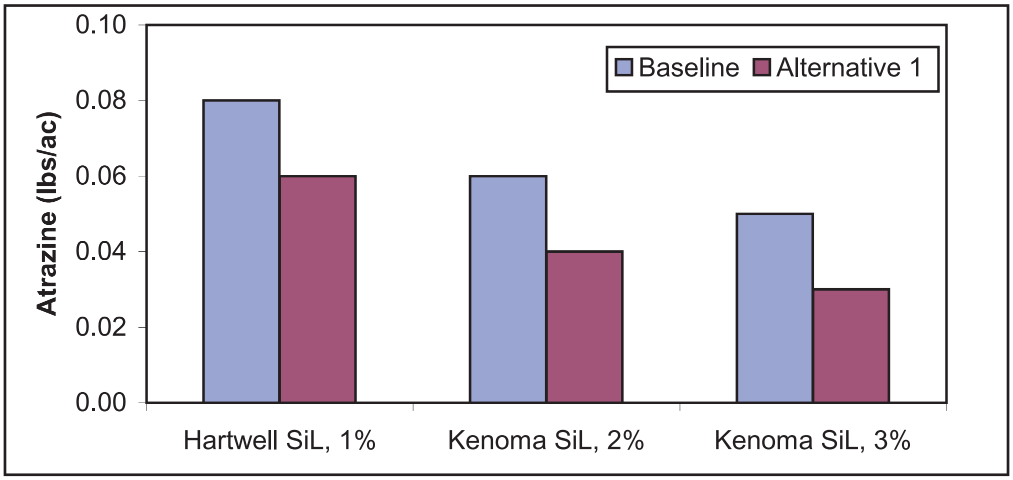


Figure 18. Estimated atrazine runoff by soil map unit under two management scenarios for the Miami Creek Representative Farm.

Objectives

MDNR and EPA commissioned FAPRI to evaluate

- alternative herbicide programs for their environmental impacts at the farm level, and
- the cumulative impact of decisions made at the farm level on the overall Miami Creek water quality.

Land Management

In 1997, a representative farm which included 1,005 cropland acres planted in two crop rotations: corn-soybean-wheat/double cropped soybeans and corn-soybean-wheat. Three soil map units were identified (Hartwell silt loam, 1% slope [Hartwell]; Kenoma silt loam, 2% slope [Kenoma 2%]; and Kenoma silt loam, 3% slope [Kenoma 3%]) with roughly one-third of the cropland acres on each soil map unit.

The farm's baseline management practices included applying atrazine at 1.8 lbs ai/ac. In alternative 1, the practices were updated to reflect the 1999 practices and included applying 0.9 lbs ai/ac of atrazine. In alternatives 2–4, the tillage operations were reduced progressively until a total no-till system was developed for alternative 4 (no atrazine applied). Alternative 5 was similar to alternative 1 except field cultivating replaced disking. Alternatives 1, 2, 3, and 5 assume the same atrazine application rate.

NRCS, FSA, and SWCD provided additional information about land uses and management that was not included in the representative farm but was represented at the watershed level.

Results

At the farm level, reduced atrazine application rates resulted in reduced atrazine runoff. This was found across all three soil map units (Figure 18). However, soil map units play an important role in determining the effectiveness of reduced atrazine rates. Given a 50% reduction in the amount of atrazine applied, the amount of atrazine in the runoff was reduced by 25% on Hartwell, 33% on Kenoma 2%, and 40% on Kenoma 3%. The lower reduction on Hartwell results from a clay-pan like layer that restricts water infiltration, leaving more atrazine on the soil surface to move with runoff events.

