East Fork Little Miami River Watershed

1997 Land Use and Chemical Application Analysis

May 1999

THE OHIO STATE UNIVERSITY EXTENSION

Clermont S.W.C.D. Soil & Water Conservation District

ACKNOWLEDGMENTS

Ohio State University Extension acknowledges the invaluable assistance provided by the Clermont Soil & Water Conservation District in the preparation of this report. Without the expertise, advise and long hours provided by Clermont SWCD, and in particular District Technician Steve Rismiller, the dramatic graphic representation and GIS analysis of land use within the East Fork Little Miami River Watershed would not have been possible.

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SECTION I INTRODUCTION

The East Fork Little Miami River (EFLMR) watershed encompasses nearly 320,000 acres in Southwestern Ohio and includes portions of five Counties: Brown, Clermont, Clinton, Highland and Warren. With 155,384 acres of the EFLMR watershed, Clermont County contains nearly half (48.6 percent) of the total 319,482 acres.

Within the watershed there exists a broad range of land uses ranging from heavily suburbanized areas in the lower (southwestern) portion to nearly exclusive agriculture in the headwater areas. Nearly 21 percent, or 65,761 acres, are in woodlands with the greatest concentration being located within the East Fork State Park in Clermont County.

Section I.1 Background

During February 1998, Ohio State University Extension contracted with the Clermont County Board of Commissioners to conduct a detailed land use and chemical application analysis within the EFLMR watershed for calender year 1997. This analysis focused on agriculture, horticulture, and highway/infrastructure land uses and the various chemical application practices associated with each.

The project was conducted using a variety of methods and available technologies. Numerous mail, telephone, and in-person surveys were used to develop data related to chemical application practices within the watershed. A highly detailed land use analysis was accomplished using ortho-photo quarter quadrangle maps, 1997 Farm Service Agency (FSA) aerial photography, land use maps, surveys and site visits. These land use classifications are entered into an ArcView 3.0a. data base for further analysis and display.

Section I.2 Agriculture

For the purposes of this study, agricultural land use includes corn, forages, forest, soybean, tobacco and wheat. During 1997, agricultural land use accounted for 224,063 acres, or 70.2 percent of the EFLMR watershed. Non-agricultural land uses include residential, commercial, industrial, infrastructure, and waterways. These land uses totaled 95,419 acres or 29.8 percent of the watershed.

Each agricultural field within the watershed with an area greater than or equal to one acre was examined using aerial photography, delineated and catalogued on a corresponding quarter quadrangle map, then digitized into ArcView 3.0a. Through an examination of the aerial photography, and survey results where applicable, crop determinations were made. This process is further described in Section II.1.

Section I.3 Horticulture

Due to the nature of many of the commercial horticulture operations, a different approach to mapping was taken. Rather than describing the total land area devoted to horticulture, the specific location of horticultural operations within the EFLMR watershed are identified in Section II.2. Chemical application practices were determined through various survey techniques.

Residential horticulture practices were determined through a comprehensive survey of home owners and commercial lawn care companies. Residential horticulture practices are divided into six classifications depending on lot size as described in Section II.2.d.

Section I.4 Highway/Infrastructure

For the purpose of this study, highway and infrastructure land use are defined as federal, state and local roadways, utility right-of-way easements, and railroads. State and local highway departments, utility companies, and railroads were surveyed to determine chemical application practices which are used for maintenance of right-of-way and snow/ice removal. The results of these surveys are discussed in Section II.3.

Section I.5 Chemical Use Analysis

Chemical use estimates for the entire EFLMR watershed were developed based upon data received through survey responses, vendor information, university research, and other published literature. Methodology, extrapolation, and analyses are described in detail in Section II.4.

Section I.6 Clermont County

As described earlier in this section, 48.6 percent of the EFLMR watershed is located within Clermont County. Another way of examining the importance of land use in Clermont County to the watershed is to recognize that 53 percent of Clermont County's total 293,295 acres are in the watershed. Clearly the relationship between land use in Clermont County and water quality within the watershed is significant. For that reason, this report provides a separate section that examines the issues described above within the context of Clermont County. This section, along with the corresponding maps and data, is designed to stand alone if necessary to allow examination and manipulation of the data to meet the unique needs of Clermont County citizens and officials.

SECTION II EAST FORK LITTLE MIAMI RIVER WATERSHED

The EFLMR watershed totals 319,482 acres and covers parts of Brown, Clermont, Clinton, Highland, and Warren Counties in Southwestern Ohio. This section describes land use management and chemical application practices associated with agriculture, horticulture, and infrastructure within the entire watershed.

Section II.1 Agricultural Land Use

An analysis of agricultural land use to include the amount and type of fertilizer and chemical compounds used in the EFLMR watershed was accomplished using several methods.

Electronic and mylar maps of the watershed were provided to Ohio State University Extension by the county's consultant, Tetra Tech. These maps contained two basic types of information. The maps divided the watershed into 51 square segments that were 3'45" x 3'45" degrees in size. Twenty of 3'45" x 3'45" degree map segments contained only rough land use information while the other 31 segments provided ortho-photo data. The land use maps identified major roads and streams but were void of any other clear land features. The ortho-photo maps were clear pictures of the land as seen at the time that the photo was obtained.

The Farm Service Agency (FSA) offices in the five counties within the watershed were contacted to obtain 1997 aerial photographs of the watershed. These photos provided information related to the specific land use application for 1997 and were readily available. The agricultural land use categories identified are corn, forage, forest, soybean, tobacco, and wheat. The determination of land use was made by viewing individual slides. The photos were taken in sequence along a flight line. Several flight lines were required over each county to provide coverage for the acreage of the watershed contained in that county. There exists a degree of overlap from slide to slide going north to south and east to west. The slides were viewed in sequence and selected based on their alignment with the various map segments. Agricultural land use for the entire watershed was determined in this fashion.

Certain land uses such as forages and forestry were relatively easy to identify. Other land uses were more difficult. Distinguishing between corn and soybean presented the most challenge. The decision to designate a field as corn or soybean was based upon varying shades of green. Corn fields would appear as dark green on the photo while the soybeans would appear as various shades of light green. Responses from the agricultural survey were also used to verify aerial photo interpretation. The wheat field appeared barren due to the July harvest and a delay in planting double crop soybeans. The tobacco fields were small, definitive areas located in certain parts of the watershed.

Another challenge was the degree to which the slides would vary in clarity even in the same flight line. In one slide a field would appear as light green while in the next slide the same field would appear much darker. Distinguishing at this point was based on shades of greens and a comparison of surrounding fields in both slides. The quality of the slides also varied a great deal. Due to over-exposure, some slides were not clear and determining any difference in shades of green was very difficult.

The maps which were land use based and not ortho based also presented a significant challenge. The first attempt to map the cropping pattern in those areas where only land use data were available consisted of viewing the slides for that area and locating the major roads, streams, and other landmarks then locating these features on the provided maps. These land use maps were limited in the details provided. A few major roads and streams were shown on an otherwise blank sheet. By locating road intersections, road and stream intersections, and sharp turns in the road(s) on the land use map and finding the corresponding locations on the slides, fields were estimated then drawn in free hand. A planimeter instrument was used for determining acreage.

After consulting with representatives from the county, it was determined that in order to provide a higher degree of accuracy, a second mapping of these areas was necessary. The individual Farm Service Agency offices provided maps for their respective counties. The age of these maps varied from 1982 to 1988. These FSA maps measure two feet by two feet in size. These maps were individually copied onto several sheets that were taped together to form a copy of the original map. This process was complicated due to overlaps on each side of the map and differences in photo projections between the FSA maps with the ones provided by Tetra Tech. The area covered by the FSA maps were also much smaller then the Tetra Tech maps. It required parts of six FSA's maps to correspond to one of the Tetra Tech maps. Due to the alignment problem, there were a mixing and matching of the FSA maps such that the Tetra Tech maps could be covered. Creating a photo-based map that corresponded to the quad maps provided by Tetra Tech was a very time consuming process.

After these newly created photo-based maps had been taped together, a second land use mapping was performed. This involved reviewing the slides from Brown, Clinton, Warren and Highland Counties. Outlining and labeling of the maps was then performed. These maps were then provided to the Clermont Soil & Water Conservation District for digitizing.

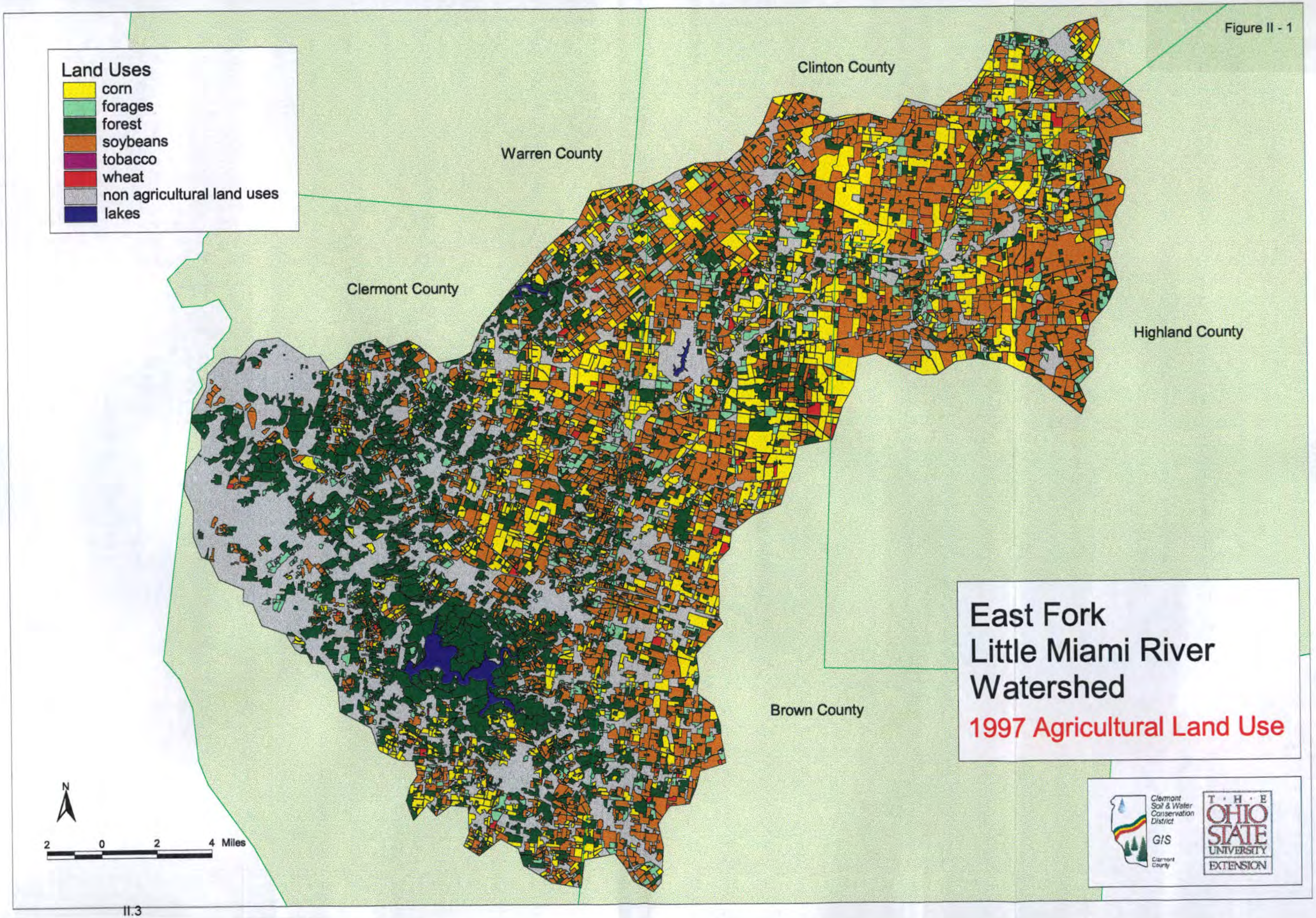
Agriculture, including forests, represents the primary land use within the 319,482 acre watershed. Production agricultural acreage totals 158,300 or 49.5 percent of the watershed. Forest covers another 65,761 acres or 21 percent. A summary of the agricultural mapping is found in Figures 11-1 through 11-10.

Table II.1 shows agriculture land use to include acres, and percent of watershed.

Table II.1 1997 Agricultural Land Use

Land Usage	Acreage	Percentage
Corn	47,779	15.0%
Soybean	88,729	27.8%
Wheat	2,557	0.8%
Forages	19,175	6.0%
Tobacco	60	0.02%
Forest	65,762	20.6%
Non-Agri.	95,420	29.87%
Total	**319,482**	**100%**

Figure II - 1



East Fork
Little Miami River
Watershed
1997 Agricultural Land Use

Agricultural Land Use By County

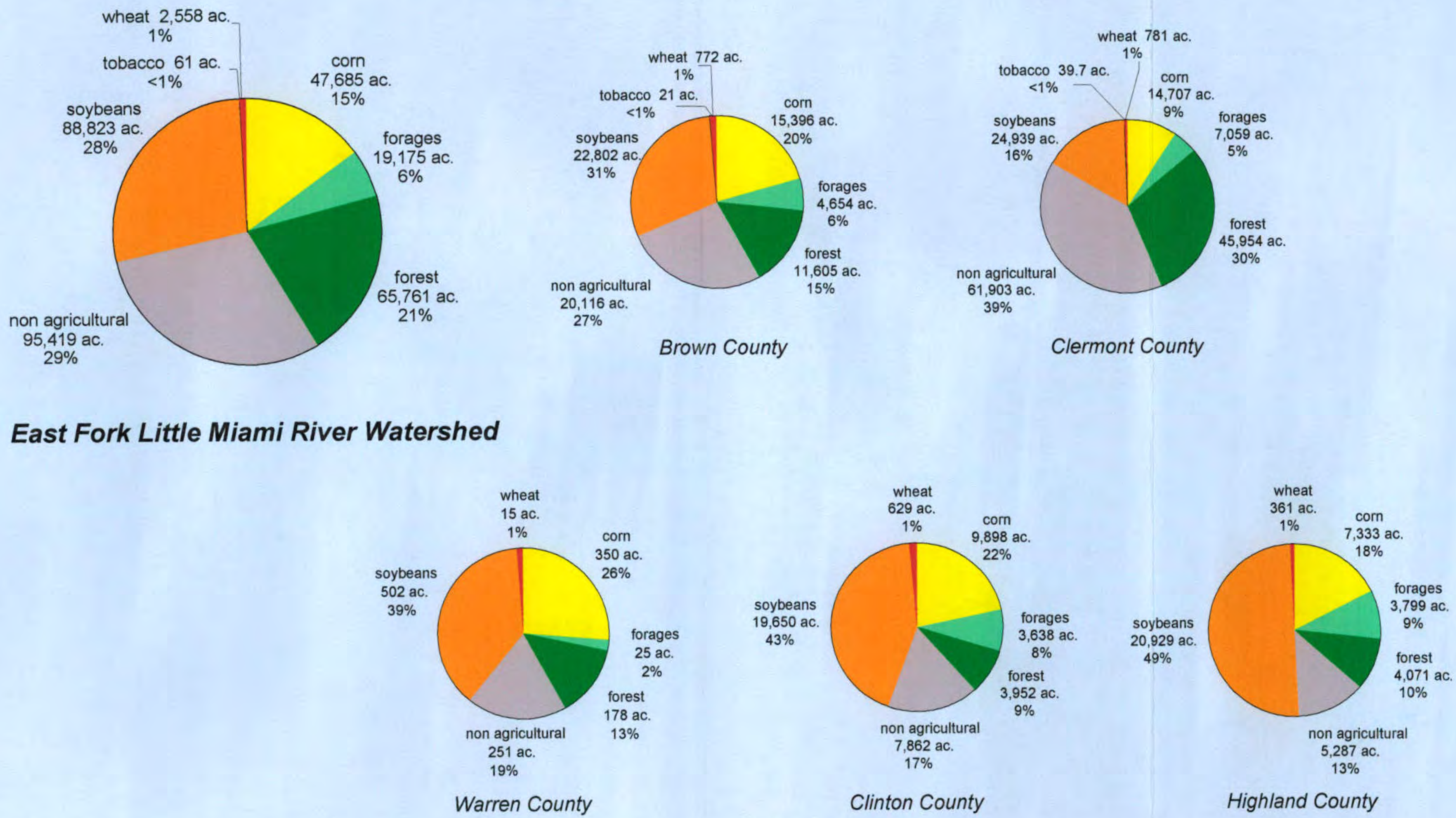
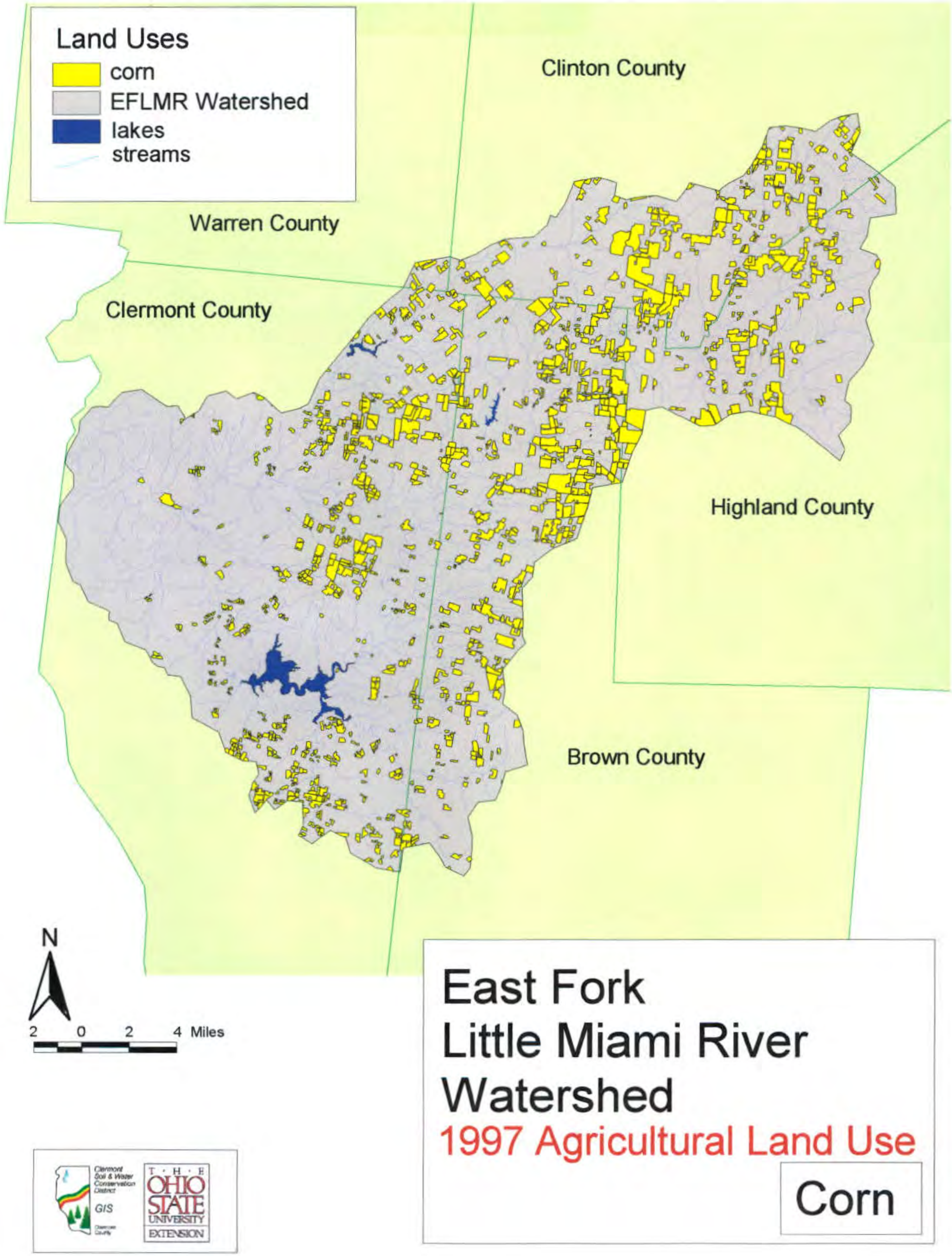


Figure II - 3


Land Uses
corn
EFLMR Watershed
lakes
streams
Clinton County
Warren County
Clermont County
Highland County
Brown County
N
2 0 2 4 Miles
East Fork
Little Miami River
Watershed
1997 Agricultural Land Use
Corn