Other interesting results at the farm level show an inverse relationship between total phosphorus movement and the amount of tillage. In alternative 4 (no-till) phosphorus is not incorporated and application

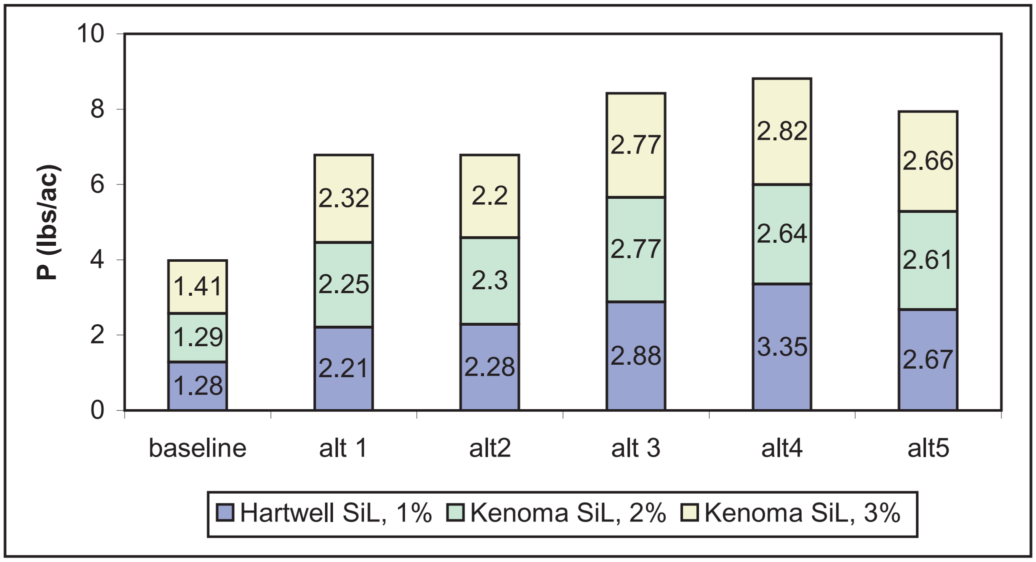


Figure 19. Estimated total phosphorus movement by management scenario on three soil map units for the Miami Creek Representative Farm.

rates exceed plant uptake, leaving excess phosphorus on the soil surface that is available to go into solution with surface water runoff. For all soil map units, alternatives with more tillage had less total phosphorus movement (Figure 19).

At the watershed level the analysis is ongoing, and only baseline (1999 management) results are reported. Monthly average atrazine concentration levels tend to peak above the EPA drinking water standard of 3 ppb in April (Figure 20). Concentrations during months

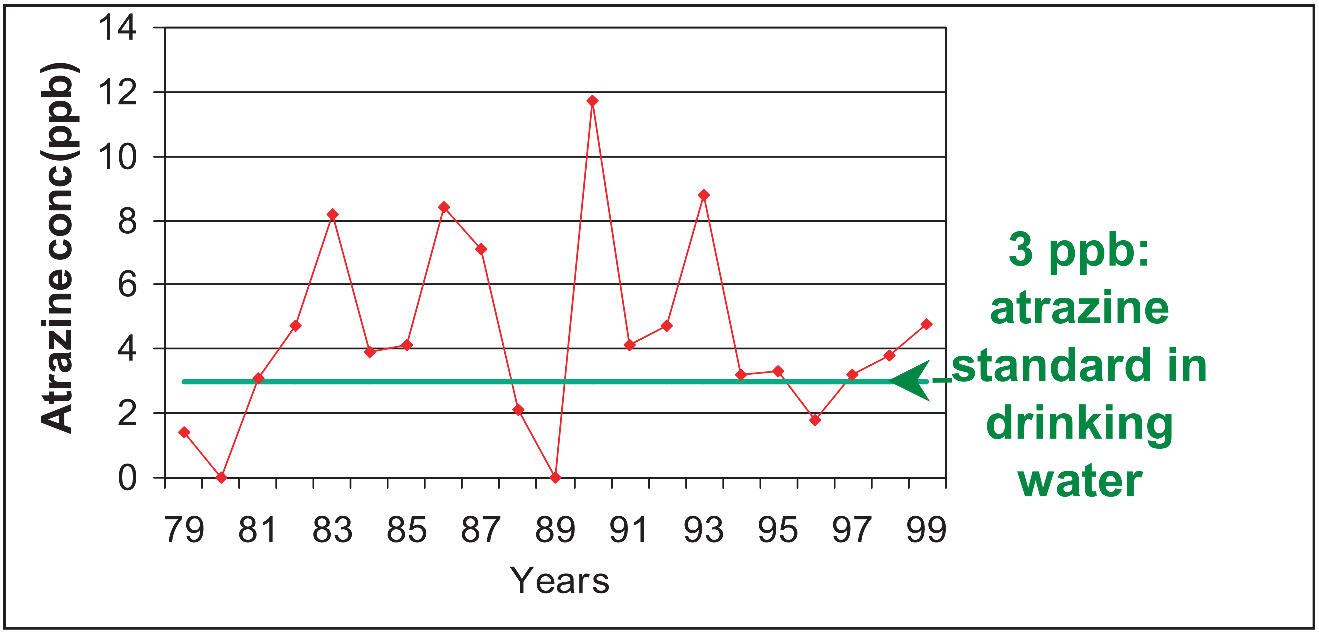


Figure 20. Estimated monthly average atrazine concentration in April at the Miami Creek Watershed outlet over the 21-year simulation.

other than April and May tend to be low. April is also the month that atrazine is applied and is most vulnerable to surface water runoff from spring rains. The percentage of time that concentrations exceed 3 ppb was calculated to be 15% in April, i.e. between 4 and 5 days on average (Figure 21). May has slightly less days with high concentrations (about 10% or 3 days on average), while June has less than 1% with high levels, i.e. 1 day every three years on average. Concentration levels exceed 70 ppb 3% of the time in April, i.e. 1 day on average during the month.

Conclusions

The Miami Creek project further demonstrates the relationship between the amount of pesticide applied and the total amount in surface water runoff. However, soil map units play an important role in the amount of pesticide that will move with surface water runoff. There is also a direct relationship between the acreage in crops with atrazine applied and the amount of atrazine at the outlet. Thus, as changes in policies affect the economics and crop distribution in a watershed, loadings of pesticides will also change.

Flatter soils with claypan or claypan-like sublayers, which restrict water percolation, may in fact have the highest levels of pesticides and nutrients moving with surface water runoff. The surface water, which tends to pond and move off very slowly, contains higher concentrations of pesticides and nutrients when it builds up on the soil surface and moves with large rainfall events. As a result, the loadings may be larger compared to the steeper soil map units which are thought to be more susceptible to pesticide and nutrient movement.

The farm level modeling indicates a potential for phosphorus buildup in the watershed's soil map units. Personal communication with Mr. Brad Powell (Bates County SWCD) has indicated that soil test results around the watershed show moderate to high levels of phosphorus.