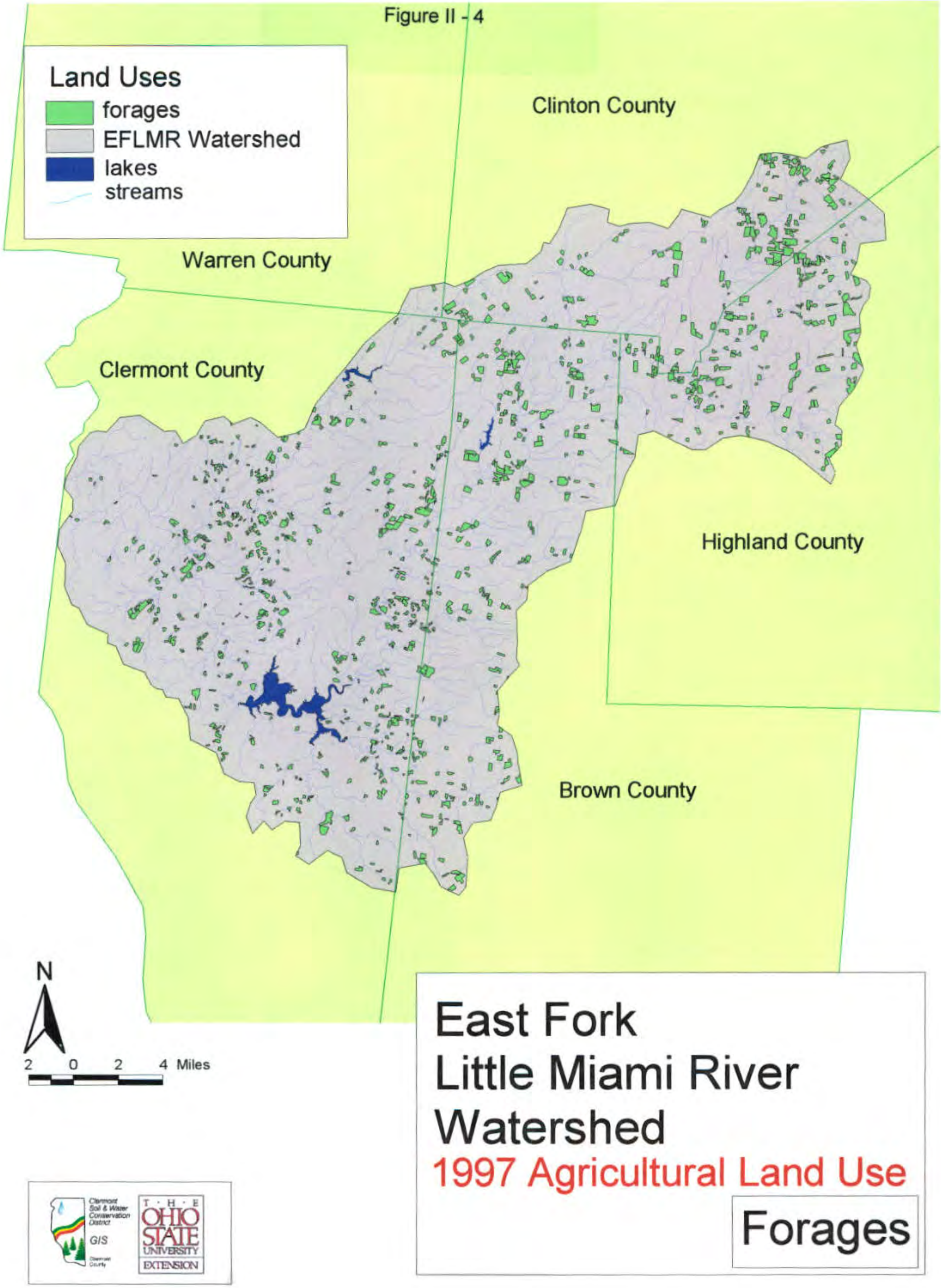
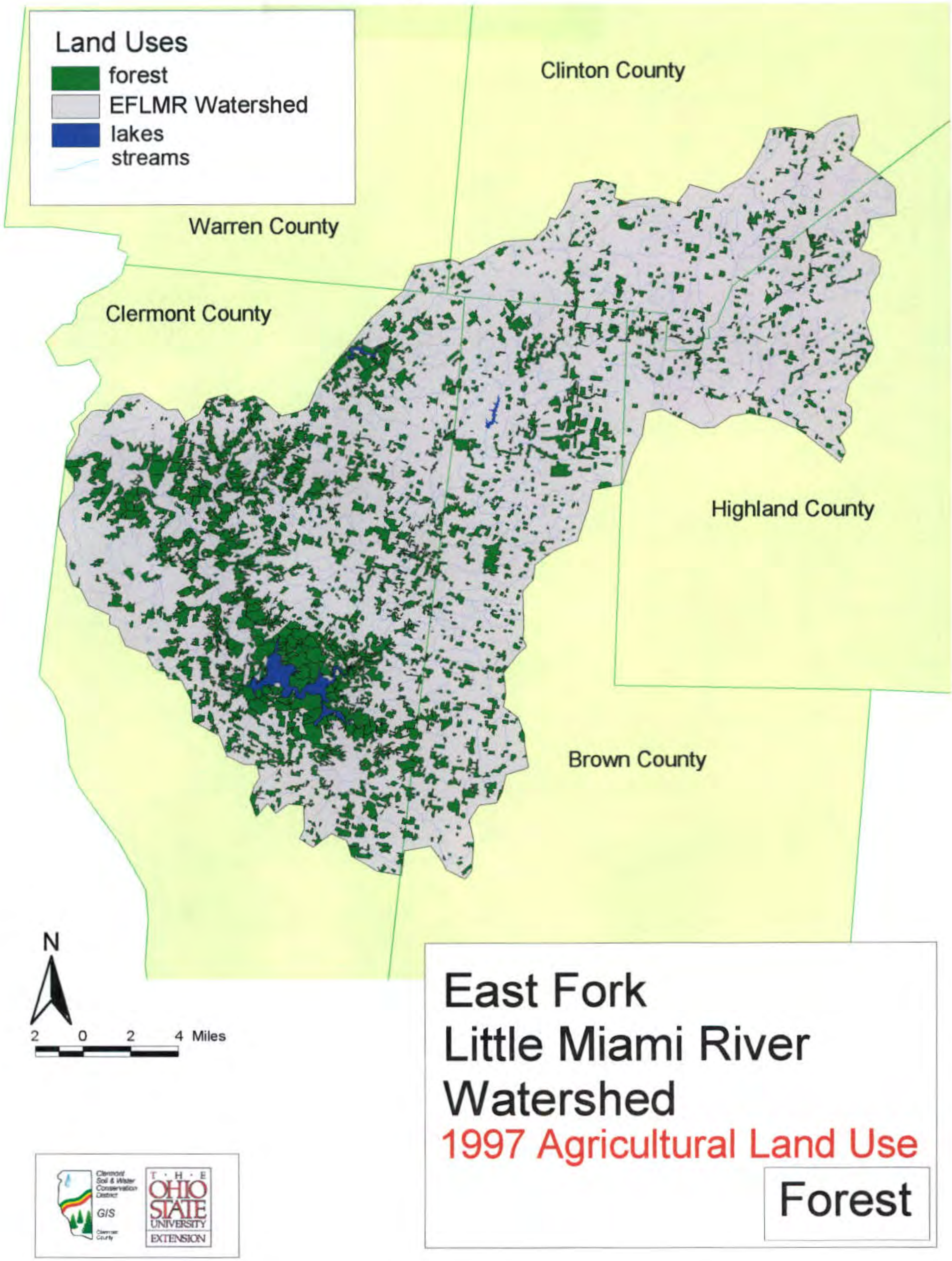


Figure II - 4
Land Uses
forages
EFLMR Watershed
lakes
streams
Clinton County
Warren County
Clermont County
Highland County
Brown County
N
2 0 2 4 Miles
East Fork
Little Miami River
Watershed
1997 Agricultural Land Use
Forages

Figure II - 5



Land Uses
forest
EFLMR Watershed
lakes
streams
Clinton County
Warren County
Clermont County
Highland County
Brown County
N
2 0 2 4 Miles
East Fork
Little Miami River
Watershed
1997 Agricultural Land Use
Forest
GIS
OHIO STATE UNIVERSITY
EXTENSION

Figure II - 6

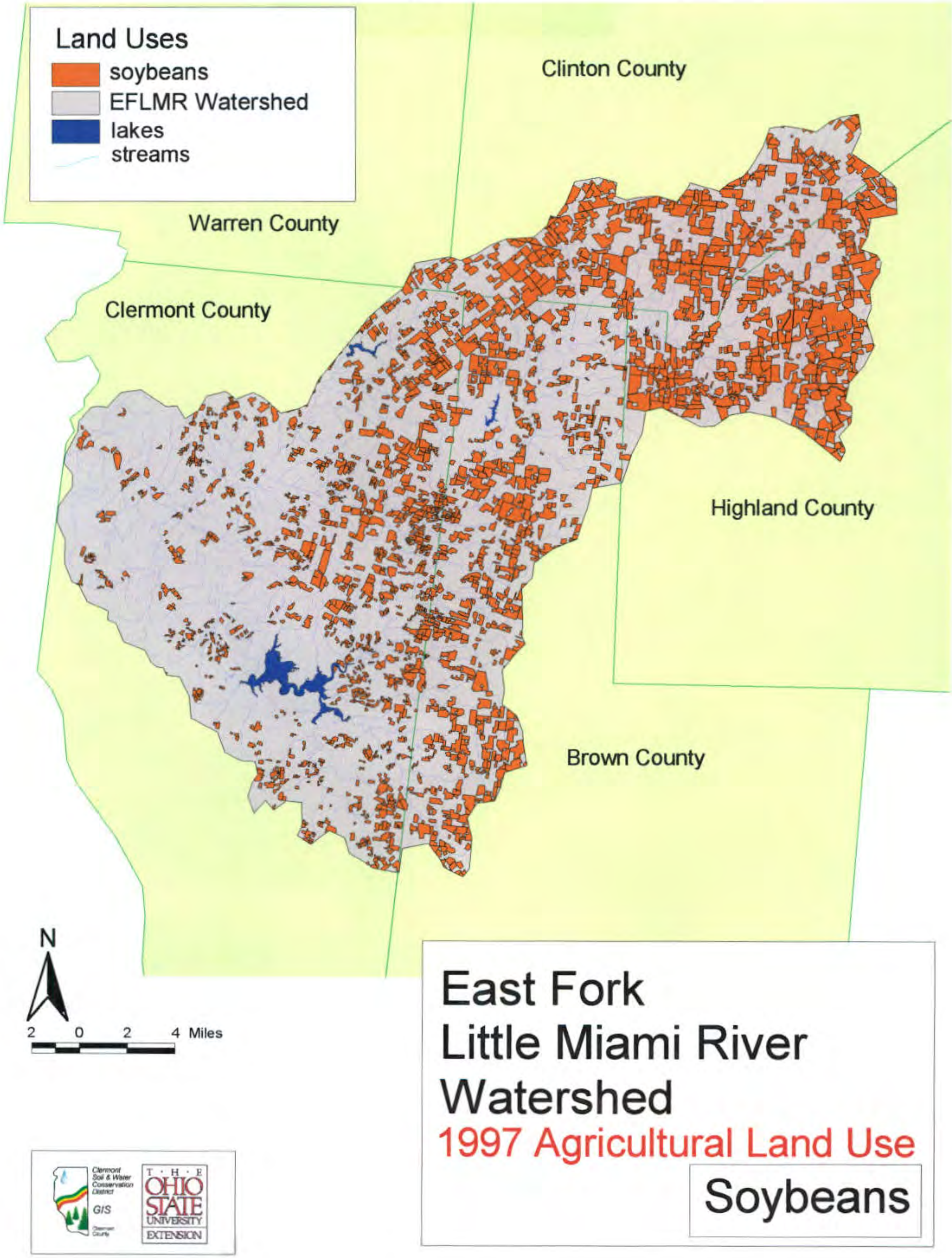

Land Uses
soybeans
EFLMR Watershed
lakes
streams
Clinton County
Warren County
Clermont County
Highland County
Brown County
N
2 0 2 4 Miles
East Fork
Little Miami River
Watershed
1997 Agricultural Land Use
Soybeans

Figure II - 7


Land Uses
tobacco
EFLMR Watershed
lakes
streams
Clinton County
Warren County
Clermont County
Highland County
Brown County
N
2 0 2 4 Miles
East Fork
Little Miami River
Watershed
1997 Agricultural Land Use
Tobacco

Figure II - 8

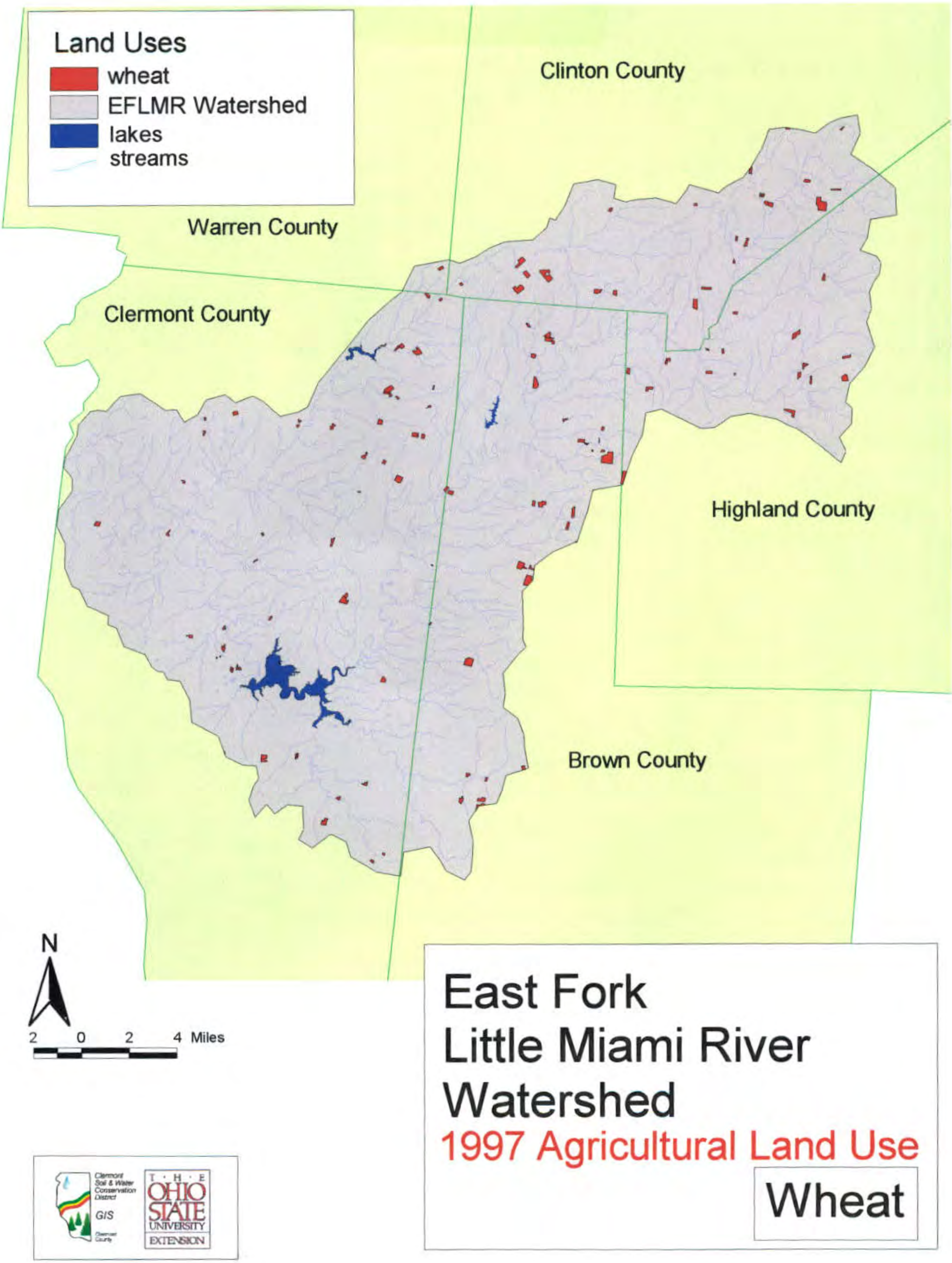

Land Uses
wheat
EFLMR Watershed
lakes
streams
Clinton County
Warren County
Clermont County
Highland County
Brown County
N
2 0 2 4 Miles
East Fork
Little Miami River
Watershed
1997 Agricultural Land Use
Wheat

Figure II - 9

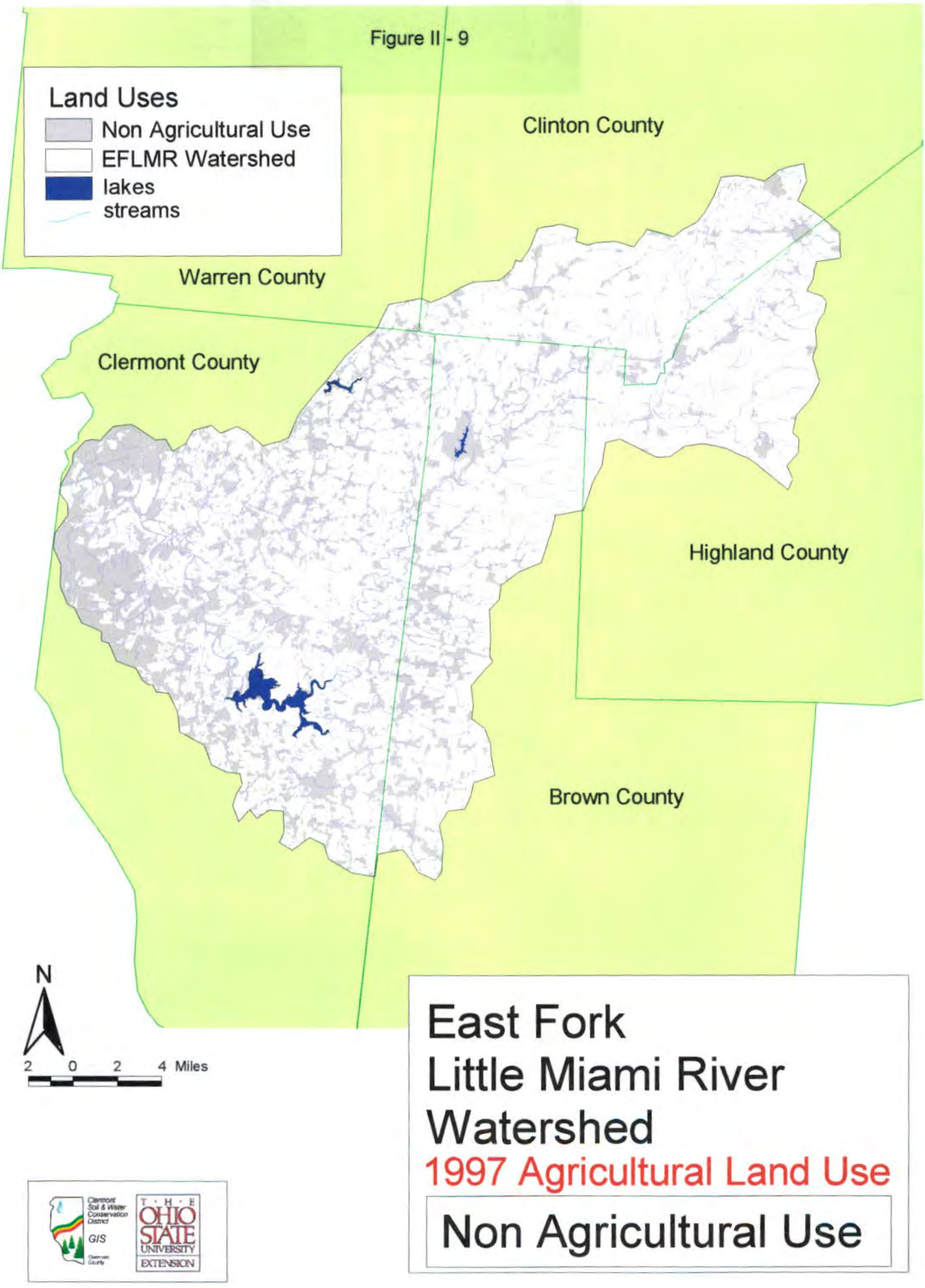

Land Uses
Non Agricultural Use
EFLMR Watershed
lakes
streams
Clinton County
Warren County
Clermont County
Highland County
Brown County
N
2 0 2 4 Miles
East Fork
Little Miami River
Watershed
1997 Agricultural Land Use
Non Agricultural Use
Clermont Soil & Water Conservation District
GIS
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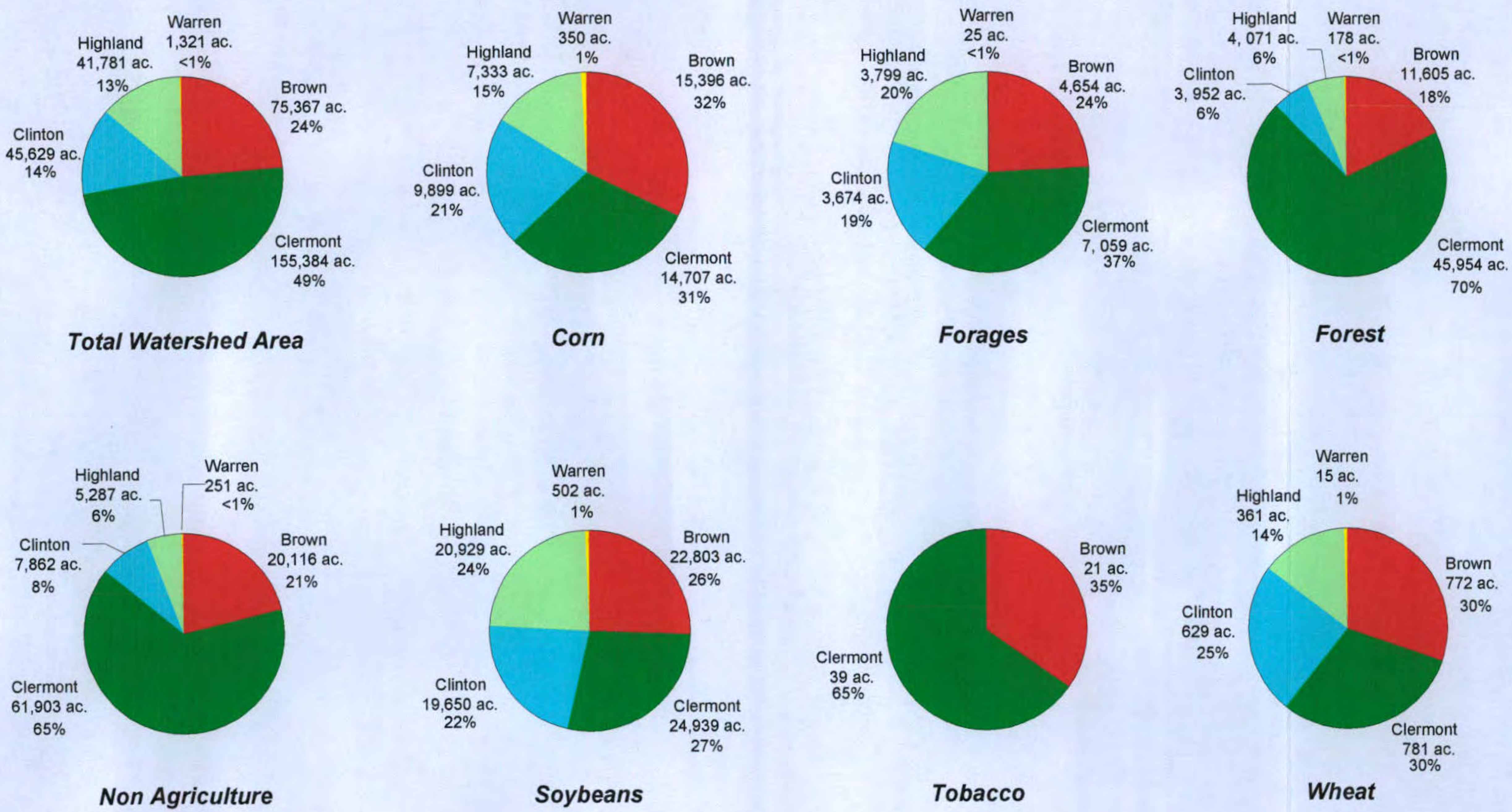
Figure II - 10

Crop Distribution By County



Section II.1.a. Agricultural Management

Agricultural management practices affect water quality. Agricultural best management practices (BMPs) have been developed to consider agricultural profitability and environmental quality issues. One of the goals of BMPs is to reduce degradation of water resources brought about by agricultural practices. Potential sources of water quality degradation in Ohio include plant nutrients, pesticides, and sediment.

To protect water resources, farmers can choose from several BMPs. Conservation tillage, contour farming, filter strips, cover crops, strip cropping, grassed waterway and others are some of the practices that farmers may select. Each BMP can reduce the threat to water quality but with varying degrees of effectiveness.

Fertilizers

Fertilizers create problems when they are applied in quantities that exceed the amount used by the crop or that exceeds the amount that can be held by the soil. Nitrogen and phosphorus are nutrients most often associated with water quality problems. Nitrogen and phosphorus can move to surface water through runoff and subsurface drainage. Ground water can be polluted by nitrogen through leaching.

Pesticides

Pesticides that are incorrectly applied can move from their target site and potentially cause ground and surface water contamination. Surface waters are directly affected when pesticides move either through runoff or eroded soil. Pest scouting and identification, proper pesticide application timing and appropriate rates can reduce the potential pollution problem and improve pesticide effectiveness.

Conservation Tillage

Sediment is another source of water pollution. Conservation tillage is the number one defense against sediment. Reducing soil loss also decreases the potential pollution problems associated with fertilizers and pesticides. Conservation tillage is designed to leave residue on the soil surface. The residue protects the soil surface from erosion by absorbing the energy of raindrops, thus reducing soil particle detachment. Residue reduces surface crusting and sealing which improve water infiltration. A third benefit of residue is the slowing of the velocity of the runoff water. This can allow particles in the runoff to be redeposited.

Conservation tillage leaves residue that is important in reducing runoff. Due to the protection that residue can provide, it was important to determine the type of tillage practices that farmers were using. Farmers were asked to state the type of tillage system that they had selected for each field that they were farming. The three tillage practices that farmers were ask to choose from were conventional, minimum, and no-till. The data collected are shown in Table II.2.