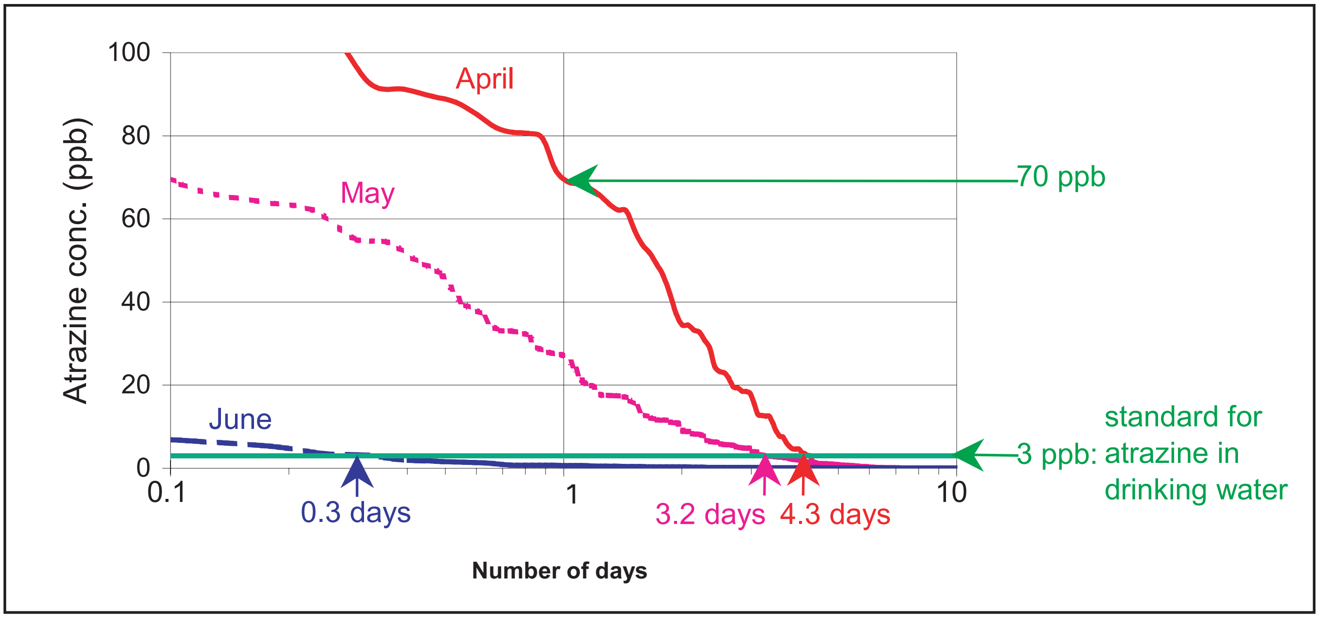
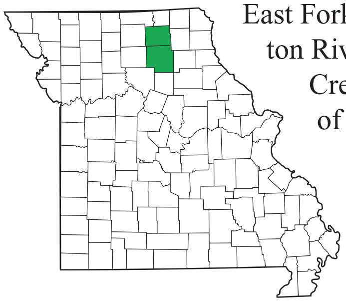


Figure 21. Estimated average number of days when atrazine concentration exceeds acceptable limits during April, May, and June at the Miami Creek Watershed outlet.

Long Branch Lake Watershed

Watershed Description

Long Branch Lake watershed comprises 66,400 acres in Macon and Adair counties in north central Missouri and is part of the Central Claypan Major Land Resorce Area 113 and the Central Mississippi Valley Wooded Slopes Major Land Resource Area 115 (Figure 22). The watershed is drained by the East Fork of the Little Chariton River and Long Branch Creek north of the City of Macon.



Long Branch Lake is 2,400 surface acres with multiple uses such as drinking water, boating, fishing, and swimming. The lake has a multiple purpose pool volume of 32,000 acre feet. The average annual rainfall (1978-1998) is 39.2 inches. The watershed is primarily agricultural with 29% cropland, 39% grassland, 27% forest, 4% water cover, and 1% urban.

Concern

Cyanazine, atrazine, and dissolved solids in the Long Branch Lake are of concern to the local community. Cyanazine detections have placed the lake on MDNR's 303(d) list. The mandatory phaseout of cyanazine use has reduced its presence in the lake; however, community concerns continue to focus on atrazine in the water supply. Also, sediment reaching the lake may contribute to the level of dissolved solids that have interfered with fish habitat and the water supply intake.

Objectives

FAPRI's role in this study was to

- analyze how current agricultural practices in the Long Branch Lake watershed affect the drinking water quality, especially with regard to atrazine and sediment, and
- identify the relative contribution of each subbasin to atrazine and sediment loading in Long Branch Lake.

Land Management

Land use distribution within the watershed subbasins is shown in Figure 23. The major crops planted in the watershed between 1994 and 1998 were corn (24%), soybeans (66%), and wheat (10%). No-till operations were predominant. The predominant active ingredients modeled were glyphosate @ 1.0 lb ai/ac