Table II.2 Tillage Practice by Crop in Acres and Percent

Tillage Practice	Corn	Soybean	Wheat
No-till	878 (21.2%)	704 (15.2%)	120 (60%)
Minimum	338 (8.2%)	1,969 (42.6%)	82 (40%)
Conventional	2,925 (70.6%)	1,946 (42.1%)	0
Total	4,141	4,619	200

Corn producing farmers are still using conventional tillage (71 percent) in the majority of their operations. The heavy, wet soils that make up a large portion of the watershed create difficulties for farmers when using either a no-till or minimum tillage practice. Compaction is another concern when working wet soils in early spring. Soybean producing farmers have adopted conservation tillage practices more extensively. Roundup Ready soybean have aided in the transition to either no-till or minimum tillage practices. The later planting dates can allow the soil to dry out more. The wheat crop for which information was available indicates extensive use of conservation tillage practices.

Section II.1.b. Agricultural Chemical Inventory

Determining the types and quantities of chemicals and fertilizers used by farmers in the EFLMR watershed were additional objectives of this project. The initial approach to gathering this information was through a comprehensive agricultural survey mailed to each registered farmer in the EFLMR watershed as identified by the five Farm Service Agencies. The survey included general questions such as crops grown, acres in field, average yields, and tillage practice. The survey also requested more detailed information for each crop grown by particular field. Information provided in this section includes pesticides used, concentration of pesticide, percent of active ingredient, quantity of pesticides used per acre, pounds of nitrogen, phosphate, and potash applied per acre, and sludge or manure applied as tons per acre. In addition, farmers were asked to state if they own livestock, type of livestock, number of heads, and if manure was applied and if so, what amount. A copy of the agriculture survey is found in Appendix A.

As mentioned, the FSA offices in the five counties were contacted in order to develop the survey mailing list. The area of the EFLMR watershed contained in each county was mapped and provided to each county FSA office. A computer search was conducted to determine the names and addresses of the farmers that were in the EFLMR watershed. This search provided a list of 1,784 farmers. Some of the names were owners but not necessarily farmers.

The surveys were mailed on March 4, 1998. The requested return date was April 6,1998. In addition to the mailing, three meetings were held to assist farmers in completing the survey. The meetings were held on April 1, 2, and 3 at locations in Clinton, Highland, and Clermont - Brown border. Of the 50 surveys received, 37 represented agricultural activity in the watershed. The results were recorded into an Excel spreadsheet. The various fields were located on the maps and identified.

To supplement the data obtained through the agricultural survey, seven area chemical vendors were contacted to gather additional information regarding farmers' chemical purchases. These companies were asked to state which chemicals and fertilizers the farmers were using and the recommended amounts of each item utilized. Based on this information, an estimate was made regarding the usage of chemicals and fertilizers by farmers in the EFLMR watershed. A list of the vendors is found in Appendix B. The comments of these vendors and the survey results are discussed in the following sections.

Herbicide Use

-- Corn

AAtrex/atrazine is used in some form by nearly every farmer. When asked, the vendors response was that 95 percent to 100 percent of all farmers use atrazine in some form. AAtrex/atrazine is the most commonly used corn herbicide because it is highly effective and economical. The majority of farmers are using the recommended rate of 2 pounds of active ingredient per acre. Reduced rates are being tried by some farmers to reduce costs and environmental risk. Table II.3 shows a summary of the data provided by the vendors.

Table II.3 Chemical Usage as Identified by Vendors - Corn

Vendors	Chemicals
A	Atrazine (100%), Princep*, Lightning, Pursuit, Bicep II*, Roundup
B	Atrazine (95%), Dual II, Lasso, Princep*, Extrazine II*
C	Atrazine (98%), Harness Xtra*, Bicep II, Bullet*, Etrazine II*
D	Atrazine (95-98%), Lasso, Dual II, Harness, Lightning, Roundup, Fieldmaster*
E	Atrazine (95%), Bladex, Harness, Roundup, Fieldmaster*, Etrazine II*
F	Atrazine (96%), Harness, Dual II, Extrazine II*, Roundup

* These herbicides contain some form of atrazine.

Information obtained from the farmer's survey revealed similar data. The use of atrazine in some form was indicated at 87 percent, slightly less than the 95 percent plus response of the vendors.

Farmers are very aware of their chemical costs and are inclined to reduce their costs when possible. Atrazine offers the best weed control/cost ratio for farmers. This is the primary reason that atrazine is utilized so extensively. Due to economics, the adoption of reduced rates and new technology such as Roundup Ready corn should continue to rise in the future. See Table II.4 for the summary of this data.

Table II.4 Chemical Use from Agriculture Survey - Corn

CHEMICAL NAME	ACRES	QUANTITY
Atrazine	8	2#/ac
Etrazine 4L**	1,897	1.25 to 1.3 qts/ac
Bicep II* Magnum	1,335	1.3 to 2.6 qts/ac
Dual II & Atrazine	18	Dual .8 - 2 pts/ac & Atrazine 2 to 4 pts/ac
Atrazine & Lasso	62	Atrazine 2 to 4 pts/ac & Lasso 2 qts/ac
Harness	477	1 to 3 pts/ac
Round-up	49	.75 to 1 qt/ac
Fieldmaster***	74	3.5 to 5 qts/ac
Lariat****	25	2.5 to 5.3 qts/ac
Lariat & 2,4-D	71	Lariat 2.5 to 5.3 qts/ac & 2,4-D .33 to 1 pt/ac
Total	4,016	N/A

* Bicep II Magnum is a combination of Dual II and atrazine
** Etrazine is a combination of Bladex and atrazine
*** Fieldmaster is a combination of Roundup Ultra, Harness and atrazine
**** Lariat is a combination of Lasso and atrazine

Of the 4,016 acres of corn reported in the survey, 526 acres did not use some form of atrazine. One farmer accounted for 477 acres of this total. This farmer stated that he had used Harness which uses actetochlor as its active ingredient. The survey results supported the estimates of the vendors. The other chemicals that were used outside the atrazine family were Lasso, Bladex, Dual II and Roundup. For a more in-depth discussion of herbicide classification, refer to Appendix C.

Two options exist that could reduce the dependency upon atrazine in the future. Roundup Ready corn made its appearance in 1997. The genetic engineering of this corn allows for the use of Roundup. Roundup presents a greatly reduced threat to water resources due to the fact that Roundup has no soil activity and rapidly becomes inactivated. The availability of seeds was very limited in 1997; however, this will change in the near future. Another limiting factor in the use of this new technology is the extra cost of the seed. As more companies increase the availability of the seed, the cost should decrease. Farmers are typically slow to adopt new technology, so a cost advantage will need to be demonstrated to farmers to assist with the wide spread acceptance of this technology. The second option is the use of reduced rates by farmers. Some farmers are already using reduced rates but to a limited extent. Research at Ohio State University Extension is being done in an effort to demonstrate that this is a cost saving option that provides adequate weed control and deserves consideration.

-- Soybean

Unlike corn, Roundup Ready soybeans have been in production longer and have been adopted much more extensively. Vendors were asked to estimate the extent of use of Roundup Ready soybeans. The adoption of this technology varies across the watershed. In the northeast sections of the watershed, use can be as high as 75 percent. While in the southeastern section the rate of use is 25 to 30 percent. The use of Roundup Ready soybeans in Clermont County falls in the 50 percent range. In those areas where adoption has been slower, the trend is on the rise. More farmers are switching to the Roundup Ready soybeans. This practice will reduce the threat to our water resources. See Table II.5 for a summary of the vendors' responses.

Table II.5 Chemical Usage as Identified by Vendors - Soybean

Vendor	Chemical
A	Roundup (30%), Canopy, Dual II, Fusion, Reflex, Basagran, Sceptor
B	Roundup (30%), Lasso, Lorox, Synchrony STS, Accent, Pursuit
C	Roundup (75%), Canopy, Lorox
D	Roundup (50%), Canopy, Turbo, Canopy II, Lasso, Pursuit, Sencor, Sceptor
E	Roundup (75%), Canopy, Command 3ME, Lasso
F	Roundup (75%), Canopy, Lasso, Synchrony STS

A variety of chemicals are used by farmers, especially in those areas that Roundup Ready soybeans are not produced. Synchrony STS is similar to Roundup Ready in that they are both amino acid synthesis inhibitors (see Appendix C).

Herbicides identified by the farmers that coincided with the vendor's responses were Canopy, Assure II, Lasso, Dual II, Sencor, Roundup, Pursuit, and Basagran. Turbo is combination of Sencor and Dual II, Tricept contains Sceptor, and Storm contains Basagran. Chemicals identified by farmers within the watershed as determined by the survey are in Table II.6.

Table II.6 Chemical Use from Ag Survey - Soybean

CHEMICAL	ACRES	QUANTITY
Canopy*	581	3 to 7 oz./ac
Canopy & Assure II	496	Canopy = 3 to 7 oz./ac, Assure II = 5 to 10 oz./ac
Canopy & Dual II	223	Canopy = 3 to 7 oz./ac, Dual II = 1.5 to 3.8 pts/ac
Turbo**	679	1.5 to 3.75 pts/ac
Turbo & Sceptor	369	Turbo = 1.5 to 3.75 pts/ac, Sceptor = 1.4 to 2.8 oz./ac
Sceptor & Lasso	112	Sceptor = 1.4 to 2.8 pts/ac, Lasso = 1.5 to 3 qts/ac
Trisept******	1,009	2.33 pts/ac
Dual II & Sencor	111	Dual II = 1.5 to 3.8 pts/ac, Sceptor = 1.4 to 2.8 pts/ac
Roundup	77	24 to 48 oz./ac
Squadron***	329	3 pts/ac
Roundup & Pursuit	106	Roundup 24 to 48 oz./ac & Pursuit 4 oz./ac
Roundup & Poast Plus & Storm**** & Pinnacle	53	Roundup 24 to 48 oz./ac & Poast Plus 1 pt/ac & Storm 1.5 pts/ac & Pinnacle 1 pt/ac
Roundup & Dual II	11	Roundup 24 to 48 oz./ac & Dual II 1.5 to 3.85 pts/ac
Pursuit	72	4 oz./ac
Canopy & Assure II & Classic	46	Canopy 3 to 7 oz./ac & Assure II 5 to 10 oz./ac & Classic .5 to .75 oz/ac

Table II.6 Chemical Use from Ag Survey - Soybean (Continued)		
CHEMICAL	**ACRES**	**QUANTITY**
Lasso & Basagran	25	Lasso 1.5 to 3 qts/ac & Basagran 1 to 2 pts/ac
Lasso & Blazer	79	Lasso 1.5 to 3 qts/ac & Blazer .5 to 1.5 pts/ac
Dual II & Cobra & Pursuit	25	Dual II 1.5 to 3.85 pts/ac & Cobra 10 to 12.5 oz./ac & Pursuit 4 oz./ac
Sceptor & Tornado***** & Lasso	48	Sceptor 1.4 to 2.8 oz./ac & Tornado 1 qt/ac & Lasso 1.5 to 3 qts/ac
Total	4,451	N/A

* Canopy = Classic and Lexone
** Turbo = Sencor and Dual
*** Squadron = Sceptor and Prowl
**** Storm = Basagran and Blazer
***** Tornado = Reflex and Fusilade
****** Tricept = Sceptor and Trifluralin

A total of 4,451 acres of soybeans were reported in the survey.

Fertilizer Use

-- Corn

The vendor's responses produced a range of estimates for each of the nutrients (nitrogen, phosphorus, and potassium) that are used by farmers. Table II.7 provides the data that were provided by the vendors.

Table II.7 Fertilizer Use as Identified by Vendors - Corn

VENDOR	NITROGEN	PHOSPHORUS	POTASSIUM
A	150 to 180	50 to 60	80 to 120
B	160 to 250	80 to 110	110 to 120
C	200 to 250	90 to 115	110 to 140
D	150 to 200	120 to 150	120 to 150
E	150 to 200	80 to 120	100 to 130
F	180 to 200	90 to 120	110 to 140
G	150 to 200	80 to 120	100 to 140

The Tri-State Fertilizer Recommendations (Extension Bulletin E-2567) for corn, soybeans, wheat, and alfalfa recommends the following rates for fertilizer of corn: for yields in the range of 140 to 180+ bushels per acre the nitrogen requirements would be 160 to 220 pounds of actual N per acre. The recommended application rate for phosphorus for similar yields would be 85 to 115+ pounds of actual P per acre. Potassium recommendations range from 65 to 180 pounds actual K per acre. The rate of application for P and K are dependent upon the cation exchange capacity and level of nutrient present in the soil as determined by the soil test. The nutrient levels are very dependent upon the practices of the farmer. A copy of Extension Bulletin E-2567 is included as Appendix D.

Nutrient removal rates for phosphorus and potassium have been determined. Corn harvested for grain will remove 0.37 pounds/bushel. of P_2O_5 and 0.27 pounds/bushel of K_2O. Corn harvested as silage will remove 3.30 pounds/ton of P_2O_5 and 8.0 pounds/ton of K_2O.

Farmers were asked to state the pounds of fertilizer applied per acre. A summary of the corn related data as reported by the farmers on the survey is found in Tables II.8 through II.10.

Table II.8 Nitrogen

Application Rate	Number of Acres	Percentage of Total Acres
Up to 179	682	16.0%
180 to 199	58	1.4%
200 to 230	3,500	82.6%
Total	4,240	N/A

Table II.9 Phosphorus

Application Rate	Number of Acres	Percentage of Acres
Up to 89	1,259	29.7%
90 to 99	292	6.9%
100 to 120 +	2,689	63.4%
Total	4,240	N/A

Table II.10 Potassium

Application Rate	Number of Acres	Percentage of Acres
Up to 119	179	4.3%
120 to 149	1,158	27.3%
150 +	2,902	68.4%
Total	4,239	N/A

The data collected from the vendors and the farmers are very similar. Farmers would appear to be over-applying fertilizer based upon the recommendations from the Tri-State Fertilizer Guide. The key points of information in determining application rates are desired yield and current level of fertility. Combining these two variables will determine nutrient requirements.

-- Soybeans

The results of the interviews with local vendors regarding fertilizer use for soybeans produced the following data. Table II.11 summarizes this information in pounds of nutrient per acre.

Table II.11 Fertilizer Use a Identified by Vendors - Soybean

Vendor	Nitrogen	Phosphorus	Potassium
A	0 to 36	69 to 92	90 to 120
B	6 to 9	36 to 54	72 to 108
C	0	57 to 69	75 to 90
D	20 to 30	50 to 100	50 to 100
E	0 to 27	69	108
F	0 to 27	69 to 92	90 to 120

The Tri-State Fertilizer Recommendations for soybeans are dependent upon the level of fertility of the soil and the desired yield. In general, the range for P_2O_5 would be 30 to 100 pounds per acre. The recommendations for K_2O would be 75 to 180 pounds per acre. The large range is due to the various combinations of nutrients level of the soil, the cation exchange capacity level and the desired yield. The nutrient removal rate for P_2O_5 is 0.80 pounds/bushel and for K_2O is 1.40 pounds/bushel of soybeans produced. The ability of the soybean plant to produce nitrogen removes this nutrient as a consideration, except as a starter fertilizer.

A summary of the data as reported by the farmers on the survey produced is found in Tables II.12 through II.14. Application rates are listed in pounds of actual nutrient per acre.

Table II.12 Nitrogen

Application Rate	**Number of Acres**	**Percentage of Total Acres**
Zero	1,954	76.1%
1 to 9	185	7.2%
10 to 19	428	16.7%
Total	2,567	100%

Table II.13 Phosphorus

Application Rate	Number of Acres	Percentage of Total Acres
0 to 29	409	16.0%
30 to 59	525	20.4%
60 to 100	1,633	63.6%
Total	2,567	100%

Table II.14 Potassium

Application Rate	Number of Acres	Percentage of Total Acres
60 to 89	736	28.7%
90 to 119	402	15.7%
120 to 149	217	8.4%
150 to 180	1,212	47.2%
Total	2,567	100%

There were 1,807 acres reported that had no indication of fertilizer applied. However, there was other detailed information provided for this acreage. In a soybean/corn crop rotation, farmers often apply higher rates of fertilizer to corn to provide a carry-over for the soybean the following year. This could explain some of the excessive fertilization of the corn crop.

-- Wheat

The survey results and the responses from the vendors were in agreement that little wheat is produced in the EFLMR watershed. Few fertilizers and chemicals are used by farmers to produce the limited wheat crop. Vendors indicated that farmers are applying fertilizer at lower than recommended rates. Recommended rates are nitrogen 40 to 75 pounds/acre, phosphorus 30 to 45 pounds/acre, potassium 40 to 45 pounds/acre. The summary of the farmers' survey is found in Tables II.15 through II.17.

Table II.15 Nitrogen

Application Rate	Number of Acres	Percentage of Total Acres
0 to 40	83	84.4%
41 to 80	0	0
81 to 120	0	0
121 to 160	15	15.6%
Total	98	100%

Table II.16 Phosphorus

Application Rate	Number of Acres	Percentage of Acres
0 to 40	75	75.8%
41 to 80	24	24.2%
81 to 120	0	0
Total	99	100%

Table II.17 Potassium

Application Rate	Number of Acres	Percentage of Total Acres
0 to 40	75	75.8%
41 to 80	7	6.6%
81 to 120	17	17.6%
Total	99	100%

The Tri-State Fertilizer Recommendations for a production level of 50 to 70 bushels per acre is nitrogen - 40 to 75 pounds/acre, P_2O_5 - 30 to 90 pounds/acre, K_2O - 40 to 120 pounds/acre. Actual application rates are dependent upon soil test results and the need to meet fertilizer deficiencies. Harvested grain removes 0.63 pounds of P_2O_5 per bushel and 0.37 pounds of K_2O per bushel. The removal of straw adds 0.09 and 0.91 respectively.

Very few chemicals are used in the production of wheat. Herbicides that are listed for use are 2,4-D amine and ester, Banvel, Buctril, Harmony Extra, and Peak. Tilt, a fungicide, will be used when disease pressure is great enough in the spring.

-- Tobacco

As with the other crops previously discussed, fertilizer use is highly dependent upon the fertility levels of the soil that will be used for production. Vendors' assessment of farmers purchases and OSU Extension's recommendations are closely related. To produce between 2,500 and 3,000 pounds of tobacco per acre the following data would apply: nitrogen application will be between 250 and 300 pounds/acre, P_2O_5 will range between 60 and 100 pounds/acre, potassium will be between 200 and 300 pounds/acre.

Herbicides that are primarily utilized in tobacco production are Prowl (3.0 to 3.6 pts/ac), Paarlan (1 qt/ac) and Command 3ME (2 to 2 2/3 pts/ac). The use of some insecticides is required. The most widely used insecticides are Orthene 75, Golden Leaf, Admire, and Diazinon 50 WP. Another chemical that is used extensively is a product that is a growth retardant for the control of suckers. The three most commonly used products are Royal MH30, Sucker Stuff, and Super Sucker Stuff.

In recent years the disease blue mold has been a major problem. To aid in the control of this disease the use of Dithane DF and Acrobat MZ has been necessary. Another chemical that is used in the control of blue mold is Ridomil. The problem that has occurred in the last four years is that the disease has started to develop a resistance to Ridomil, resulting in the utilization of other chemicals.

-- Forages

The extent of use of fertilizers and chemicals in forage production is very limited. The exception to this statement would be in the production of alfalfa. Due to the wet soil conditions that exist in a majority of the watershed, alfalfa is not a major crop. Herbicides that could be utilized are Butyrac 200, Buctril, Poast, Pursuit, Sencor, Sinbar, and Treflan. Alfalfa is a consumer of nutrients. The harvesting of one ton of forage removes 13 pounds of P_2O_5 and 50 pounds of K_2O. With yields of four to five tons per acre possible, farmers that are treating alfalfa as a crop will replace these nutrients. Alfalfa is a legume, like soybean, and produces its own nitrogen.

With most hay fields and pastures being a combination of grasses and legumes, no chemicals are presently available that can be utilized. Cultural practices such as timely harvesting, clipping pastures, maintaining proper fertility and pH, seeding of desired species and controlling grazing will eliminate 80 percent of the weed concern.

Section II. 2 Horticultural Land Use

This section addresses commercial horticultural land use, commercial horticultural chemical use, and residential chemical usage in the EFLMR watershed. Commercial horticulture is defined as fruit and vegetable farms, greenhouses, nurseries, Christmas tree farms, parks, and golf courses. Horticultural chemicals include insecticides, fungicides, herbicides, and fertilizers. Residential horticultural chemical use is defined as the typical chemical usage by homeowners in their yard and garden.

A total of 42 horticultural businesses were identified to have pesticide and fertilizer input into the watershed. Each of these horticultural businesses are labeled on the watershed map as horticultural land use data. See Figure II-11 for the location of these horticultural businesses. The majority of the horticultural businesses in the watershed are located in Clermont County. Thirty three horticultural businesses were identified in Clermont County, 4 in Highland County, 3 in Brown County, and 2 in Clinton County. During 1997, there were 4 vegetable farms, 6 fruit farms, 4 parks, 15 nurseries, 2 sod farms, and 2 golf courses in the watershed.

Most of the horticultural businesses in the watershed are very small in comparison to agricultural farms. Some vegetable growers had as little as half an acre while others had as much as 57 acres. Fruit farms are quite small as well. Small fruit farms average 5 acres while larger operations may have 50 acres. The nurseries in the watershed are in the 2 to 5 acre range. Parks are in the range of 4 to 40 acres. Sod farms are in the range of 10 to 15 acres. The size of golf courses are 40 acres or larger. No total acreage of horticultural businesses was calculated since many horticultural business owners did not return our surveys. In addition, the aerial photos did not have enough resolution for us to draw the boundaries. However, it is reasonable to assume that the total acreage of horticultural operation in the entire watershed is very small in comparison to the agricultural production.

Section II.2.a. Commercial Horticultural Management

Commercial horticulture covers a very diverse group of plants ranging from fruits, vegetables, trees, shrubs, and turfgrasses. There are several hundred plant species involved with nurseries, greenhouses, garden centers, and parks. There are 10 to 20 species that are involved with fruit and vegetable farms. The chemicals labeled for each type of operation are very different from another. Horticultural management differs greatly from one operation to another or even within each type of operation depending on the expectations of owners and prospective consumers.

The common chemicals applied in the commercial horticultural businesses are insecticides, fungicides, herbicides, and fertilizers. The margin of error for crops such as bedding plants, fruits, vegetables, nurseries, and golf courses is very small. This is why chemical input in these types of horticultural operations is higher than agricultural crops on a per acre basis. However, the horticultural industry as a whole is still too small to present significant threat to the watershed. In addition, some horticultural operations such as fruit farms grow sod between their crops for erosion control and ease of management. While greenhouse crops are in an enclosed area on very small acreage, many of the chemicals applied do not get into streams readily. Although golf courses are intensely managed, most of the chemicals applied are utilized by turfgrasses, while many of the insecticides and fungicides are utilized by soil microorganisms as part of their metabolism. Hence, the potential impacts of chemical applications may not be as high as expected.

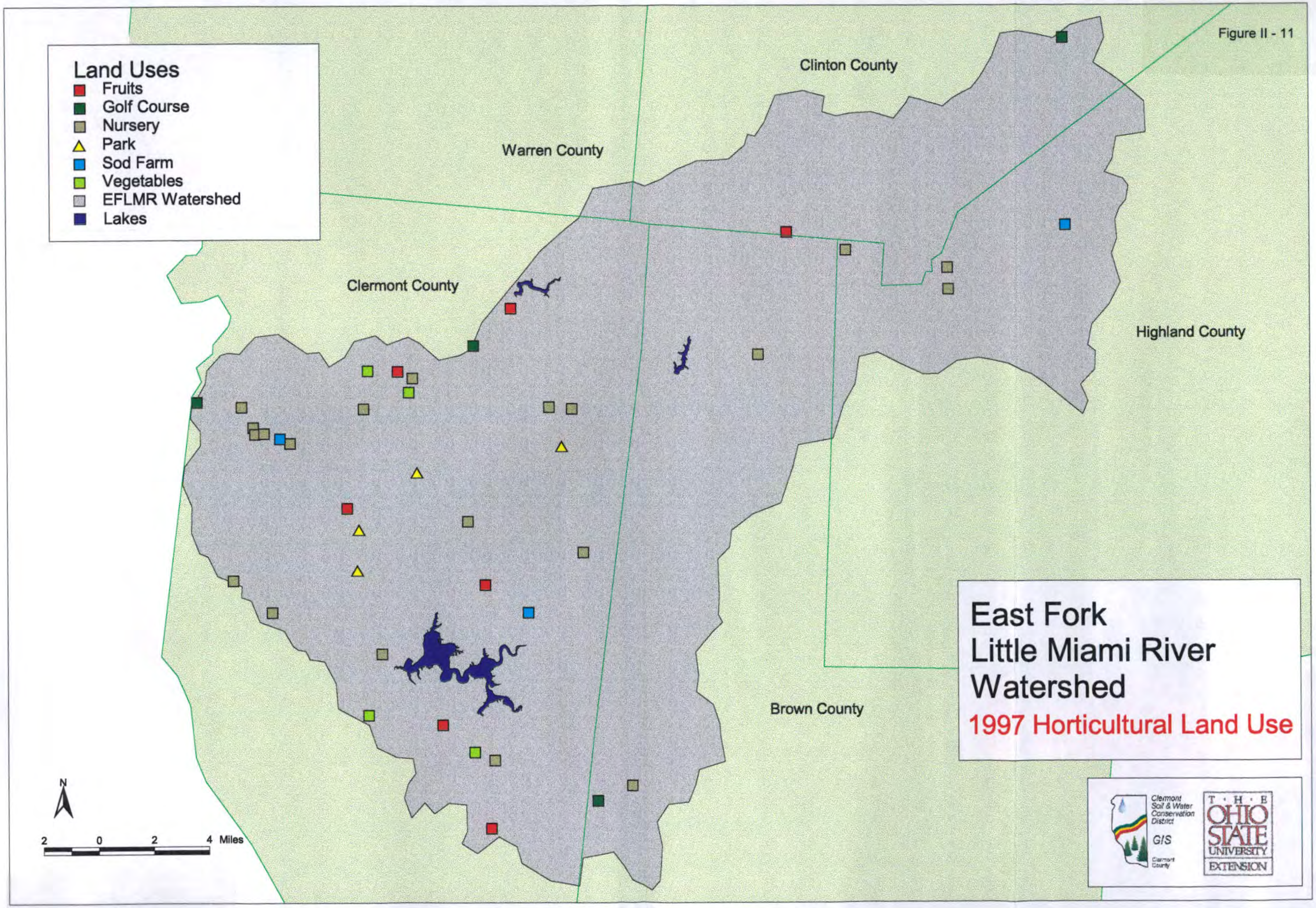


Figure II - 11
Land Uses
Fruits
Golf Course
Nursery
Park
Sod Farm
Vegetables
EFLMR Watershed
Lakes
Clinton County
Warren County
Clermont County
Highland County
Brown County
East Fork
Little Miami River
Watershed
1997 Horticultural Land Use
N
2 0 2 4 Miles
Clermont Soil & Water Conservation District
GIS
Clermont County
THE OHIO STATE UNIVERSITY EXTENSION

Section II.2.b. Commercial Horticultural Pesticide Usage

Since most of the horticultural businesses occupy small acreage in comparison to agricultural farms, the labeled chemicals applied by different horticultural businesses are very different, especially between food production horticulture and ornamental horticulture. Five different surveys were designed so that each pesticide usage survey is specific to the type of operation, i.e. orchard or golf course. Copies of the horticultural surveys are found in Appendix E.

Horticultural business owners are not required by law to provide any of the pesticide usage or land use information to Ohio State University Extension, but every effort was made to ensure the highest possible response rate. Surveys were sent to every pesticide applicator that was involved in horticultural businesses in Brown, Clermont, Clinton, Highland, and Warren Counties. The mailing list used in the comprehensive survey was generated from a list of commercial and private pesticide applicators by the Section of Pesticide regulations, Ohio Department of Agriculture. Pesticide use and land use surveys were sent to 35 fruit growers, 41 vegetable growers, and 114 turf and ornamental professionals in Brown, Clermont, Clinton, Highland, and Warren Counties. Those surveys included questions about the types of plants grown, acreage, and the amounts of applied chemicals such as insecticides/miticides, fungicides, herbicides, and fertilizers.

A total of 52 responses were received after two separate mailings, numerous phone calls, personal visits, and offering small cash awards as well as Ohio State University Extension educational bulletins. Out of the 52 returns, 15 were from fruit growers, 14 from vegetable growers, and 23 from turf and ornamental professionals. Many of the fruit farms either went out of business before 1997 or were located outside of the watershed. Out of the 52 responses received, 9 responses came from horticultural businesses in the watershed. The responses came from vegetable farms, orchards, parks, and a nursery. The chemicals applied by these businesses are tabulated in Microsoft Excel for later retrieval.

Based on the survey results, the horticultural industry that is most intensively managed is golf courses. There are two golf courses identified in the watershed during 1997. The common insecticides used on the golf courses were Merit 0.5G, Scimitar, and Crusade 5 G. The common golf course herbicides are Presan 7G, Dimension, and Confront, MecAmine D. The common fungicides were Daconil, Heritage, and Chico 26019. Fertilizer applications on golf courses were 155 pounds of nitrogen, 7.75 pounds of phosphorus, and 15.5 pounds of potassium per acre.

The second most intensively managed horticultural operation is fruit farms or orchards due to the many insects, fungi, and weeds attacking fruits. Fruit growers typically sprayed insecticides 10 times during a season using several insecticides including Thiodan, Sevin, and Imidan. Common fungicides used by fruit growers are Benlate, Captan, and Ziram.

Vegetable growers appear to have applied much fewer chemicals. The commonly applied insecticides by vegetable growers were Sevin XLR, and Malathion while fungicides were Bravo and Captan. The commonly applied herbicides by vegetable growers are Devrinol, and Dual 8 E.

During 1997, the nurseries in the watershed were not very intensively managed. Very few insecticides were used. Common herbicides used in the nurseries were Surflan, Poast, and Roundup.

The horticultural operation with the least amount of the chemical input was parks. The common insecticide applied was Sevin while the commonly applied herbicide was Roundup. The common fungicide applied was Deconil.

One of the largest sectors of the horticultural industry not included the mapping of horticultural land use and chemical usage is lawn care and grounds maintenance. Since lawn care and grounds maintenance companies mainly service home lawn or yards, we could only find out the typical chemical application of these companies. Based on the survey results we received from 5 local lawn care companies, the chemical applications were similar to homeowner management practices. For example, common herbicides applied were 2,4-D and Roundup. Common insecticides applied were Merit, Diazinon, and Malathion. Very few fungicides were used. This information is further discussed in Section II.2.c.

Unlike the agricultural activities in the watershed which are dominated by corn or soybean, horticultural businesses deal with many plant species. The makeup of the horticultural plants is very different from one business to another. Hence, pesticides are drastically different for each business. Another complicating factor is that growers may purchase some of the plants they grow from other sources. Some growers even refused to provide the types of crops grown and respective acreage for their crops because the Ohio Department of Agriculture can use the data for crop tax or check-off programs. Without actual responses from each business, to extrapolate the chemical usage to the entire watershed based on selected survey responses would yield incomplete or inaccurate data.

Section II.2.c. Residential Horticultural Chemical Inventory

The objective of the residential survey was to determine the average pesticide and fertilizer usage by homeowners in the watershed. The data will be used to determine the environmental impact that existing and new residential housing development may have on water quality within the watershed.

A comprehensive survey was sent to 900 households in Clermont County. Every attempt was made to ensure that the surveys were user-friendly. As a result, 96 returns were received. Forty six surveys were included in the summary of typical pesticide and fertilizer usage. The remainder of the returns were not filled out properly. Residential lots were divided into 6 categories. These categories included lots that are less than 1/4 acre, 1/4 - 1/2 acre, 1/2 - 1 acre, 1 acre - 2 acres, 2 - 3 acres, and larger than 3 acres. The average total pesticide and fertilizer usage were recorded in Tables II.18, "Summary of Typical Pesticide Usage by Homeowners in Clermont County" and II.19, "Summary of Typical Fertilizer Usage by Homeowners in Clermont County."

Results are listed in Tables II.18 and II.19. The common insecticides used in the home garden and landscape are Sevin dust, Malathion, and Diazinon. The total amount of Sevin applied ranged from 0.17 to 3.5 pounds per yard. Different pesticides have varying impacts on water quality and wildlife such as mallard ducks, fish, and invertbartes according to the fact sheet "Pesticides in Residential Areas-Protecting the Environment" published by Oklahoma State University. A copy of this fact sheet is included as Appendix F. Mallard ducks were used as an indicators of waterfowl status in the watershed. Sevin has a medium relative runoff potential, very small ground water leaching potential and medium toxicity to fish, and very low toxicity to mallard ducks. The half life of Sevin is approximately 10 days. Diazinon has medium relative

Table II.18 Summary of Typical Pesticide Usage by Homeowners in Clermont County

Yard Size	Insecticides	Amount of Insecticides	Fungicides	Fungicide Amount	Herbicides	Herbicide Amount
Less than 1/4 acre	Diazinon (lbs.)	0	Benomyl (fl. oz)	0	Broadleaf Weed Killer (fl. oz)	0.125
	Malathion (fl.oz)	0	Captan (fl. oz)	2.7	Preen (lbs)	14.5
	Sevin Dust (lbs.)	0.25	Deconil (fl. oz.)	0	Pre-emergent (lbs.)	0
	Sevin Liquid (fl. oz)	0	Funginex (fl. oz)	0.33	Roundup (fl. oz)	0
1/4 - 1/2 acre	Diazinon (lbs.)	0	Benomyl (fl. oz)	0	Broadleaf Weed Killer (fl. oz)	1.06
	Malathion (fl. oz)	0	Captan (fl. oz)	0	Preen (lbs)	0
	Sevin Dust (lbs.)	0.55	Deconil (fl. oz.)	0	Pre-emergent (lbs.)	0
	Sevin Liquid (fl. oz)	1	Funginex (fl. oz)	0	Roundup (fl. oz)	12.08
1/2 - 1 acre	Diazinon (lbs.)	0	Benomyl (fl. oz)	0	Broadleaf Weed Killer (fl. oz)	0.69
	Malathion (fl. oz)	0	Captan (fl. oz)	0	Preen (lbs)	0.25
	Sevin Dust (lbs.)	3.5	Deconil (fl. oz.)	0	Pre-emergent (lbs.)	0

Table II.18 Summary of Typical Pesticide Usage by Homeowners in Clermont County (Continued)

Yard Size	Insecticides	Amount of Insecticides	Fungicides	Fungicide Amount	Herbicides	Herbicide Amount
	Sevin Liquid (fl. oz)	1.75	Funginex (fl. oz)	0	Roundup (fl. oz)	39.59
1 acre - 2 acres	Diazinon (lbs.)	0	Benomyl (fl. oz)	0	Broadleaf Weed Killer (fl. oz)	0
	Malathion (fl. oz)	1.18	Captan (fl. oz)	0	Preen (lbs)	1.95
	Sevin Dust (lbs.)	0.3	Deconil (fl. oz.)	0	Pre-emergent (lbs.)	0
	Sevin Liquid (fl. oz)	2	Funginex (fl. oz)	1	Roundup (fl. oz)	20.72
2 - 3 acres	Diazinon (lbs.)	0	Benomyl (fl. oz)	0	Broadleaf Weed Killer (fl. oz)	0
	Malathion (fl. oz)	0	Captan (fl. oz)	0	Preen (lbs)	0.33
	Sevin Dust (lbs.)	0.17	Deconil (fl. oz.)	0	Pre-emergent (lbs.)	0
	Sevin Liquid (fl. oz)	3.63	Funginex (fl. oz)	0	Roundup (fl. oz)	21.33
Larger than 3 acres	Diazinon (lbs.)	0	Benomyl (fl. oz)	1.7	Broadleaf Weed Killer (fl. oz)	45.71

Table II.18 Summary of Typical Pesticide Usage by Homeowners in Clermont County (Continued)

Yard Size	Insecticides	Amount of Insecticides	Fungicides	Fungicide Amount	Herbicides	Herbicide Amount
	Malathion (fl. oz)	0	Captan (fl. oz)	0.43	Preen (lbs)	0
	Sevin Dust (lbs.)	1.29	Deconil (fl. oz.)	0.29	Pre-emergent (lbs.)	0
	Sevin Liquid (fl. oz)	0.29	Funginex (fl. oz)	0	Roundup (fl. oz)	6.04

Table II.19 Summary of Typical Fertilizer Usage by Homeowners in Clermont County

Yard Size	Nitrogen (lbs.)	Phosphorus (lbs) (P_2O_5)	Potassium (lbs.) (K_2O)
Less than 1/4 acre	9.25	1.49	2.35
1/4 - 1/2 acre	9.33	2.26	2.21
1/2 - 1 acre	1.69	2.30	1.59
1 acre - 2 acres	7.21	7.19	6.10
2 - 3 acres	17.37	4.50	3.71
Larger than 3 acres	20.36	21.43	21.17

runoff potential, and large ground water leaching potential. Diazinon has a very high toxicity to both mallard ducks, and fish. It has a half life of 30 days. Malathion has very small runoff potential and ground water leaching potential. However, it is highly toxic to fish. The insecticides that have large relative runoff potential are Amdro (hydramethylnon), Dursban (chlropyrios), Kelthane and (dicofol).

Homeowners use very little fungicides. The most common fungicides used are Captan, Funginex, and Deconil. Captan has very low toxicity to mallards, but is highly toxic to fish. The half day life of Captan is 3 days. Funginex (triorine) has medium runoff potential, and small ground water leaching potential. It has very low toxicity to fish, with a half life of 21 days. Deconil has large runoff potential, and small ground water leaching potential. It is highly toxicity to mallards, fish and invertebrates, with a half life of 30 days.

The amount of residential herbicide application varied significantly. The common pre-emergent herbicides are Preen (Trifluralin), and Pendimethalin. The amount of Preen application varied from 0 to 14.5 pounds per yard. Pendimethalin is the active ingredient in many crabgrass preventers. It has a large runoff potential and small ground water leaching potential. Its toxicity to mallards is low. However, it is highly toxic to fish. The half life of Pendimethalin is 90 days. The common non-selective herbicide used is Roundup which ranged from 0 to 39.59 pounds per yard. Roundup has a large runoff potential and small ground water leaching potential. Roundup has very low toxicity to fish. The broadleaf weed killer used most often was 2,4-D with amounts varying from 0 to 45.71 pounds per yard. 2,4-D has a small runoff potential and a medium ground water leaching potential. It has a very low toxicity to fish.

Many homeowners applied fertilizers in their garden and landscape. The kinds of fertilizers varied from Miracle-Gro, Scotts Four Step program, to different store brands. The amount of nitrogen applied ranged from 1.69 to 20.36 pounds per yard. The phosphorus applied was from 1.49 to 21.43 pounds per yard. The potassium application ranged from 1.59 to 21.17 pounds per yard.

Homeowner horticultural practices covered a very wide spectrum in our survey responses. There were many organic gardeners while others relied heavily on pesticides and fertilizers. It is difficult to predict what a new group of homeowners will do. Homeowner education will go a long way in reducing unnecessary pesticide and fertilizer application into our water streams.

Section II.3 Highway and Infrastructural Land Use

The section examines land use and chemical applications related to highways and other infrastructure such as utility easements and railroads within the EFLMR watershed.

Section II.3.a. Highway and Infrastructural Management

Highway and infrastructure land use and chemical analysis were conducted through telephone survey, map interpolation, and GIS data examination. The greatest challenge was estimating the number of highway miles located within the watershed. Total highway miles for each county are known. However, these totals also include the vast areas located outside the watershed. GIS information regarding highways is presented in the form of thousands of separate line segments, most of which do not contain data related to the length of the segment.

Highways

Major highway mileage was determined by first placing a scaled watershed outline overlaid upon a regional highway map, then measuring the total number of highway miles contained within the watershed outline. Major highways include interstates, U.S. highways, and State routes. Based upon this analysis, there are approximately 310 highway miles within the EFLMR watershed.

During actual or anticipated snow and ice events, crews treat these major highways almost exclusively with sodium chloride (salt). At times when the temperature is less than 15 degrees Fahrenheit, small amounts of liquid calcium chloride may be sprayed in high intensity areas such as hills and intersections. The application of calcium chloride allows the sodium chloride to continue to be effective to temperatures as low as 0 degrees Fahrenheit. However, sodium chloride accounts for more than 99 percent of the snow and ice treatment application.

The Ohio Department of Transportation (ODOT) uses spot spray application of Roundup for vegetation control along guardrails and other difficult to access areas. The vast majority of vegetation control is accomplished through mechanical means.

Utility Easements

Based upon telephone interviews with representatives from Cinergy Corporation, during 1997 all utility easements were maintained through a combination of manual and mechanical means. During 1997, no chemical applications were used for vegetation control.

Railroads

Repeated attempts to contact railroad representatives were unsuccessful. Follow up efforts will be conducted and included as an addendum to this report.

II.3.b. Highway and Infrastructural Chemical Inventory

The Ohio Department of Transportation reported spot spray application of Roundup Pro for weed control primarily along guardrails. According to survey responses, two applications were made consisting of 100 gallons each of 2.5 percent of active ingredient over 75.35 road miles.

Section II.4 Chemical Use Analysis

This section presents the chemical use data obtained through the various survey methods described in the previous sections along with extrapolation and analysis of agriculture, horticulture, and highway/infrastructure chemical use throughout the entire EFMLR watershed.

Section II.4.a. Agricultural Chemical Use Analysis

Preserving and improving the quality of the water resources of the EFLMR watershed are two key goals. With the increasing demands upon Lake Harsha to be a reliable source of clean, safe drinking water, it is imperative that a proactive approach be taken to ensure that this valuable resource be maintained. With 50 percent of the watershed being in some form of agricultural utilization, efforts are certainly needed to address concerns that are associated with this industry.

Figure II-12 shows the location of fields included among the agricultural chemical survey results. Corn acreage within the watershed was 47,685 in 1997. Based on the information collected, 90 percent to 95 percent of this acreage received some form of atrazine herbicide. Most farmers are using the chemicals at the rate of two pounds of active ingredient per acre. This would indicate that between 43,000 and 45,500 acres will have atrazine applied for weed control. This would translate to atrazine applications between 86,000 and 91,000 pounds. Harness was another herbicide that was used on the remaining 2,300 to 4,500 acres. Harness and atrazine are restricted pesticides and have a ground water advisory statement.

Table II.20 provides an inventory of chemicals associated with corn production and the estimated total amount of each herbicide applied in the watershed during 1997.

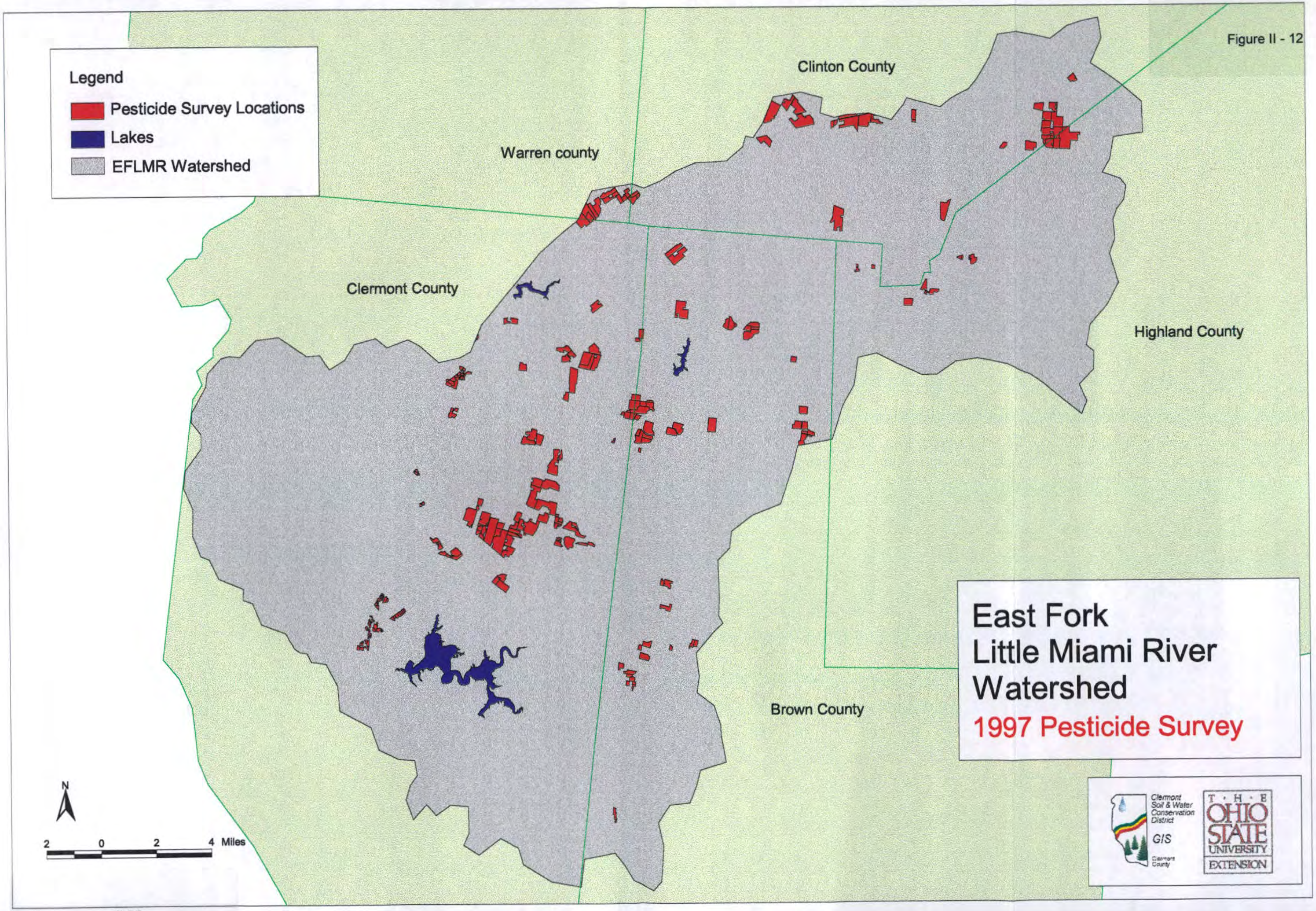
Table II.20 Estimated Chemical Use in Watershed - Corn Production

Chemical Name	% Use Watershed	Total Acres	Total Amount
Etrazine 4L (Bladex & Atrazine)	46%	1,897	2,371 qts.
Bicep II (Dual II & Atrazine)	36%	1,477	2,954 qts.
Harness	12%	519	519 qts.
Lariat (Lasso & Atrazine)	4%	159	636 qts.
2,4-D	2%	71	35 qts.
Total	100%	4,123	N/A

Herbicides

Atrazine is the corn herbicide that has received considerable attention regarding water quality. Restrictions regarding the use of this chemical have increased in recent years. Farmers are more aware of the concerns surrounding the use of this herbicide. Restrictions are in place that limits application within 200 feet of a lake or reservoir. A 66 foot buffer strip has been established for application near a stream. If the land is highly erodible, the 66 foot buffer zone must be planted in a cover crop. For mixing and loading, a 50 foot set back is required to protect wells and streams.