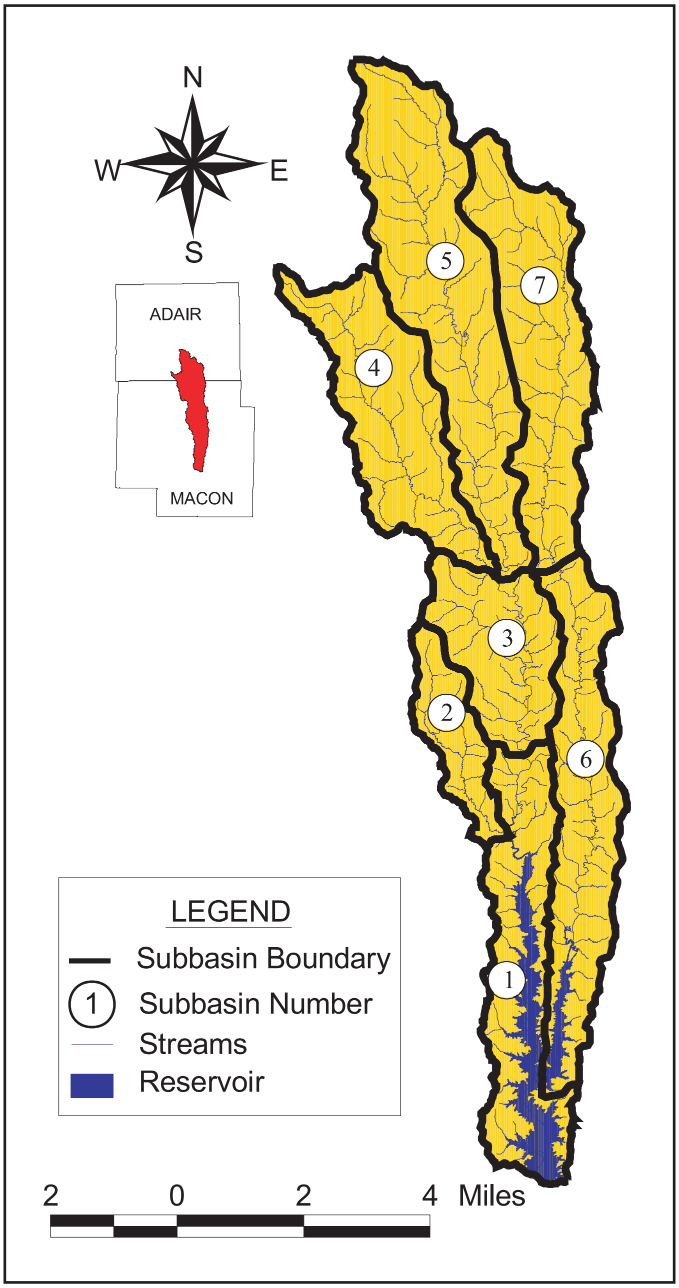


Figure 22. Subbasins in the Long Branch Lake Watershed.

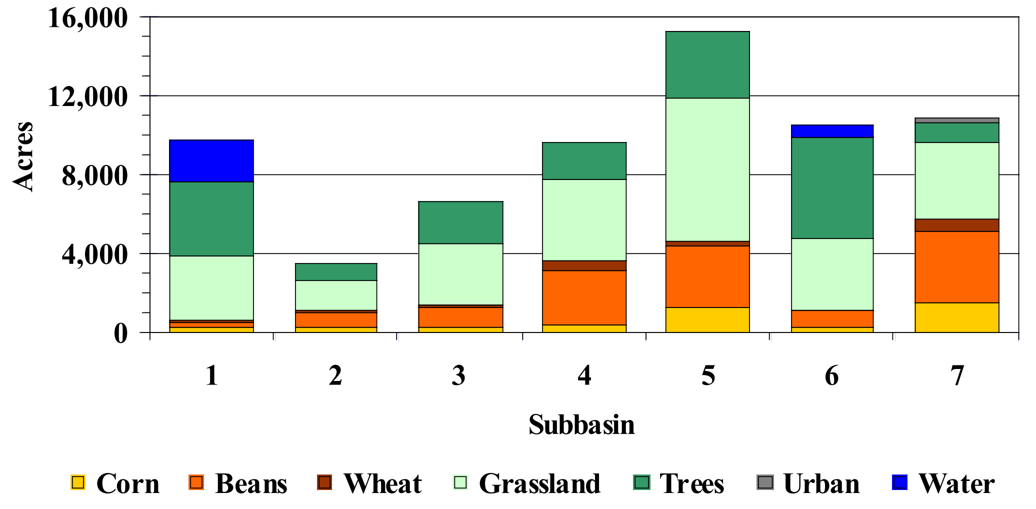


Figure 23. Land use in the subbasins of the Long Branch Lake Watershed.