Figure II - 12



East Fork Little Miami River Watershed
1997 Pesticide Survey

With the financial pressure and small profit margins (or no profit) that has existed for the past three years, the use of atrazine will continue. Atrazine provides the best weed control for the dollar spent. As the Roundup Ready corn becomes more available and affordable, this technology should become more acceptable. Farmers are aware of the concerns surrounding atrazine and do not want more restrictions or the complete loss of this valuable herbicide. Chemicals are expensive and farmers can not afford to waste money.

Other herbicides applied within the watershed are Dual II, Bladex, 2,4-D, Lasso, Harness and Roundup. These chemicals are typical applied with atrazine or in a pre-mix combination.

Nearly double that of the corn acreage, soybeans were the major crop grown in the watershed during 1997. The 88,823 acres represents 56 percent of the total production agricultural land. The herbicide of choice is Roundup. With the advantages that exist with Roundup from an economic stand point, weed control results and reduced labor costs, the use of this technology will continue to increase. In 1999, there could be a 65 percent to 75 percent use of Roundup Ready soybean across the watershed. In those areas where the utilization of this technology has lagged behind, the trend is that more farmers are adopting this method. The areas of the watershed that produce the majority of the soybean are presently utilizing this technology on 75 percent of the acreage. With the advantages associated with the use of Roundup from both the farmers' viewpoint and a water quality standpoint, this certainly presents an encouraging picture for the future. Table II.21 lists the estimated chemical use in the watershed for the production of soybeans.

Table II.21 Estimated Chemical Use in Watershed for Soybean Production

Chemical Name	Total Acres	Total Amount
Canopy (Classic & Lexone)	1,346	210 qts.
Turbo (Sencor & Dual II)	1,048	1,376 qts.
Dual II	334	443 qts.
Sencor	111	42 qts.
Squadron (Sceptor & Prowl)	329	494 qts.
Tricept (Sceptor & Treflan)	1,009	1,160 qts.
Sceptor	481	32 qts.
Assure II	542	13 qts.
Roundup	247	247 qts.
Lasso	104	234 qts.
Pursuit	203	25 qts.

Due to the combination of herbicides such as Tricept, Squadron, Turbo and Canopy the total amount of each specific chemical is more difficult to determine. For example, Sencor was applied to 19 acres not 111 because of the pre-mix Turbo. Sceptor was applied to a total of 1,819 acres not 481 acres due to the application of Squadron and Tricept. The survey did not indicate a large number of acres with Roundup even though there is an extensive amount of Roundup Ready soybean being grown in the watershed.

Fertilizers

Fertilizers are also a concern when considering water quality. Based on the Ohio Agricultural Statistics and Ohio Department of Agriculture Annual Report an expected yield of 140 bushels is reasonable for the watershed. The Tri-State Fertilizer Recommendations for corn for this desired yield would be 160 pounds of nitrogen per acre. Data collected would indicate that farmers (83 percent) are using 200 plus pounds per acre. Based on the corn acreage of 47,780, nitrogen application is between 7,644,800 and 10,511,600 pounds of actual nitrogen in the watershed. Corn is very dependent upon nitrogen for high yields. It would appear that farmers are applying too much nitrogen. Applying 220 pounds of nitrogen per acre should produce 180 plus bushels per acre. This would appear to be a waste of money for the farmers and may be exposing the water resources to nearly 3,000,000 pounds of nitrogen that is not required. An educational effort is necessary to inform farmers regarding this matter.

Phosphorus is the second major nutrient of concern. The recommendations for phosphorus are harder to state in an across the board application due to varying levels of soil fertility, pH and the cation exchange capacity of the soil. To produce one bushel of corn, phosphorus is required at the 0.37 pounds per acre (P_2O_5) rate. This is strictly a maintenance level of production. To produce 140 bushels of corn per acre a farmer would need to apply 52 pounds of actual phosphorus per acre. If average fertility levels (30 to 60 pounds/acre) exist in the field then this application rate would be adequate. Application rates can exceed 100 pounds per acre if soil fertility levels are low. If soil fertility is below average (20 pounds available/acre), to produce a 140 bushel yield would require an additional 75 pounds of actual phosphorus. Based on the data collected from the farmers' survey and the vendors' responses, farmers would appear to be applying excessive phosphorus. This data would indicate that 70 percent of farmers are applying phosphorus at the rate of 90 pounds or more per acre. Application of 100 pounds or more are being applied by 63 percent of the farmers surveyed. If application rates were reduced by 40 pounds/acre across the watershed there would be a reduction of 1,911,200 pounds of actual phosphorus applied.

The third nutrient of concern is potassium. Corn harvested as grain removes 0.27 pounds of K_2O/acre. However, to make a potassium application recommendation that would be applicable to all farms is more difficult than phosphorus. The reason being the numerous combinations of soil fertility level, cation exchange capacity, and desired yield. An average soil test would have a soil fertility level of 200 to 260 pounds/acre, a CEC of 10 and desired yield of 140 bushels /acre. An application of 60 pounds/acre of actual potassium would be required. Data collected would indicate that farmers are applying too much potassium. Vendors stated that farmers are applying between 100 to 140 pounds/acre. The surveys indicated that farmers are applying potassium at the rate of 120 to 149 pounds/acre (27 percent) and 150+ pounds/acre (68 percent). It would appear that double the recommended amount of potassium is being applied. A reduction of 60 pounds/acre would result in 2,866,800 pounds of potassium not being applied.

As stated previously, some farmers could be applying higher rates of phosphorus and potassium to their corn crop to provide nutrients for the next year's soybean crop. Not all farmers utilize this farming practice. A corn/soybean rotation is not practiced by all farmers. Excessive nitrogen is being applied and it is very likely that phosphorus and potassium are being applied at rates that are higher than recommended.

Farmers in the watershed are producing 88,729 acres of soybean. Approximately 75 percent of this acreage receives zero nitrogen. The remaining acres have less then 30 pounds/acre of nitrogen applied. The impact on water quality is not a concern.

Phosphorus is removed at the rate of 0.80 pounds/bushel produced. A typical field would need 30 to 40 of P_2O_5 pounds/acre to produce a yield range of 40 to 50 bushel/acre. The vendors indicated that farmers are purchasing between 50 to 90 pounds of phosphorus per acre. Farmers indicated that they are utilizing 60 to 100 pounds/acre (64 percent), 30 to 59 pounds/acre (20 percent) and 0 to 29 pounds/acre (16 percent). Based on this information, farmers are applying phosphorus at rates that are excessive. If 70 percent of farmers would reduce their application rate by 40 pounds/acre there would be a reduction of 2,484,412 pounds across the watershed.

Soybeans remove potassium at the rate of 1.40 pounds/bushel harvested. A yield of 40 to 50 bushels/acre would consume 56 to 70 pounds/acre. Tri-State Fertilizer Recommendation for a field with average fertility characteristics of 200 to 260 available K and a CEC of 10, producing a 40 to 50 bushels/acre yield would be 75 to 90 pounds/acre. The vendors indicated that farmers are applying potassium at the rate of 75 to 110 pounds/acre. The survey indicated that 29 percent of the farmers are applying K at the recommended rate. Application rates of 150 to 180 pounds/acre were being utilized by 47 percent of the farmers surveyed. An additional 8 percent were applying K at the rate of 120 to 149 pounds/acre. This would suggest that 55 percent of the farmers are applying excessive K. If application rates would be reduced by 50 pounds/acre in the highest application range, a 2,085,131 pound reduction would result. Additional reduction would occur if the additional 8 percent would bring their application rates more in line with recommendation levels.

Wheat production is limited in the watershed. Few chemicals are utilized in the production of the wheat crop. Fertilizer usage falls in the recommended range. The impact upon water quality would be very limited.

Tobacco acreage is extremely small in the watershed. The use of fertilizers can be heavy, especially nitrogen. Chemical usage for insect and disease control is more prevalent than for other crops. Due to the small acreage the overall impact to water resources is limited.

Forage production is not utilizing fertilizers and chemicals to any great extent. The impact on the watershed is very limited.

Section II.4.b. Horticultural Chemical Use Analysis

This section addresses the status of chemical application by homeowners and horticultural businesses in comparison to the official recommendations of Ohio State University Extension. This section is divided by the types of horticultural operations including home lawn care, grounds maintenance, golf course, nursery/greenhouse, fruits, and vegetables.

Home Lawn Care

Home lawn care involves many horticultural practices such as proper grass selection, seeding, mowing, water, core aeration in addition to lawn fertilization, weed control, and pest management. Typically a recommended fertilization program is a four step program. Fertilizers should be applied once in May, once in July, once in September, and once more in November. However, if someone only fertilizes their lawn once, late fall fertilization should be the best option. If two lawn fertilizations are made, fertilization once in late fall, and once in spring would work well. Fertilizer ratios of 3-1-2 to 5-1-2 are preferred. The recommended rate is about 0.5 to 1.5 pounds actual nitrogen per 1,000 sq. ft. One recommended fertilizer for home lawn is the one with N-P-K ration of 24-4-12 at 2 to 4 pounds per 1,000 sq. ft.

The fertility programs used by national lawn care companies are typically 4 to 5 steps, similar to what Ohio State University Extension recommends for a high maintenance program. The fertility programs by local lawn care companies varied greatly based on the knowledge of business owners. There is a great deal of fertilizer application misuse by both homeowners and some lawn care companies. One good example is the application of fertilizers 10-10-10 or 19-19-19 for grasses instead of recommended N-P-K ratios of 3-1-2 to 5-1-2. This practice resulted in the over application of phosphorus and potassium, and under appliation of nitrogen. Some of the commercial blends like Scotts' or TrueGreen ChemLawn lawn fertilizers have too much nitrogen, and too little phosphorus and potassium.

Weed control programs in home lawns are pretty standard. Many homeowners applied pre-emergent herbicides for the control of crabgrasses in late winter to early spring as recommended by manufactures. For broadleaf weeds, many homeowners or commercial companies applied 2,4-D, Dicamba, and MCPP as recommended. However, these products were put down too early resulting in the application of additional herbicides later in the season. Best timing for dandelion control is when it reaches puffball stage. That developmental stage is typically May.

For insect control such as white grubs, misuse of insecticides is much more widespread. Many garden centers start selling grub control chemicals in spring. That leads to the application of many insecticides at the wrong time. The correct timing for most grub control materials is in late July and early August. One chemical that should be applied earlier is GrubEx. The proper timing for GrubEx is mid May.

Grounds Maintenance

Many grounds maintenance companies are involved in mulching, fertilization, weed control, and pesticide. There is a very large variation among these companies in terms of the levels of expertise. There are many hundreds of ornamental plant species with 10 to 15 common insect and disease problems. Misdiagnosis does occur and leads to misapplications of pesticides. The companies we received survey responses from did not seem to fall in that category since they make use of Extension offices, attend pesticide applicator training, and tend to follow recommendations by Ohio State University Extension.

Golf Courses

Golf course superintendents go through intensive training each year since golfers and greens committees demand perfection. Several pesticides and fertilizers are applied on the golf courses. Most of golf courses follow the recommendations by Ohio State University Extension very closely. Based on the survey received from one golf course superintendent in Brown County, it appears that very little misuse exists.

Nursery/Greenhouses

There are several small nurseries and greenhouses located in the watershed. Many bulletins have been developed for specific crops in the floriculture industry by Ohio Florists' Association in close cooperation with Extension specialists at Ohio State University. Most nursery and greenhouse growers tend to spray less than what are recommended in OSU Extension bulletins. For example, there are bulletins on geraniums, garden mums, bedding plants, and hanging baskets. With nurseries, growers can grow an assortment of trees, shrubs, perennials, ground covers, and ornamental grasses. No two growers have identical crop makeup in either nurseries or greenhouses, especially with smaller operations. Many growers will purchase plants from other growers (to resale), in addition to the plants they grow themselves. Generally chemical application by our greenhouse and nursery growers is very low, mainly due to higher tolerance to insects, diseases, and weeds compared to that of flower growers in Western parts of Cincinnati or nursery growers in Lake County, the nursery capital of the mid-west.

Fruits

The recommended spray programs are listed in the OSU Extension bulletins "Commercial Tree Fruit Spray Guide" and "Commercial Small Fruit and Grape Spray Guide." A typical spray program for apple trees is listed in Table II.22

Table II.22 Spray Program for Apple Trees

Developmental Stages	**Insecticides**	**Fungicides**
Dormant to silver tip	None	Bordeaux mix plus oil and Ridomil 2E if needed
Green Tip	Apollo SC at 4-8 fl. oz for mite control	Benlate 50 WP at 8-12 oz./acre or fungicides
Half-inch green	Thiodan 3 EC at 2.67 - 4 qt./acre or other insecticides	None

Table II.22 Spray Program for Apple Trees (Continued)		
Developmental Stages	**Insecticides**	**Fungicides**
Tight cluster	Savey 50 WP at 4-8 fl./acre or other miticides	Mancozeb 80 WP at 3 lbs./acre or other fungicides
Pink	Carzol 92% SP at 2 lbs. Per acre or other insecticides.	Bayleton 50 DF at 2-8 oz plus Captan at 6 lbs. per acre or other fungicides
Bloom	None to save honeybees!	Fungicides plus Streptomycin 17 W at 2 lbs. per acre
Petal Fall	Guthion 50 WP at 2-3 lbs. Per acre and Lannate 90 SP at 1 lb. per acre	Nova 40 WP at 5-8 oz. per acre
First and second cover	Ziram 76 DF at 6-8 lbs. per acre or other insecticides	Mancozeb 80 WP at 3 lbs. per acre or other fungicides
Third cover	Sevin EXL at 3-4 qt. per acre or other insecticides	Captan 50 WP at 6 lbs. per acre or other fungicides
Summer cover sprays	Imidan 70 WP at 2.13 - 5.3 lbs. per acre or other insecticides	Captan 50 WP at 6 lbs. per acre or other fungicides

Spray programs are developed from many years of field research. In the watershed, fruit growers with significant acreage follow the spray programs very closely. The common fruits grown in the watershed are apples, pears, peaches, blackberries, blueberries, and raspberries. Growers with few fruit trees and bushes sprayed very little since they do not depend on the fruit production as a significant source of their income.

In general, successful fruit growers make use of both soil testing and tissue testing for their fertilizer recommendations. The desirable soil test maintenance levels are listed in Table II.23.

Table II.23 Desirable Soil Test Maintenance Levels

Nitrogen	Phosphorus	Potassium
40 to 150 lbs. of N per acre	30 - 90 lbs. of available P per acre	200 - 400 lbs. of exchangeable K per acre

A fruit grower in Clermont County did not apply fertilizers in his orchard in 1997 while another grower in Highland County (outside the watershed) applied 250 pounds. of nitrogen, 125 pounds of phosphorus, and 125 pounds of potassium. One grower experienced severe under fertilization while the other experienced over application of nitrogen and phosphorus.

Vegetables

Common vegetables grown in the watershed are tomatoes, peppers, pumpkins, green beans, and sweet corns. Chemicals labeled for each crop are different. The fertility program for tomatoes is listed in Table II.24

Table II.24 Fertility Program for Tomatoes

Nitrogen	Phosphorus (P_2O_5)	Potassium (K_2O)
Broadcast 60-80 lb N/A prior to planting. Sidedress with an additional 30-60 lb N/A with calcium nitrate.	100-175 lbs.	200-350 lbs.

Vegetables are definitely not pest free. There are many pesticides that need to be applied on vegetable crops if high quality crops are expected. Vegetable growers seem to have applied much fewer chemicals than the OSU Vegetable Production Guide called for. This is likely due to a combination of economics and good pesticide management practices. Most vegetable growers sell their crops at local farmers' markets where consumers are willing to accept some imperfections on the produce.

Generally the pesticides applied by horticultural businesses in the watershed were minimal. Fertilizers represent the largest percentage of chemical input in both commercial horticulture and residential areas. In the future, we might see more small farms specializing in horticultural crops especially flowers, vegetables, trees and shrubs, and sod. We might see more housing developments, and possibly more golf courses. Education of small scale farmers, developers, and homeowners will be critical to maintain and improve the water quality in the watershed.

Section II.4.c. Highway and Infrastructural Chemical Use Analysis

Based upon the estimated 310 miles of major highway within the EFLMR total watershed, application of 2,973 tons of salt and 822 gallons of 2.5 percent active ingredient Roundup Pro are estimated to have been applied.

SECTION III CLERMONT COUNTY

Nearly half of the entire watershed is located within Clermont County. In addition, one of the most significant features of the watershed (Harsha Lake) is also located in Clermont County. Therefore, this report also examines agriculture, horticulture, infrastructure land use, and chemical application practices as they pertain specifically to Clermont County. The results of this analysis are presented in this section.

Section III.1 Agricultural Land Use in Clermont County

As shown in Figure III.1, the EFLMR watershed contains 319,482 acres of which 155,384 acres are in Clermont County. Crops and acreage during 1997 are shown in Table III.1

Table III.1 Clermont County EFLMR Watershed Agricultural Land Usage

Land Usage	Acreage	Percentage
Corn	14,707.5	9.5%
Soybean	24,939.2	16.1%
Wheat	780.9	0.5%
Forages	7,059.2	4.5%
Tobacco	39.7	0.02%
Forest	45,954.4	29.6%
Non-Agri	61,903.1	39.8%
Total	**155,384**	**100%**

The agriculture acreage totals were determined by the Arc View 3.0 program based on the mapping of the watershed as shown in Figure III.2. A discussion of each individual crop will provide more details concerning chemical and fertilizer usage.

<u>Section III.1.a.</u> <u>Agricultural Management</u>

Sediment is a source of water pollution. Conservation tillage is the number one defense against sediment. Reducing soil loss also decreases the potential pollution problems associated with fertilizers and pesticides. Conservation tillage is designed to leave a residue on the soil surface. The residue protects the soil surface from erosion by absorbing the energy of raindrops, thus reducing soil particle detachment. Residue reduces surface crusting and sealing which improve water infiltration. A third benefit of residue is the slowing of the velocity of the runoff water. This can allow particles in the runoff to be redeposited.

Conservation tillage leaves residue that is important in reducing runoff. Due to the protection that residue can provide, it was important to determine the type of tillage practices that Clermont County farmers were using. Farmers were asked to state the type of tillage system that they had selected for each field that they were farming. The three tillage practices that farmers were asked to choose from were conventional, minimum and no-till. The data collected representing agriculture management practices are shown in Table III.2.

Figure III - 1

East Fork Little Miami River Watershed
Clermont County Portion

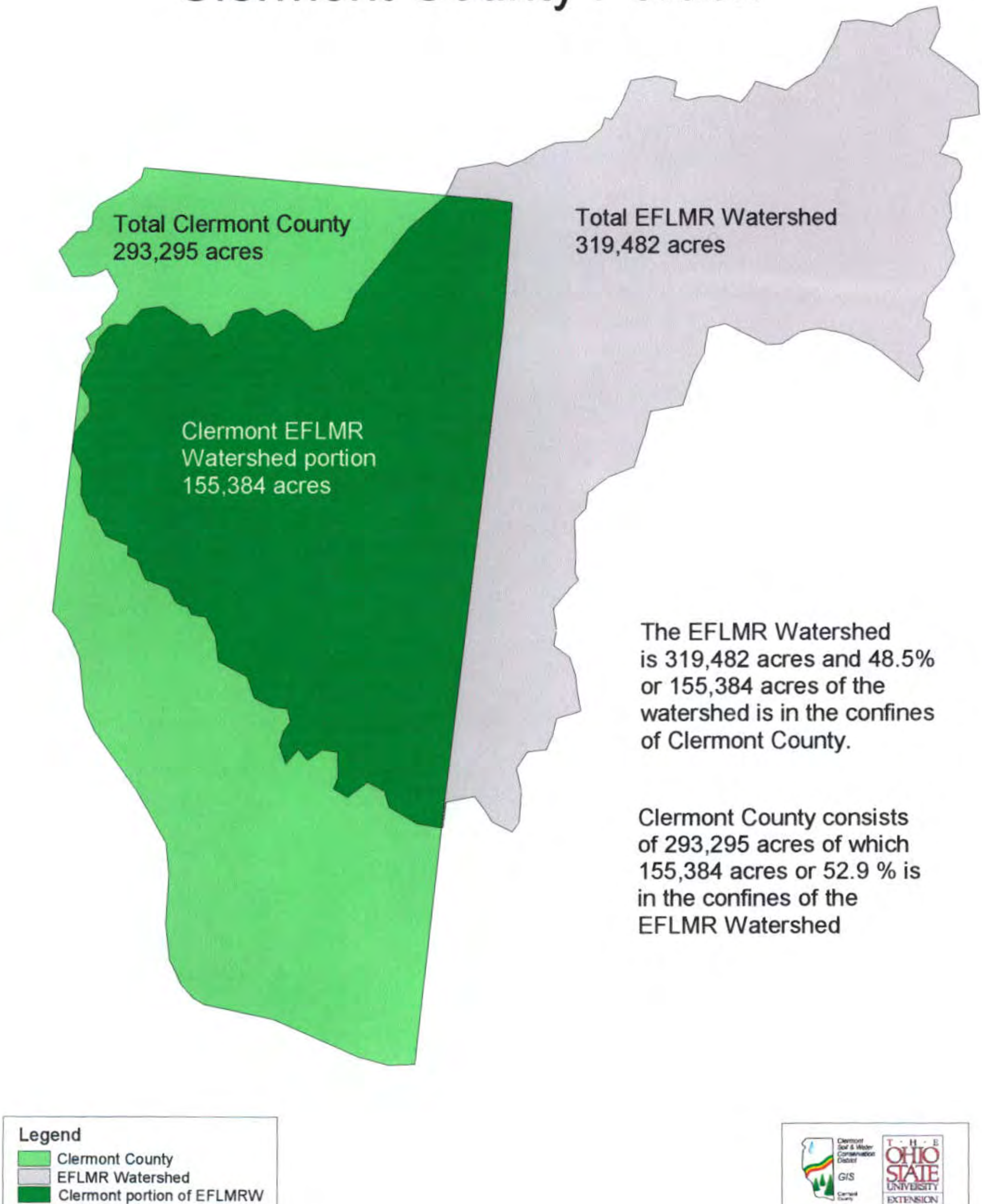


Table III.2 Tillage Practice by Crop in Acres and Percent - Clermont County

Tillage Practice	Corn	Soybean	Wheat
No-till	173 (6.5%)	276 (12.7%)	0
Minimum	122 (4.6%)	367 (16.8%)	21.6 (100%)
Conventional	2,365 (88.9%)	1,539 (70.5%)	0
Total	2,660	2182	200

Clermont County farmers have continued to use conventional tillage for both corn and soybean. These percentages are higher than the rest of the watershed. Table III.3 and III.4 provides a comparison of tillage practices used by farmers in the total watershed, the watershed outside of Clermont County, and inside Clermont County for both corn and soybean.

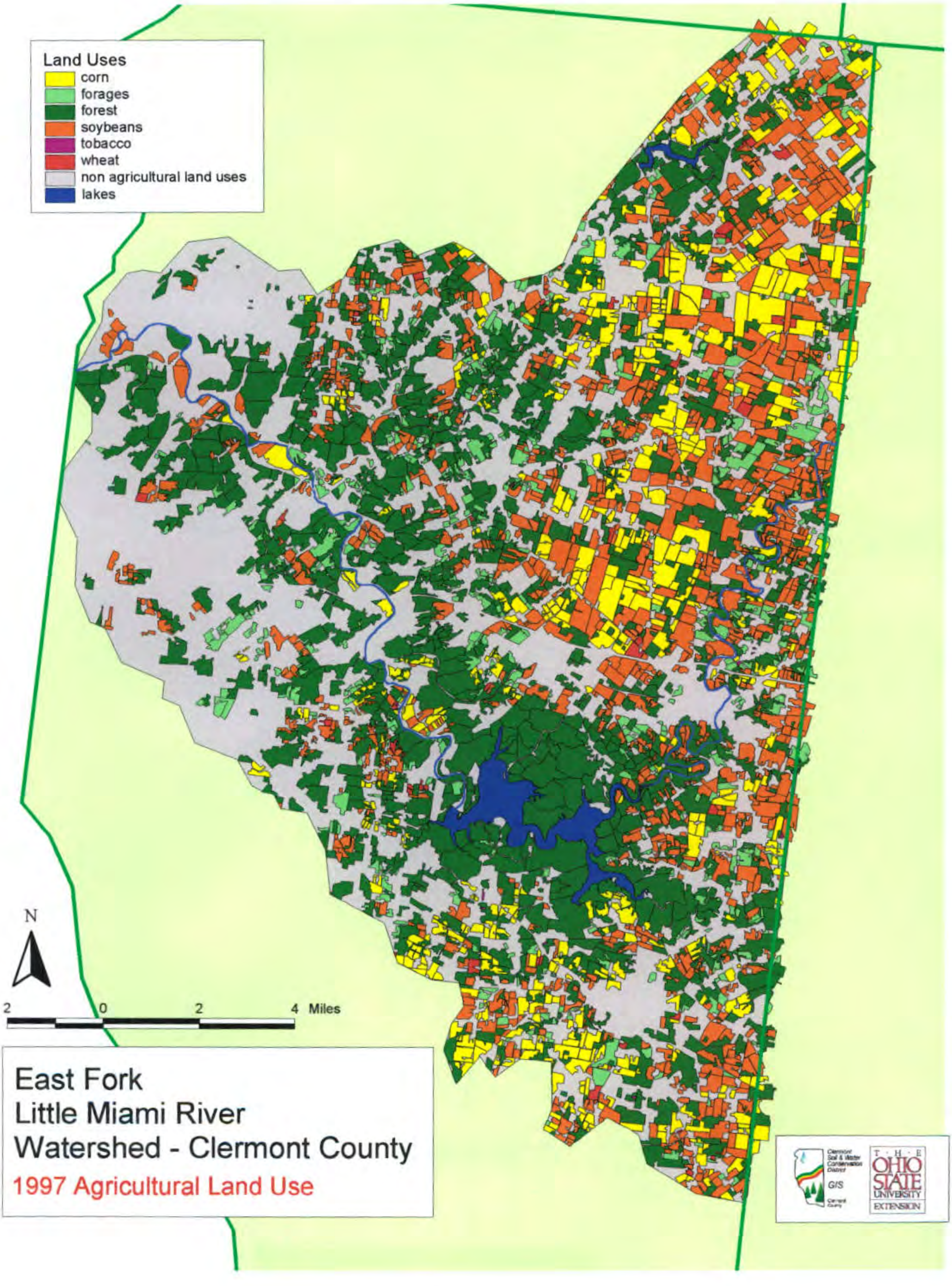
Table III.3 Tillage Practices Used by Farmers in the Total Watershed, Watershed Outside of Clermont County and Clermont County - Corn Production

Group	No-till %	Minimum %	Conventional %
Whole Watershed	21.2%	8.2%	70.6%
Outside Clermont	47.6%	14.6%	37.8%
Clermont	6.5%	4.6%	88.9%

Table III.4 Tillage Practices Used by Farmers in the Total Watershed, Watershed Outside of Clermont County and Clermont County - Soybean Production

Group	No-till	Minimum	Conventional
Whole Watershed	15.2%	42.6%	42.1%
Outside Clermont	17.6%	65.7%	16.7%
Clermont	12.7%	16.8%	70.5%

These tables show that Clermont County farmers are using conventional tillage (89 percent) to a much greater extent than farmers in the rest of the watershed (38 percent) in the production of corn. An examination of tillage practices associated with soybean production indicates a similar situation. The farmers in Clermont County use conventional tillage in the production of soybean 71 percent of the time as compared to 17 percent for the rest of the watershed. Soils in Clermont County are very poorly draining which creates tillage difficulties. Many farmers believe that conservation tillage does not work as well as conventional tillage. Residues from conservation tillage can cause the soil to remain cooler and also slow down the drying process.


Land Uses
corn
forages
forest
soybeans
tobacco
wheat
non agricultural land uses
lakes
N
2
0
2
4 Miles
East Fork
Little Miami River
Watershed - Clermont County
1997 Agricultural Land Use
GIS
THE OHIO STATE UNIVERSITY EXTENSION

Section III.1.b. Agricultural Chemical Inventory - Clermont County

Corn

Atrazine is the most widely used corn herbicide. Nearly 100 percent of all corn acreage will have some form of atrazine applied. What was seen across the watershed in terms of atrazine use was also evident in Clermont County. Table III.5 provides the breakdown of the herbicides utilized in Clermont County.

Table III.5 Chemical Usage Corn - Clermont County

Chemical Name	Acres
Extrazine 4L*	1,819
Bicep II*	815
Harness	207
Lariat*	25
Lariat* & 2,4-D	71
Dual II & Atrazine	18
Warrior*	54
Roundup	11
Total	3,020

* These herbicides contains some form of atrazine.

There was a total of 3,020 acres of corn production reported in Clermont County. Of this total there was 2,802 acres (93 percent) that had some form of atrazine applied. Atrazine will continue to be the herbicide of choice as long as it maintains its cost benefit and weed control effectiveness.

Soybean

Roundup Ready soybean are being used more and more each year. Vendors estimated that 50 percent of the soybean grown in the county were Roundup Ready soybean. There were a wide variety of herbicides utilized and these are summarized in Table III.6

Table III.6 Chemical Usage Soybean - Soybean

Chemical	Acres
Turbo	679
Canopy	178
Canopy & Assure	496
Lasso & Blazer	80
Lasso & Basagran	25
Squadron	293
Dual & Sencore	74
Dual & Roundup	11
Dual & Pursuit &Cobra	25
Roundup	26
Canapy & Assure II & Classic	46
Total	1,933

There was 1,933 acres reported that provided information regarding chemical usage.

Fertilizer Usage

-- Corn

Survey information was available for 2,607 acres concerning fertilizer usage. The typical farmer was applying 220 to 230 pounds/acre nitrogen, 110 to 115 pounds/acre phosphorus, and 150 to 160 pounds/acre potassium. Table III.7 has the breakdown of the acreage and fertilizer use in pounds per acres.

Table III.7 Nitrogen - Clermont County

Application Rate	Number of Acres	Percentage of Acres
120	97	3.7%
200 to 210	218	8.4%
220 to 230	2,292	87.9%
Total	2,607	100%

Table III.8 Phosphorus - Clermont County

Application Rate	Number of Acres	Percentage of Acres
55 to 65	115	4.4%
100 to 110	11	0.4%
110 to 120	2,481	95.2%
Total	2,607	100%

Table III.9 Potassium - Clermont County

Application Rate	Number of Acres	Percentage of Acres
120 to 130	225	8.7%
150 to 160	2,371	90.9%
180 +	11	0.4%
Total	2,607	100%

-- Soybean

There was very limited acreage recorded for Clermont County. A total of 187 acres were reported with fertilizer rates indicated. The data indicated the following: nitrogen - zero, phosphorus - 50 pounds/acre, and potassium - 100 pounds/acre. There were 1,515 acres reported with detailed chemical information but no fertilizer application rates provided. Some farmers do not apply fertilizer when soybean follows corn in the crop rotation.

Section III. 2. Horticultural Land Use in Clermont County

This section addresses commercial horticultural land use, commercial horticultural chemical use, and residential chemical usage in the Clermont County portion of EFLMR watershed. Commercial horticulture is defined as fruit and vegetable farms, greenhouses, nurseries, Christmas tree farms, parks, and golf courses. Horticultural chemicals include insecticides, fungicides, herbicides, and fertilizers. Residential horticultural chemical use is defined as the typical chemical usage by homeowners in their yard and garden.

Thirty three horticultural businesses were identified in Clermont County. Each of these horticultural businesses are labeled on Figure III-3. During 1997, there were 4 vegetable farms, 6 fruit farms, 4 parks, 15 nurseries, 2 sod farms, and 2 golf courses in the Clermont County portion of the watershed.

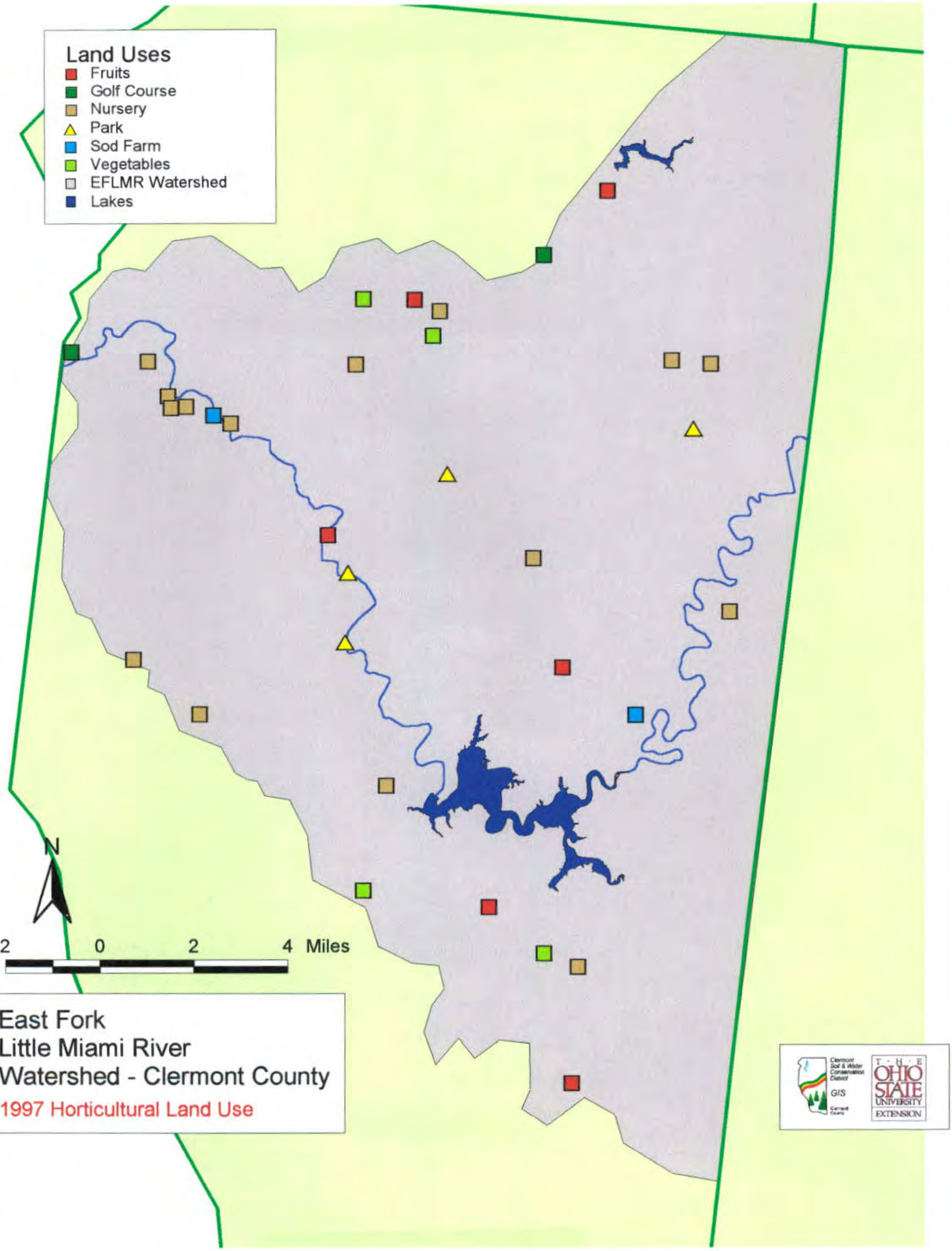
Most of the horticultural businesses in Clermont County are very small in comparison to agricultural farms. Some vegetable growers had as little as half an acre while others had as many as 57 acres. Fruit farms are quite small as well. Small fruit farms average 5 acres while larger operations maybe as large as 50 acres. The nurseries in the watershed are in the 2 to 5 acre range. Parks are in the range of 4 to 40 acres. Sod farms are in the ranges of 10 to 15 acres. The size of golf courses are 40 acres or larger. No total acreage of horticultural businesses was calculated since many horticultural business owners did not return our surveys. In addition, the aerial photos did not have enough resolution for us to draw the boundaries. However, total acreage of horticultural operation in Clermont County is insignificant in comparison to agricultural production.

Section III.2.a. Commercial Horticultural Management in Clermont County

Commercial horticulture covers the production of a very diverse group of plants ranging from fruits, vegetables, trees, shrubs, and turfgrasses. There are several hundred plant species involved with nurseries, greenhouses, garden centers, and parks along with 10 to 20 species connected with fruit and vegetable farms. The chemicals labeled for each type of operation are very different from another. Horticultural management is very different from one operation to another even within each type of operation depending on the expectations of owners and prospective consumers.

The common chemicals applied in the commercial horticultural business are insecticides, fungicides, herbicides, and fertilizers. The margin of error for such crops as bedding plants, fruits, vegetables, nurseries, and golf courses is very small. This is why chemical input in these types of horticultural operations is higher than agricultural crops on a per acre basis. However, the horticultural industry as a whole is still too small to present a significant threat to the watershed. In addition, some horticultural operations such as fruit farms grow sod between their crops for erosion control and ease of management. Greenhouse crops are typically produced in an enclosed area on very small acreage, inhibiting the migration of chemicals to the stream. Although golf courses are intensively managed, most of the chemicals applied are utilized by turfgrasses, and many of the insecticides and fungicides are utilized by soil microorganisms.

Figure III - 3



Land Uses
Fruits
Golf Course
Nursery
Park
Sod Farm
Vegetables
EFLMR Watershed
Lakes
N
2
0
2
4 Miles
East Fork
Little Miami River
Watershed - Clermont County
1997 Horticultural Land Use

Section III.2.b Commercial Horticultural Chemical Inventory

Since most of the horticultural businesses occupy small acreage in comparison to agricultural farms, the labeled chemicals applied by different horticultural businesses are very different, especially between food production horticulture and ornamental horticulture. Five different surveys were designed so that each pesticide usage survey is specific for the types of operation, i.e. orchard or golf course. Copies of the horticultural surveys were found in Appendix E.

Horticultural business owners are not required by law to provide any of the pesticide usage or land use information to Ohio State University Extension, but every effort was made to ensure the highest possible response rate. Surveys were sent to every pesticide applicator that was involved in a horticultural business in Brown, Clermont, Clinton, and Highland Counties. The mailing list used in the comprehensive survey was generated from a list of commercial and private pesticide applicators by the Section of Pesticide regulations, Ohio Department of Agriculture. Pesticide use and land use surveys were sent to 35 fruit growers, 41 vegetable growers, and 114 turf and ornamental professionals in Brown, Clermont, Clinton, Highland, and Warren counties. Those surveys included questions about the types of plants grown, acreage, and the amounts of applied chemicals such as insecticides/miticides, fungicides, herbicides, and fertilizers.

A total of 52 responses were received after two separate mailings, numerous phone calls, personal visits, and offering small cash awards as well as Ohio State University Extension educational bulletins. Out of the 52 returns, 15 were from fruit growers, 14 from vegetable growers, and 23 from turf and ornamental professionals. Many of the fruit farms either went out of business before 1997 or were located outside of the watershed. Out of the 52 responses received, 9 responses came from horticultural businesses in the Clermont County portion of the watershed. The responses came from vegetable farms, orchards, parks, and a nursery. The chemicals applied by these businesses are tabulated in Microsoft Excel for later retrieval.

Based on the survey results, the horticultural industry that is most intensively managed is golf courses. There are two golf courses identified in the Clermont County portion of the watershed during 1997. The common insecticides used on the golf courses were Merit 0.5G, Scimitar, and Crusade 5 G. The common golf course herbicides are Presan 7G, Dimension, and Confront, MecAmine D. The common fungicides were Daconil, Heritage, and Chico 26019. Fertilizer applications on golf courses were 155 pounds of nitrogen, 7.75 pounds of phosphorus, and 15.5 pounds of potassium per acre.

The second most intensively managed horticultural operation is fruit farms or orchards due to the many insects, fungi, and weeds attacking fruits. Fruit growers typically sprayed insecticides 10 times during a season using several insecticides including Thiodan, Sevin, and Imidan. Common fungicides used by fruit growers are Benlate, Captan, and Ziram.

Vegetable growers appear to have applied much fewer chemicals. The commonly applied insecticides by vegetable growers were Sevin XLR, and Malathion while fungicides were Bravo and Captan. The commonly applied herbicides by vegetable growers are Devrinol, and Dual 8 E.

The nurseries in the watershed were not very intensively managed. Very little insecticides were used. Common herbicides used in the nurseries were Surflan, Poast, and Roundup.

The horticultural operation with the least amount of the chemical input was parks. The common insecticide applied was Sevin while the commonly applied herbicide was Roundup. The common fungicide applied was Deconil.

One of the largest sectors of the horticultural industry not including the mapping of horticultural land use and chemical usage is lawn care and grounds maintenance. Since lawn care and grounds maintenance companies mainly service home lawn or yards, we could only find out the typical chemical application of these companies. Based on the survey results we received from 5 local lawn care companies, the chemical applications were similar to homeowner management practices. For example, common herbicides applied were 2,4-D, and Roundup. Common insecticides applied were Merit, Diazinon, and Malathion. Very few fungicides were used. This information is further discussed in Section III.2.c.

Unlike the agricultural activities in the watershed which are dominated by corn or soybean, horticultural businesses deal with many plant species. The makeup of the horticultural plants is very different from one business to another. Hence, pesticides are drastically different for each business. Another complicating factor is that growers may purchase some of the plants they grow from other sources. Some growers even refused to provide the types of crops grown and respective acreage for their crops because the Ohio Department of Agriculture can use the data for crop tax or check-off programs. Without actual responses from each business, to extrapolate the chemical usage to the entire watershed based on selected survey responses would yield incomplete or inaccurate data.

Section III.2.c. Residential Horticultural Chemical Inventory

The objective of the residential survey was to determine the average pesticide and fertilizer usage by homeowners in the watershed. The data will be used to determine the environmental impact that existing and new residential housing development may have on water quality within the watershed.

A comprehensive survey was sent to 900 households in Clermont County. Every attempt was made to ensure that the surveys were user-friendly. As a result, 96 returns were received. Forty six surveys were included in the summary of typical pesticide and fertilizer usage. The remainder of the returns were not filled out properly. Residential lots were divided into 6 categories. These categories included lots that are less than 1/4 acre, 1/4 - 1/2 acre, 1/2 - 1 acre, 1 acre - 2 acres, 2 - 3 acres, and larger than 3 acres. The average total pesticide and fertilizer usage were recorded in Tables III.10, "Summary of Typical Pesticide Usage by Homeowners in Clermont County" and III.11, "Summary of Typical Fertilizer Usage by Homeowners in Clermont County."

Results are listed in Tables III.10 and III.11. The common insecticides used in the home garden and landscape are Sevin dust, Malathion, and Diazinon. The total amount of Sevin applied ranged from 0.17 to 3.5 pounds per yard. Different pesticides have varying impacts on water quality and wildlife such as mallard ducks, fish, and invertbartes according to the fact sheet "Pesticides in Residential Areas-Protecting the Environment" published by Oklahoma State University. A copy of this fact sheet is included as Appendix F. Mallard ducks were used as an indicators of waterfowl status in the watershed. Sevin has a medium relative runoff potential, very small ground water leaching potential and medium toxicity to fish, and very low toxicity to mallard ducks. The half life of Sevin is approximately 10 days. Diazinon has medium relative runoff potential, and large ground water leaching potential. Diazinon has a very high toxicity to both mallard ducks, and fish. It has a half life of 30 days. Malathion has very small runoff potential and ground water leaching potential. However, it is highly toxic to fish. The insecticides that have large relative runoff potential are Amdro (hydramethylnon), Dursban (chlropyrios), Kelthane and (dicofol).

Homeowners use very little fungicides. The most common fungicides used are Captan, Funginex, and Deconil. Captan has very low toxicity to mallards, but is highly toxic to fish. The half day life of Captan is 3 days. Funginex (triorine) has medium runoff potential, and small ground water leaching potential. It has very low toxicity to fish, with a half life of 21 days. Deconil has large runoff potential, and small ground water leaching potential. It is highly toxicity to mallards, fish and invertebrates, with a half life of 30 days.

The amount of residential herbicide application varied significantly. The common pre-emergent herbicides are Preen (Trifluralin), and Pendimethalin. The amount of Preen application varied from 0 to 14.5 pounds per yard. Pendimethalin is the active ingredient in many crabgrass preventers. It has a large runoff potential, and small ground water leaching potential. Its toxicity to mallards is low. However, it is highly toxic to fish. The half life of Pendimethalin is 90 days. The common non-selective herbicide used is Roundup which ranged from 0 to 39.59 pounds per yard. Roundup has a large runoff potential and small ground water leaching potential. Roundup has very low toxicity to fish. The broadleaf weed killer used most often was 2,4-D with amounts varying from 0 to 45.71 pounds per yard. 2,4-D has a small runoff potential and a medium ground water leaching potential. It has a very low toxicity to fish.

Many homeowners applied fertilizers in their garden and landscape. The kinds of fertilizers varied from Miracle-Gro, Scotts Four Step program, to different store brands. The amount of nitrogen applied ranged from 1.69 to 20.36 pounds per yard. The phosphorus applied was from 1.49 to 21.43 pounds per yard. The potassium application ranged from 1.59 to 21.17 pounds per yard.

Homeowner horticultural practices covered a very wide spectrum in our survey responses. There were many organic gardeners while others relied heavily on pesticides and fertilizers. It is difficult to predict what a new group of homeowners will do. Homeowner education will go a long way in reducing unnecessary pesticide and fertilizer application into our water streams.