(corn and soybeans), atrazine @ 2.02 lb ai/ac (corn only), and metolachlor @ 1.56 lb ai/ac (corn only).

Soil erosion and sediment yield are affected by soil and landscape factors such as slope, slope length, and erodibility, as well as by land cover management, conservation practices, and rainfall factors.

Land cover management (such as crop rotation and residue management) and conservation practices (such as terraces, contouring, buffer strips) have considerable impact on soil erosion. Some crop rotations, such as continuous soybeans, are particularly erosive. However, grassland (including hay, well managed pasture, CRP acres) generally has low erosion rates, as does forest cover. A high proportion of grassland and forest in an area, coupled with good conservation practices, will lead to a low overall sediment yield from the specific subbasins.

Results

Cropland has significantly higher erosion rates than non-cropland. Also, steeper soil slopes, as found in subbasin 1, contribute to high erosion rates.

High erosion rates lead to high sediment yields from a field. With greater non-crop acreage relative to crop acreage, subbasins 1 and 6 have lower overall sediment yield.

Estimated average annual sediment deposit in the lake from agricultural sources is 10 acre-feet/year (Figure 24). This is a fraction of the 50 acre-feet/year average reported by the

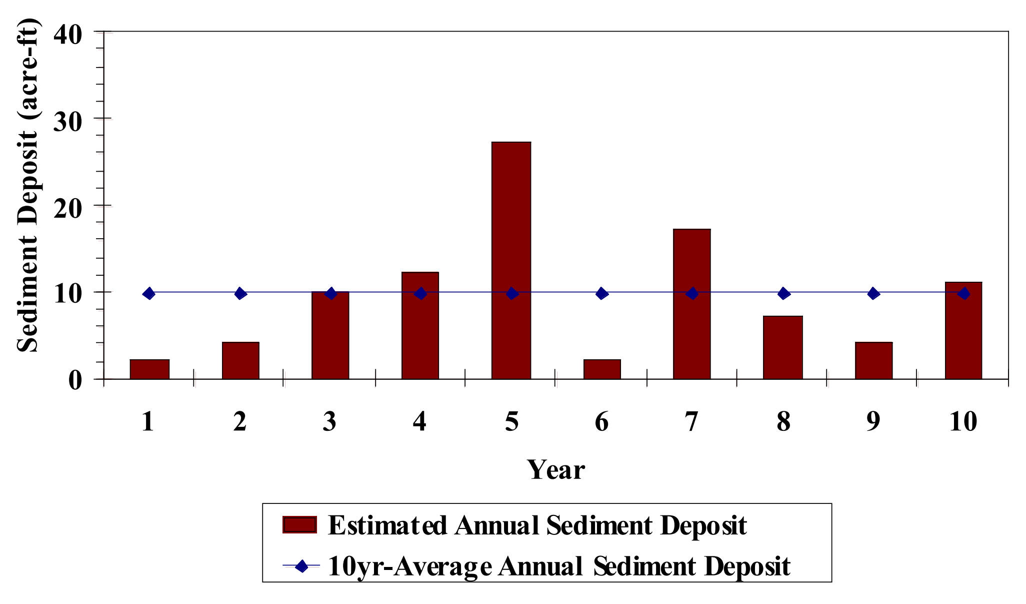


Figure 24. Estimated annual sediment deposit from agricultural sources in Long Branch Lake.

Army Corp of Engineers who measured sediment from all sources, including gully and shoreline erosion, stream bank degradation, and road ditches.

The average annual atrazine loss estimated as a percentage of total applied to the field was 12%, but ranged from 5 to 38%. The estimated percent atrazine loss was largely dependent on rainfall runoff near the time of application, with smaller variations for soil characteristics.