Table III.10 Summary of Typical Pesticide Usage by Homeowners in Clermont County

Yard Size	Insecticides	Amount of Insecticides	Fungicides	Fungicide Amount	Herbicides	Herbicide Amount
Less than 1/4 acre	Diazinon (lbs.)	0	Benomyl (fl. oz)	0	Broadleaf Weed Killer (fl. oz)	0.125
	Malathion (fl.oz)	0	Captan (fl. oz)	2.7	Preen (lbs)	14.5
	Sevin Dust (lbs.)	0.25	Deconil (fl. oz.)	0	Pre-emergent (lbs.)	0
	Sevin Liquid (fl. oz)	0	Funginex (fl. oz)	0.33	Roundup (fl. oz)	0
1/4 - 1/2 acre	Diazinon (lbs.)	0	Benomyl (fl. oz)	0	Broadleaf Weed Killer (fl. oz)	1.06
	Malathion (fl. oz)	0	Captan (fl. oz)	0	Preen (lbs)	0
	Sevin Dust (lbs.)	0.55	Deconil (fl. oz.)	0	Pre-emergent (lbs.)	0
	Sevin Liquid (fl. oz)	1	Funginex (fl. oz)	0	Roundup (fl. oz)	12.08
1/2 - 1 acre	Diazinon (lbs.)	0	Benomyl (fl. oz)	0	Broadleaf Weed Killer (fl. oz)	0.69
	Malathion (fl. oz)	0	Captan (fl. oz)	0	Preen (lbs)	0.25

Table III.10 Summary of Typical Pesticide Usage by Homeowners in Clermont County (Continued)

Yard Size	Insecticides	Amount of Insecticides	Fungicides	Fungicide Amount	Herbicides	Herbicide Amount
	Sevin Dust (lbs.)	3.5	Deconil (fl. oz.)	0	Pre-emergent (lbs.)	0
	Sevin Liquid (fl. oz)	1.75	Funginex (fl. oz)	0	Roundup (fl. oz)	39.59
1 acre - 2 acres	Diazinon (lbs.)	0	Benomyl (fl. oz)	0	Broadleaf Weed Killer (fl. oz)	0
	Malathion (fl. oz)	1.18	Captan (fl. oz)	0	Preen (lbs)	1.95
	Sevin Dust (lbs.)	0.3	Deconil (fl. oz.)	0	Pre-emergent (lbs.)	0
	Sevin Liquid (fl. oz)	2	Funginex (fl. oz)	1	Roundup (fl. oz)	20.72
2 - 3 acres	Diazinon (lbs.)	0	Benomyl (fl. oz)	0	Broadleaf Weed Killer (fl. oz)	0
	Malathion (fl. oz)	0	Captan (fl. oz)	0	Preen (lbs)	0.33
	Sevin Dust (lbs.)	0.17	Deconil (fl. oz.)	0	Pre-emergent (lbs.)	0

Table III.10 Summary of Typical Pesticide Usage by Homeowners in Clermont County (Continued)

Yard Size	Insecticides	Amount of Insecticides	Fungicides	Fungicide Amount	Herbicides	Herbicide Amount
	Sevin Liquid (fl. oz)	3.63	Funginex (fl. oz)	0	Roundup (fl. oz)	21.33
Larger than 3 acres	Diazinon (lbs.)	0	Benomyl (fl. oz)	1.7	Broadleaf Weed Killer (fl. oz)	45.71
	Malathion (fl. oz)	0	Captan (fl. oz)	0.43	Preen (lbs)	0
	Sevin Dust (lbs.)	1.29	Deconil (fl. oz.)	0.29	Pre-emergent (lbs.)	0
	Sevin Liquid (fl. oz)	0.29	Funginex (fl. oz)	0	Roundup (fl. oz)	6.04

Table III.11 Summary of Typical Fertilizer Usage by Homeowners in Clermont County

Yard Size	Nitrogen (lbs.)	Phosphorus (lbs) (P_2O_5)	Potassium (lbs.) (K_2O)
Less than 1/4 acre	9.25	1.49	2.35
1/4 - 1/2 acre	9.33	2.26	2.21
1/2 - 1 acre	1.69	2.30	1.59
1 acre - 2 acres	7.21	7.19	6.10
2 - 3 acres	17.37	4.50	3.71
Larger than 3 acres	20.36	21.43	21.17

Section III.3 Highway and Infrastructural Land Use - Clermont County

This section examines land use and chemical applications related to highways and other infrastructure such as utility easements and railroads within the Clermont County portion of the EFLMR watershed.

Section III.3.a. Highway and Infrastructural Management

Highway and infrastructure land use and chemical analysis were conducted through telephone survey, map interpolation, and GIS data examination. The greatest challenge was estimating the number of highway miles located within the watershed. Total highway miles for each county are known. However, these totals also include the vast areas located outside the watershed. GIS information regarding highways is presented in the form of thousands of separate line segments, most of which do not contain data related to the length of the segment.

Highways

Major highway mileage was determined by measuring the total number of highway miles contained within the Clermont County portion of the watershed. Major highways include interstates, U.S. highways, and State routes. Based upon this analysis, there are approximately 160 highway miles within the Clermont County EFLMR watershed as shown in Figure III-4.

During actual or anticipated snow and ice events, crews treat these major highways almost exclusively with sodium chloride (salt). At times when the temperature is less than 15 degrees Fahrenheit, small amounts of liquid calcium chloride may be sprayed in high intensity areas such as hills and intersections. The application of calcium chloride allows the sodium chloride to continue to be effective to temperatures as low as 0 degrees Fahrenheit. However, sodium chloride accounts for more than 99 percent of the snow and ice treatment application.

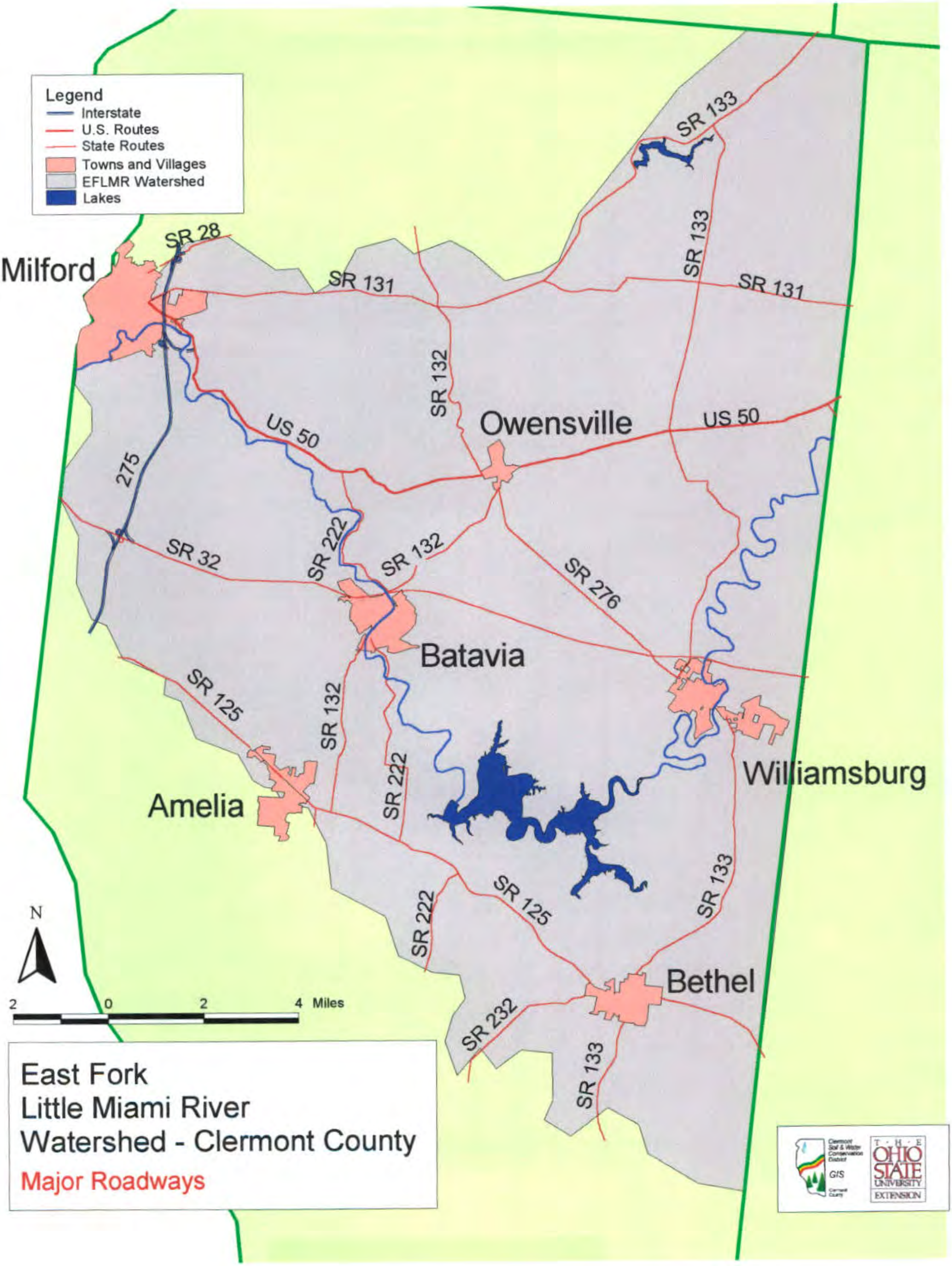
The Ohio Department of Transportation (ODOT) uses spot spray application of Roundup for vegetation control along guardrails and other difficult to access areas. The vast majority of vegetation control is accomplished through mechanical means.

Utility Easements

Based upon telephone interviews with representatives from Cinergy Corporation, during 1997 all utility easements were maintained through a combination of manual and mechanical means. During 1997, no chemical applications were used for vegetation control.

Railroads

Repeated attempts to contact railroad representatives were unsuccessful. Follow up efforts will be conducted and included as an addendum to this report.


Legend
Interstate
U.S. Routes
State Routes
Towns and Villages
EFLMR Watershed
Lakes
Milford
Owensville
Batavia
Williamsburg
Amelia
Bethel
SR 28
SR 131
SR 132
SR 133
US 50
275
SR 32
SR 222
SR 276
SR 125
SR 232
N
2
0
2
4 Miles
East Fork
Little Miami River
Watershed - Clermont County
Major Roadways

III.3.b. Highway and Infrastructural Chemical Inventory

The Ohio Department of Transportation reported spot spray application of Roundup Pro for weed control primarily along guardrails. According to the survey response from Clermont County, two applications were made consisting of 100 gallons each of 2.5 percent of active ingredient over 75.34 road miles.

The Clermont County Engineer's office reported that during 1997, 3,684 tons of salt (defined as sodium chloride and calcium chloride as described above) were applied over 384 miles of highway. This yields an average of 9.59 tons of salt applied per highway mile. A copy of the Clermont County Engineer Snow and Ice Control Tracking data is found in Appendix G.

Section III.4 Chemical Use Analysis for Clermont County

This section presents the chemical use data obtained through the various survey methods described in the previous sections along with extrapolation and analysis of agriculture, horticulture, and highway/infrastructure chemical use in the Clermont County portion of the EFMLR watershed.

Section III.4.a. Agricultural Chemical Use Analysis

Farmers in Clermont County are similar to the farmers in the entire watershed in that fertilizer is being applied at rates that are too high for the desired yields. The high application rates for the three nutrients are even higher in Clermont County when compared to the entire watershed. Table III.12 illustrates the comparison for the two groups and the three nutrients.

Table III.12 Comparison Fertilizer Usage Entire Watershed versus Clermont County Farmers

Group	Nitrogen @ 200#/ac	Phosphorus @ 90#/ac	Potassium @ 120#/ac
Watershed	83%	70%	95%
Clermont	96%	96%	100%

As stated previously, application rates that would be more reasonable would be nitrogen at 160 pounds/acre, phosphorus at 50 to 60 pounds/acre, and potassium at 60 pounds/acre. A decrease of fertilizer usage would reduce the threat to water resources and save the farmer money. Another consideration is the carry-over variable for soybean production. There was 1,515 acres of soybean that were identified as having no fertilizer applied. Some if not all of the 1,515 acres of soybean could be following corn, which would account for some of the excessive fertilizing. Throughout the rest of the watershed there was only 292 acres reported with zero fertilizer application for soybean. The excessive nitrogen application would not be explained by the carry-over for soybean production because nitrogen is not applied to soybean in general.

Section III.4.b. Horticultural Chemical Use Analysis

This section addresses the status of chemical application by homeowners and horticultural businesses in Clermont County and compares them to the official recommendations of Ohio State University Extension. This section is divided by the types of horticultural operations including home lawn care, grounds maintenance, golf course, nursery/greenhouse, fruits, and vegetables.

Home Lawn Care

Home lawn care involves many horticultural practices such as proper grass selection, seeding, mowing, water, core aeration in addition to lawn fertilization, weed control, and pest management. Typically a recommended fertilization program is a four step program. Fertilizers should be applied once in May, once in July, once in September, and once more in November.

However, if someone only fertilizes their lawn once, late fall fertilization should be the best option. If two lawn fertilizations are made, fertilization once in late fall, and once in spring would work well. Fertilizer ratios of 3-1-2 to 5-1-2 are preferred. The recommended rate is about 0.5 to 1.5 pounds actual nitrogen per 1,000 sq. ft. One recommended fertilizer for home lawn is the one with N-P-K ration of 24-4-12 at 2 to 4 pounds per 1,000 sq. ft.

The fertility programs used by national lawn care companies are typically a 4 to 5 step one, similar to what Ohio State University Extension recommends for a high maintenance program. The fertility programs by local lawn care companies varied greatly based on the knowledge of business owners. There is a great deal of fertilizer application misuse by both homeowners and some lawn care companies. One good example is the application of fertilizers 10-10-10 or 19-19-19 for grasses instead of recommended N-P-K ratios of 3-1-2 to 5-1-2. This practice resulted in the over application of phosphorus and potassium, and under appliation of nitrogen. Some of the commercial blends like Scotts' or True Green ChemLawn lawn fertilizers have too much nitrogen, and too little phosphorus and potassium.

Weed control programs in home lawns are pretty standard. Many homeowners applied pre-emergent herbicides for the control of crabgrasses in late winter to early spring as recommended by manufactures. For broadleaf weeds, many homeowners or commercial companies applied 2,4-D, Dicamba, and MCPP as recommended. However, these products were put down too early resulting in the application of additional herbicides later in the season. Best timing for dandelion control is when it reaches puffball stage. That developmental stage is typically early May.

For insect control such as white grubs, misuse of insecticides is much more widespread. Many garden centers start selling grub control chemicals in spring. That leads to the application of many insecticides at the wrong time. The correct timing for most grub control materials is in late July and early August. One chemical that should be applied earlier is GrubEx. The proper timing for GrubEx is mid May.

Grounds Maintenance

Many grounds maintenance companies are involved in mulching, fertilization, weed control, and pesticide. There is a very large variation among these companies in terms of the levels of expertise. There are several hundreds of ornamental plant species with 10 to 15 common insect and disease problems. Misdiagnosis does occur and leads to misapplications of pesticides. The companies we received survey responses from did not seem to fall in that category since they make use of Extension offices, attend pesticide applicator training, and tend to follow recommendations by Ohio State University Extension.

Golf Courses

Golf course superintendents go through intensive training each year since golfers and greens committee demand perfection. A lot of pesticides and fertilizers are applied on the golf courses. Most of golf courses follow the recommendations by Ohio State University Extension very closely. Based on the survey received from one golf course superintendent in Brown County, it appears that very little misuse exists.

Nursery/Greenhouses

There are quite a few small nurseries and greenhouses in the watershed. Many bulletins have been developed for specific crops in the floriculture industry by Ohio Florists' Association in close cooperation with Extension specialists at Ohio State University. Most nursery and greenhouse growers tend to spray less than what are recommended in OSU Extension bulletins. For example, there are bulletins on geraniums, garden mums, bedding plants, and hanging baskets. With nurseries, growers can grow an assortments of trees, shrubs, perennials, ground covers, and ornamental grasses. No two growers have identical crop makeup in either nurseries or greenhouses, especially with smaller operations.Many growers will purchase plants from other growers (to resale), in addition to the plants they grow themselves. Generally it seems that chemical input by our greenhouse and nursery growers is very low, mainly due to higher tolerance to insects, diseases, and weeds.

Fruits

The recommended spray programs are listed in the OSU Extension bulletins "Commercial Tree Fruit Spray Guide" and "Commercial Small Fruit and Grape Spray Guide." A typical spray program for apple trees is listed in Table III.13

Table III.13 Spray Program for Apple Trees

Developmental Stages	**Insecticides**	**Fungicides**
Dormant to silver tip	None	Bordeaux mix plus oil and Ridomil 2E if needed
Green Tip	Apollo SC at 4-8 fl. oz for mite control	Benlate 50 WP at 8-12 oz./acre or fungicides
Half-inch green	Thiodan 3 EC at 2.67 - 4 qt./acre or other insecticides	None
Tight cluster	Savey 50 WP at 4-8 fl./acre or other miticides	Mancozeb 80 WP at 3 lbs./acre or other fungicides
Pink	Carzol 92% SP at 2 lbs. Per acre or other insecticides.	Bayleton 50 DF at 2-8 oz plus Captan at 6 lbs. Per acre or other fungicides
Bloom	None to save honeybees!	Fungicides plus Streptomycin 17 W at 2 lbs. per acre
Petal Fall	Guthion 50 WP at 2-3 lbs. Per acre and Lannate 90 SP at 1 lb. per acre	Nova 40 WP at 5-8 oz. per acre

Table III.13 Spray Program for Apple Trees (Continued)		
Developmental Stages	**Insecticides**	**Fungicides**
First and second cover	Ziram 76 DF at 6-8 lbs. per acre or other insecticides	Mancozeb 80 WP at 3 lbs. acre or ther fungicides
Third cover	Sevin EXL at 3-4 qt. per acre or other insecticides	Captan 50 WP at 6 lbs. per acre or other fungicides
Summer cover sprays	Imidan 70 WP at 2.13 - 5.3 lbs. per acre or other insecticides	Captan 50 WP at 6 lbs. per acre or other fungicides

Spray programs are developed from many years of field research. In the watershed, fruit growers with significant acreage follow the spray programs very closely. The common fruits grown in the watershed are apples, pears, peaches, blackberries, blueberries, and raspberries. Growers with a few fruit trees and bushes sprayed very little since they do not depend on the fruit production as a significant source of their income.

In general, successful fruit growers make use of both soil testing and tissue testing for their fertilizer recommendations. The desirable soil test maintenance levels are listed in Table III.14

Table III.14 Desirable Soil Test Maintenance Levels

Nitrogen	Phosphorus	Potassium
40 to 150 lbs. of N per acre	30 - 90 lbs. of available P per acre	200 - 400 lbs. of exchangeable K per acre

A fruit grower in Clermont County did not apply fertilizers in his orchard in 1997 while another grower in Highland County (outside watershed) applied 250 pounds. of nitrogen, 125 pounds of phosphorus, and 125 pounds of potassium. One grower experienced severe under fertilization while the other experienced over application of nitrogen and phosphorus.

Vegetables

Common vegetables grown in the watershed are tomatoes, peppers, pumpkins, green beans, and sweet corns. Chemicals labeled for each crop are different. The fertility program for tomatoes is listed in Table III.15.

Table III.15 Fertility Program for Tomatoes

Nitrogen	Phosphorus (P_2O_5)	Potassium (K_2O)
Broadcast 60-80 lb N/A prior to planting. Sidedress with an additional 30-60 lb N/A with calcium nitrate.	100-175 lbs.	200-350 lbs.

Vegetables are definitely not pest free. There are many pesticides that need to be applied on vegetable crops if high quality crops are expected. Vegetable growers seem to have applied fewer less chemicals than the OSU Vegetable Production Guide called for. This is likely due to a combination of economics and good pesticide management practices. Most vegetable growers sell their crops at local farmers' markets where consumers are willing to accept some imperfections on the produce.

Generally the pesticides applied by horticultural businesses in the watershed were minimal. Fertilizers represent the largest percentage of chemical input in both commercial horticulture and residential areas. In the future, we might see more and more small farms specializing in horticultural crops especially flowers, vegetables, trees and shrubs, and sod. We might see more housing developments, and possibly more golf courses. Education of small scale farmers, developers, and homeowners will be critical to maintain and improve the water quality in Clermont County and the watershed.

Section III.4.c. Highway and Infrastructure Chemical Use Analysis

Based upon the estimated 160 miles of highway within the watershed in Clermont County, this application rate would indicate that approximately 1,535 tons of salt and 425 gallons of 2.5 percent active ingredient Roundup Pro were applied.

A

Name: ____________________

EASTFORK WATERSHED SURVEY: AGRICULTURE 1997 DATA

PRODUCTION PRACTICES :

1. Fill in the blanks the number of acres in production in 1997 for each crop listed :

CROP	ACRES	YIELD(AVERAGE)
Corn	____	__________
Soybean	____	__________
Wheat	____	__________
Pasture	____	__________
Oats	____	__________
Tobacco	____	__________
Forage(hay)	____	__________
Other	____	__________

2. Fill in the blanks the percentage of each tillage practice utilized in the production of each crop:

CROP	ACRES	CONVENTIONAL	MIN. TILL	NO-TILL
Corn	____	________%	_____%	_____%
Soybean	____	________%	_____%	_____%
Wheat	____	________%	_____%	_____%
Pasture	____	________%	_____%	_____%
Oats	____	________%	_____%	_____%
Tobacco	____	________%	_____%	_____%
Forage(hay)	____	________%	_____%	_____%
Other	____	________%	_____%	_____%

LIVESTOCK PRACTICES:

3. Do you own livestock? If yes, answer the next three questions.

   Yes ☐ No ☐

4. What type(s) and number(s) of livestock do you have?

TYPE OF LIVESTOCK	NUMBER OF HEAD
Dairy cattle	_____
Beef cattle	_____
Feeder calves	_____
Hogs (breeding stock)	_____
Feeder pigs	_____
Sheep	_____
Horses	_____
Chicken	_____
Others	_____

5. Did you apply manure? ☐ Yes ☐ No
   How many tons per acre did get applied? _____
   How many total acres did you apply the manure to? _____
   On what type of land did the manure get spread? Pasture ____ Hay field____ Crop____

CHEMICAL LISTING GUIDE

The following is a listing of some of the most commonly used chemicals in production agriculture. Use this list to assist with the filling in of the table. This is not all of the chemicals that are available.

Chemical | **Chemical**

Herbicides

- 2,4-D
- Atrazine/AAtrex
- Assure II
- Balan
- Banvel/Clarity
- Bicep II
- Bladex
- Blazer
- Broadstrike/Dual
- Basagran
- Buctril
- Canopy
- Classic
- Cobra
- Command
- Dual
- Dacthal
- Eradicane Extra
- Extrazine II
- Fusilade
- Galaxy
- Gromoxone Extra
- Harmony Extra
- Kreb
- Lasso
- Lariat/Bicep/Bullet
- Lorox
- Marksman
- Pinnacle
- Poast Plus
- Prinup
- Prowl
- Pursuit
- Reflex
- Roundup Ultra
- Sencor
- Sceptor
- Sinbar
- Stinger
- Surflan
- Sutan
- Tillam
- Treflan

Insecticides, Miticides, and Fungicides

- Alachlor
- Apron, Ridomil
- Benlate
- Bravo
- Bayleton
- Captan
- Carbamate
- Cygon
- Diazinon
- Dicamba
- Dithane
- Dursban
- Dormant oil, Sun spray
- Fonofos
- Fursdan
- Guthion
- Imidan
- Lindane
- Malathion
- Maneb
- Omite
- Orthene
- Penncap-M
- Sevin
- Terbufos

e Use Survey for Ag[hole punch]nomic Crops

Rented Acreage)

****(Please complete other side of form also) - Thank You!***

Pesticides			Fertilizer				
icide Used	Concentration of Pesticide % of Active Ingredient Dry Materials or Number of Pounds A.I. for liquids	Quantity of Undiluted Pesticide Formulation Used per Acre For Each Application (Specify lb., pt., qt., gal., oz., etc.)	Pounds of Anhydrous Ammonia per Acres	Pounds of Nitrogen (Urea, 28% Nitrogen) per Acre	Pounds of Phosphate P205 per Acre	Pounds of Potash K2O per Acre	Sludge or Manure (Tons/Acres)
trazine	50%	L	-	190	85	110	-

Please give a detailed description of the location of the various fields that were discussed on the other side.