The quantity of atrazine lost from a subbasin was proportional to the corn acreage in that subbasin. Subbasins 5 and 7 combined had 63% of the corn acreage in the watershed, and accounted for 66% of the total estimated annual atrazine lost from crop fields.

Atrazine lost from fields varies considerably from year to year. The estimated atrazine load entering the lake, drinking water supply, is shown in Figure 25.

Conclusions

Model results show that management practices and additional conservation practices will reduce erosion rates on cropland, especially on steeper slopes near the lake.

According to model results, sheet and rill erosion from cropland contributes less than one-fourth of the sediment deposited annually in the lake.

Total atrazine loss is proportional to corn and sorghum acreage. Total atrazine loss can be reduced by various means, including reduction in atrazine application rates, substitution of alternative pesticides, careful attention to the weather conditions when applying atrazine, and reduction in corn and sorghum acreage utilizing atrazine.

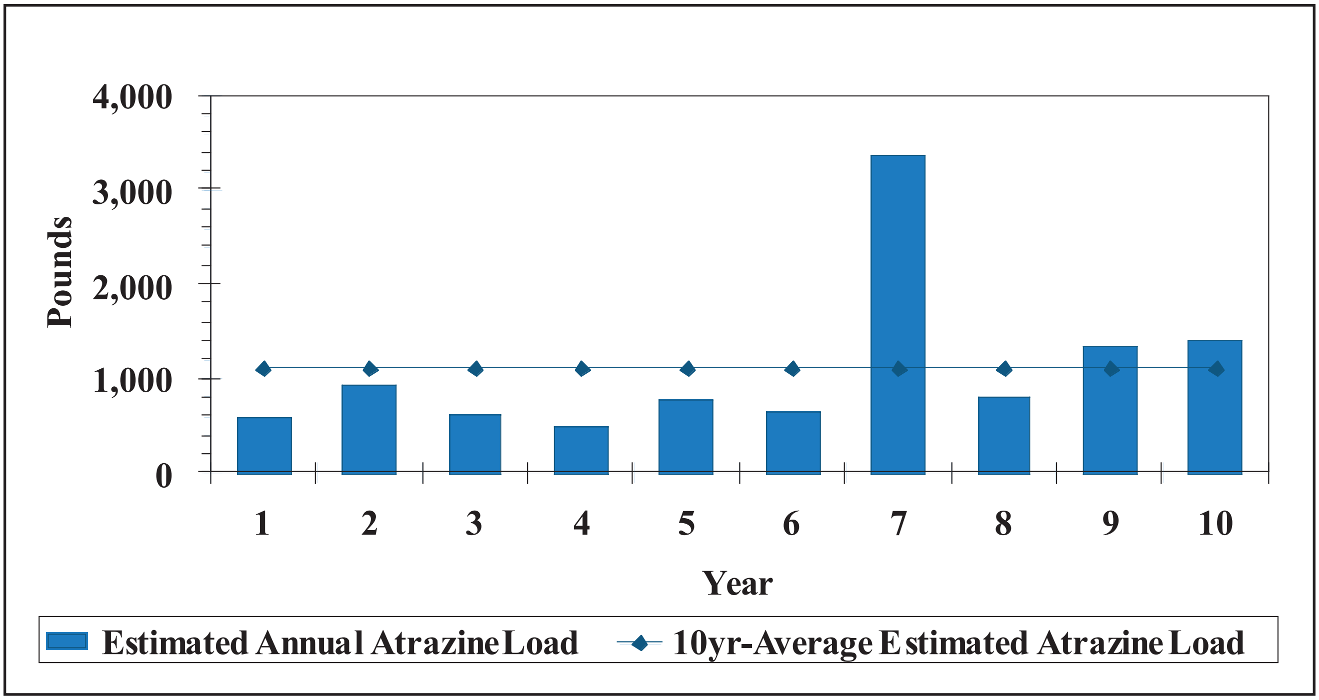


Figure 25. Estimated annual atrazine loading to Long Branch Lake.