1. ***(Example: Field is one mile east of the intersection of S.R. 50 and S.R. 133 located on the north side of the road).***

2.

3.

4.

5.

6.

7.

8.

9.

10.

11.

12.

13.

14.

B

AGRICULTURE CHEMICAL VENDOR LIST

IMC Agribusiness

PO Box 328
Morrystown, OH 45155
937.442.3671

PO Box 413
Hillsboro, OH 45133
937.393.9966

161 Railroad Road
Midland, OH 45158
937.783.4111

Clarksville Ag Service
279 W. Main Street
Clarksville, OH 45113
937.289.2311

T.J. Wolfer & Sons
1634 Highway 50
Marathon, OH 45154
937.625.5131

Adams Agri. Business
PO Box 18
Pleasant Plains, OH 45162
937.877.2121

Agri-Urban Georgetown
5867 Countrymark Road
Georgetown, OH 45121
937.378.4105

C

Herbicide Classification by Mode of Action:

Herbicide mode of action can be defined as the primary mechanism of herbicide interference with plant function or metabolism that leads to plant death. Herbicides are often classified according to their mode of action, because as a general rule, herbicides with the same mode of action will produce similar symptoms on susceptible plants. There are seven major modes of action categories described in this section: cell membrane disruptors; growth regulators; photosynthesis inhibitors; pigment inhibitors; seedling growth inhibitors; ACCase inhibitors; and amino acid synthesis inhibitors. For a more comprehensive explanation of herbicide mode of action and injury symptoms, refer to North Central Regional Publication 377, Herbicide Mode of Action and Injury Symptoms, at the Clermont County Extension office.

I. Cell Membrane Disruptors

Most of the herbicides listed are effective when applied postemergence, where they are absorbed by foliage and disrupt cell membranes in susceptible plants. Membrane disruptions in treated plants have a water soaked appearance, which is followed by rapid wilting and eventually a "burned" or frost damaged appearance of the foliage. Because these herbicides generally have limited translocation in plant tissues, adequate spray coverage and a proper adjuvant are often required for maximum weed control activity. Activity of these herbicides increases with sunlight, temperature, and humidity. Some examples of herbicides in this classification are: Gramoxone Extra, Ortho Diquat, Blaxer, Cobra,and Authority.

II. Growth Regulators

Plant growth regulators mimic the activity of hormones occurring naturally in the plant system. However, growth regulators are toxic to many plants because they are more potent than natural hormones and can cause secondary effects that inhibit normal plant growth. Most herbicides in this family are highly systemic, meaning they translocate internally to other parts of the shoot, the roots, and other underground vegetative organs if applied at the proper stage of growth. They are mainly toxic to broadleaf plants. Injury symptoms on susceptible plants develop first on the newly developing tissues in the meristematic regions (growing points) of the plant. Growth abnormalities in susceptible plants may include malformed or strapped leaves, parallel leaf veins, twisted stems, and stem splitting or brittleness. Symptoms on grasses include onionleafing, brittle stalks, fused and malformed brace roots, curved stems, and malformed ears or seedheads. Herbicides included in this class include: Banvel, Clarity, 2,4-D, MCPA and Stinger.

III. Photosynthesis Inhibitors

Photosynthesis inhibitors block the process whereby plants convert sunlight into the chemical energy required for further growth processes. Toxicity exists primarily for broadleaf plants. Some herbicides in this class are mobile in the plant (Triazines), moving upward from the site of absorption, with water and minerals. These herbicides are usually soil-applied so that weeds will absorb the herbicide via the roots. Other photosynthesis inhibitors are not mobile in plants and are classified as postemergence contact herbicides. These herbicides have no soil activity. The most common symptom of mobile photosynthesis inhibitors is chlorosis (yellowing)of the leaf tissue. In grasses, symptoms first appear on the older leaves near the base of the plant. Leaf tips and margins first show chlorosis and eventually turn necrotic. Herbicides found in this class include: Atrazine, Bladex, Princep, Lorox, Spike, Basagran, Buctril, and Sinbar.

IV. Pigment Inhibitors

Pigment inhibitors inhibit the production of certain plant pigments necessary for photosynthesis. Symptoms include bleaching and chlorosis of the foliar tissue, which sometimes results in plants that appear totally white. This class of herbicides is translocated in the apoplast (upward) and is used primarily as soil-applied treatments. Chemicals that are in this class are Command, Sonar, and Pyramin.

V. Seedling Growth Inhibitors

Regions of active cell division (meristems) in plants are located in both the shoots and roots. Seedling growth inhibitors affect some fundamental process in meristematic regions that prevents normal growth and development of young plant tissue. These herbicides are soil applied because they are taken up by plants after germination until the seedling emerges from the soil. These chemicals are effective only on seedling annual or perennial weeds. This broad category can be further subdivided into two types of herbicides: shoot meristem inhibitors and root meristem inhibitors. Chemicals that are in this class are Dual, Harness, Eradicane, Balan, Treflan, Prowl, and Eptam.

VI. Amino Acid Synthesis Inhibitors

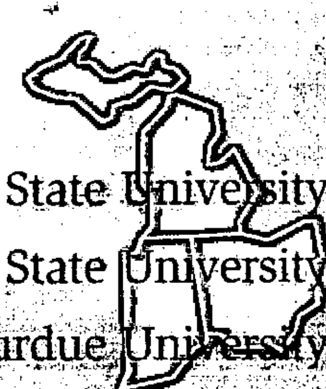
This class of inhibitors acts on a specific enzyme to prevent the production of amino acids, which are the building blocks for protein synthesis and, thus, plant growth and development. Injury symptoms are slow to develop and include stunting or slowing of plant growth and eventual death. Symptoms are likely to show in the new plant growth first because movement of these herbicides is to those areas. Herbicides that are included in this class includes Septor, Pursuit, Lightning, Classic, Broadcast, Roundup, and Liberty.

VII. ACCase Inhibitors

ACCase or lipid inhibitors prevent the formation of fatty acids which are essential components for the production of plant lipids. This occùrs through the inhibition of a single enzyme involved in fatty acid synthesis. Lipids are vital to the integrity of cell membranes and to new plant growth. Broadleaf plants are unaffected by these herbicides, but most grasses are susceptible. This class of herbicides includes Fusion, Fusilade DX, Poast and Select.

D

Tri-State Fertilizer Recommendations for Corn, Soybeans, Wheat & Alfalfa



Michigan State University
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Tri-state Fertilizer Recommendations for Corn, Soybeans, Wheat and Alfalfa

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FOREWORD

When fertilizer first became readily available in the 1930s, university researchers began to conduct field studies, develop soil tests and make fertilizer recommendations. One of the early publications in the tri-state region was "How to Fertilize Corn Effectively in Indiana" by G.D. Scarseth, H.L. Cook, B.A. Krantz and A.J. Ohlrogge, Bulletin 482, 1944, Purdue University, Agricultural Experiment Station. Since that time, many soil fertility scientists have made significant contributions to our understanding of plant nutrition and the development of fertilizer recommendations. We have learned a great deal from this legacy and are very grateful for their contributions.

In the past, universities have developed fertilizer recommendations independently without much regard for differences that might have existed between states. We have reached a time in our history when different recommendations at the state boundary line are being questioned. It is time to break with tradition and develop common fertilizer recommendations that will serve more than one state. In this publication, we have developed common fertilizer recommendations for the major crops in the tri-state region. The task has not been easy. We found that some changes and compromises were necessary. This is our first attempt at developing tri-state fertilizer recommendations for corn, soybeans, wheat and alfalfa. More work is needed on other crops and has already begun. We look forward to the continued development of these recommendations and are confident that they will be of great value to many farmers, consultants and agribusiness associates in the tri-state region.

ACKNOWLEDGEMENTS

The editors would like to thank those colleagues who have contributed greatly to the writing of this publication. They are D.R. Christenson and D.D. Warncke, Department of Crop and Soil Sciences, Michigan State University; M.E. Watson, Research and Extension Analytical Laboratory, and D.J. Eckert, School of Natural Resources, The Ohio State University; B.C. Joern and S.E. Hawkins, Department of Agronomy, Purdue University. We would also like to thank G.N. Jackson and S.A. Dlugosz from Countrymark Cooperative Inc. for their encouragement and help in facilitating the discussion that led to this publication. In addition, we would also like to acknowledge our department chairs, E.A. Paul, F.P. Miller and W.W. McFee, for their support and encouragement of this publication.

CONTENTS

SAMPLING, HANDLING AND TESTING SOILS

The accuracy of a fertilizer recommendation depends on how well the soil sample on which the recommendation was based represents the area on which the recommendation will be used. The physical and chemical characteristics of soil in an area can vary considerably from place to place because of natural factors and the management to which the area has been subjected. Natural variation arises from soil-forming processes (such as mineral weathering and erosion) that lead to accumulations or losses of nutrients at different sites. Management factors might include tillage and fertilization practices, crop selection and irrigation. It may be necessary to take many samples from a given area (at random or in a systematic manner) to assess its fertility accurately.

SAMPLING STRATEGIES

Four variables are generally considered when taking soil samples:

1. The spatial distribution of samples across the landscape.
2. The depth of sampling.
3. The time of year when samples are taken.
4. How often an area is sampled.

Proper consideration of these variables ensures that the sample accurately reflects the fertility of the area in question and allows for the best possible fertilizer recommendations.

Sample Distribution

Sample distribution usually depends on the degree of variability in a given area. In relatively uniform areas smaller than 25 acres, a composite sample of 20 to 30 cores taken in a random or zigzag manner is usually sufficient. Larger areas are usually subdivided into smaller ones. Non-uniform areas should be subdivided on the basis of obvious differences such as slope position or soil type.

Banding fertilizer creates zones of very high fertility in soils because the fertilizer is mixed with only a small portion of the soil. Samples taken in the band can greatly overestimate the overall fertility of a site. Because the position of fertilizer bands is rarely known with certainty, one should take more random samples than usual in fields with fertilizer bands and vary sampling position with respect to row location to ensure that the bands do not bias test results.

For non-uniform sites, a systematic sampling approach is best. Sampling in a grid pattern can give an idea of variability in a field and fertilizer application can be adjusted according to the distribution of soil test results within the grid. The grid spacing can vary from as little as 30 feet to several hundred feet. Often the grid spacing is some multiple of fertilizer applicator width. Grid geometry can be adjusted to account for characteristics of the site in question. For example, a rectangular grid may be more useful than a square grid when fertilizer applications have been primarily in one direction. Eight to 10 cores are usually taken and combined for analysis at each sampling point in the grid.

Sampling Depth

Soil samples used for nutrient recommendations should be taken at the same depth that is used in the research generating the recommendations, normally 0 to 8 inches. A major exception involves sampling sites subjected to little or no inversion tillage, including those in established forages, no-till and ridges. In such cases, *additional* samples should be taken at a shallower depth (0 to 4 inches) to assess acidification of the soil surface and make appropriate lime recommendations. Surface soil pH may greatly affect herbicide activity and/or carry-over problems. Occasionally sampling the soil profile in 4-inch increments also may be useful for assessing the degree of nutrient stratification in fields managed with conservation tillage, but no recommendations are being made at this time based on the results of such samples.

Time of Year to Sample

Sampling after harvest in the fall or before planting in the spring is recommended. Fall sampling is preferred if lime applications are anticipated. Sampling during the growing season may give erroneous results due to effects of crop uptake and other processes. In-season sampling should be used only to test soils for nitrate as a guide to sidedressing additional N. Recommendations for sampling soils for nitrate are not consistent across Indiana, Michigan and Ohio, so those interested in such tests should use in-state recommendations.

Sampling should occur at the same time of the year each time a particular field is sampled. This allows better tracking of trends in soil test values over time, which may be as important as the test values themselves.

Intervals Between Sampling

Most sites should be sampled every three to four years. On sites where rapid changes in fertility (particularly decreases) are expected or when high-value crops are involved, shorter sampling intervals (1 to 2 years) are recommended. Regardless of the sampling interval, records of changes in soil test values over time should be kept for each site tested.

SAMPLE HANDLING

After the sample has been collected, contamination must be avoided. Common sources of contamination include dirty sampling tools, storage vessels and surfaces on which soils are spread to dry. Ashes from tobacco products can cause considerable contamination of soil samples. Soils should be shipped to the testing laboratory only in containers approved by the lab.

Individual cores should be mixed thoroughly to form a composite sample. Moist cores should be crushed into aggregates approximately 1/8 to 1/4 inch across for optimum mixing. If the mixed sample is to be dried, the drying should be done at temperatures no greater than 120 degrees F (50 degrees C). After drying, a subsample of appropriate size should be taken from the composite mixture and sent to the testing laboratory for analysis.

SOIL TESTING PROCEDURES

Several tests are available to measure the availability of individual nutrients in the soil. The recommendations made here are based on research conducted using very specific tests, which are identified for each nutrient. Producers and consultants should always be certain their fertilizer recommendations are based on research using the same procedures used to generate their soil test results.

The specific procedures used to test soils in Indiana, Michigan and Ohio are described in NCR Publication 221, 1988, Recommended Chemical Soil Test Procedures for the North Central Region, written by the USDA-sanctioned North Central Regional Committee on Soil Testing and Plant Analysis (NCR-13) and published by the North Dakota Agricultural Experiment Station. Other procedures may yield results incompatible with the recommendations given here.

All soil test data in this publication are reported as parts per million (ppm) rather than pounds per acre (lb/acre). The change to ppm is being made because it more truly represents what is measured in the soil. Soil test values are an index of availability and do not reflect the total amount of available nutrients in soil. The use of lb/acre in the past has also led to some confusion about soil testing and the resulting fertilizer recommendations. Most commercial soil test laboratories are currently reporting soil test values in terms of ppm. To convert ppm to lb/acre, multiply ppm by 2.

SOIL pH AND LIME RECOMMENDATIONS

Different crops require different soil pH levels for optimum performance; when pH falls below these levels, performance may suffer (Table 1). The pH of organic soils (more than 20 percent organic matter) is generally maintained at much lower levels than the pH in mineral soils (less than 20 percent organic matter) to minimize chances of micronutrient deficiencies. The topsoil in fields with acid subsoils (most common in eastern Ohio) should be maintained at higher pHs than those fields with neutral or alkaline subsoils to minimize chances for nutrient deficiencies associated with acid soil conditions.

Soil pH should be corrected by liming when the pH in the zone of sampling falls 0.2 to 0.3 pH units below the recommended level. The rates of application given in Table 2 are based on the lime test index obtained using the SMP-buffer lime requirement test and are applicable to an 8-inch depth. For no-till and established forages, lime recommendations are based on a 0- to 4-inch depth, so the rates of application should be one-half the values given in Table 2. These rates are for agricultural ground limestone with a neutralizing value of 90 percent. They should be adjusted if other types of liming material are used. To adjust for a liming material with a different neutralizing value (nv), multiply the lime recommendation given in the table by 0.90 and divide by the new neutralizing value.

Table 2.
Tons of agricultural limestone needed to raise the soil pH to the desired pH level based on the SMP lime test index and an incorporation depth of 8 inches.

Lime test index[1]	Desired pH levels: Mineral soils 6.8	6.5	6.0	Organic soils: Soil pH	5.3
	tons agricultural limestone/acre[2]				tons/acre
68	1.4	1.2	1.0	5.2	0.0
67	2.4	2.1	1.7	5.1	0.7
66	3.4	3.0	2.4	5.0	1.3
65	4.5	3.8	3.1	4.9	2.0
64	5.5	4.7	3.9	4.8	2.6
63	6.5	5.6	4.6	4.7	3.2
62	7.5	6.5	5.3	4.6	3.9
61	8.6	7.3	6.0	4.5	4.5
60	9.6	8.2	6.7	4.4	5.1

[1]Lime test index is the SMP buffer pH x 10.

[2]These values are based on agricultural limestone with a neutralizing value of 90 percent (Indiana RNV = 65, Ohio TNP = 90+). Adjustments in the application rate should be made for liming materials with different particle sizes, neutralizing values and depths of incorporation.

Table 1.
Soil pH recommended for various crops on various soils.

Crop	Mineral soils with subsoil pH > pH 6	< pH 6	Organic soils
	pH		
Alfalfa	6.5	6.8	5.3
Other forage legumes	6.0	6.8[1]	5.3
Corn	6.0	6.5	5.3
Soybeans	6.0	6.5	5.3
Small grains	6.0	6.5	5.3
Other crops	6.0	6.5	5.3

[1] Birdsfoot trefoil should be limed to pH 6.0.

Example: Lime recommendation = [(tons per acre x 0.90) / 0.80] if nv is 80 percent.

The relative availability of the liming material is also affected by the lime particle size. For information on adjusting lime recommendations because of differences in lime particle size, see in-state publications.

Lime rates also should be adjusted for other depths of incorporation. To adjust for other depths, divide by 8 and multiply by the new incorporation depth.

Example: Lime recommendation = [(tons per acre / 8) x 10] if incorporation depth is 10 inches.

Lime recommendations (LR) are calculated from the lime test index (LTI) for mineral soils and the soil pH for organic soils using the following formulas and rounding to the nearest tenth of a ton:

Mineral soils
to pH 6.8: LR = 71.4 - 1.03 x LTI
to pH 6.5: LR = 60.4 - 0.87 x LTI
to pH 6.0: LR = 49.3 - 0.71 x LTI
Organic soils
to pH 5.3: LR = 32.9 - 6.31 x soil pH

These rates should raise soil pH to the desired pH level, but the exact pH is not always achieved. Applications of less than 1 ton/acre often may not be practical and will not appear in computer-generated recommendations. When the recommendation is for 2 tons/acre or less, the application can be made any time in a cropping sequence. When the lime recommendation exceeds 4 tons per acre, apply the lime in a split application — i.e., half before plowing and half after plowing. Do not apply more than 8 tons of lime in one season. Large applications of lime without thorough mixing may cause localized zones of high alkalinity, reducing the availability of some essential nutrients. If the soil test indicates more than 8 tons per acre are required, retest two years after the application to see if more lime is needed.

Surface applications of urea forms of N fertilizer are not recommended on fields where lime has been surface applied recently. The potential N loss by ammonia volatilization is high when urea reacts with unincorporated lime. Urea forms of N should not be surface applied within one year of the lime application. Surface applications of ammonium nitrate, ammonium sulfate, or injected 28 percent N or anhydrous ammonia are preferred when lime is not incorporated.

WEAKLY BUFFERED SOILS

Because sandy soils are often weakly buffered, there is concern about lime requirements determined by the SMP lime test. These soils may have a soil water pH below the desired pH range for optimum crop growth but the lime index test does not indicate a need for lime. This occurs because weakly buffered soils do not have sufficient capacity to lower the pH of the SMP buffer solution. When this situation occurs, growers may want to consider using 1 ton of lime per acre when the soil water pH is more than 0.3 pH units below the desired soil pH and 2 tons per acre when the soil water pH is more than 0.6 pH units below the desired soil pH.

NITROGEN

Profitability, concern for groundwater quality and conservation of energy are good reasons to improve nitrogen use efficiency. Placement of fertilizer nitrogen and timing of application affect nitrogen use efficiency. Placement and timing of nitrogen application are management decisions within a producer's production system. Soil characteristics, rainfall and temperature, tillage system and fertilizer source affect the efficacy of application. Because of our inability to predict the occurrence and amounts of rainfall for a specific year, nitrogen placement and timing should be based on conditions that most frequently occur. Most of the fertilizer nitrogen applied in the eastern Corn Belt is used on corn, so most of the discussion here is on nitrogen management practices for corn.

NITROGEN PLACEMENT

Tillage system and fertilizer source affect proper placement of fertilizer nitrogen. The most satisfactory way to apply anhydrous ammonia is by injection in a band. Knife spacing provides an application option for anhydrous ammonia. Injection into the soil by knives or spoke injector, spraying on the surface and surface banding are techniques used to apply fertilizer N solutions. Dry sources can be broadcast or placed in a band. The need to incorporate N sources placed on the surface depends on the tillage system and whether the N source contains urea.

The enzyme urease hydrolyzes urea to ammonia and carbon dioxide ($NH_2CONH_2 + H_2O \dashrightarrow 2NH_3 + CO_2$). The ammonia vaporizes and is lost if this occurs at the soil surface. Urease is an enzyme common to soil organic matter and plant residue. Factors that enhance ammonia volatilization losses are: soil factors — high soil pH and low buffering capacity; environmental factors — warm temperature, moist soil surface that is drying and rapid air movement; management factors — surface application of high rates of urea-containing fertilizer, broadcast application, liquid fertilizer and crop residue on soil surface. Injecting or incorporating urea-containing fertilizer or receiving ½ inch or more of rainfall before hydrolysis occurs reduces or eliminates volatilization losses. Data shown in Tables 3 and 4 illustrate the effect of application method in no-tillage for various N sources. Dribble or band application of urea-ammonium nitrate (UAN) solution concentrates the N solution, which reduces contact with urease enzyme. This application technique slows the

Table 3.
THE EFFECT ON GRAIN YIELD OF NO-TILL CORN BY N SOURCES AND METHOD OF APPLICATION IN INDIANA.[1]

N treatment	*Average grain yield bu/acre at 15.5% water*
NH_3 injected	139
UAN injected	135
UAN surface	118
urea surface	123

[1]Adapted from D.B. Mengel et al. 1982. Placement of nitrogen fertilizers for no-till and conventional corn. Agron. J. 74:515-518.

Table 4.
CORN GRAIN YIELDS AS AFFECTED BY SEVERAL N MANAGEMENT STRATEGIES AT WOOSTER AND SPRINGFIELD, OHIO, 1984-1985.[1]

N		*Application*		*Corn following*	
Rate	Source[2]	Time	Method	Corn	Soybean
lb/acre				*bu/acre*	
0				86	97
150	AA	Preplant	Knife	154	162
150	UAN	Preplant	Broadcast	145	154
150	UAN	Preplant	Dribbled (30" spacing)	154	155
150	UAN	Split ⅓ preplant ⅔ sidedress	Dribbled	150	157
150	UAN	Split ⅔ preplant ⅓ sidedress	Dribbled	151	156

[1]Adapted from D.J. Eckert. 1987. UAN management practices for no-tillage corn production. Journal of Fertilizer Issues. Vol 4:13-18.

[2]AA = anhydrous ammonia; UAN = urea ammonium nitrate solution.

conversion of urea to ammonia and carbon dioxide and lengthens the time N solutions can remain on the surface with minimum losses. Urease inhibitors show some promise in reducing volatilization losses. Though there is an advantage to soil incorporation on some soils, incorporating fertilizers containing urea conflicts with the objectives of maintaining crop residues on the surface and reducing tillage operations. The development of the spoke-wheel and high-pressure liquid applicators provides a method of injecting urea-ammonium nitrate solutions into the soil with minimum disturbance of crop residue and controlling the placement relative to the corn row.

Knife spacing is a consideration for sidedressing ammonia and in controlled traffic such as ridge-tillage systems. Data in Table 5 show that an ammonia band between every other pair of rows is satisfactory compared to injecting in the middle of every inter-row. Ammonia applied preplant diagonally will result in corn roots reaching the N band at different times. This may result in a rolling appearance to the cornfield. The use of 20 to 40 pounds of N per acre applied as starter fertilizer with the planter or as a preplant broadcast application will minimize the rolling appearance of corn. This practice will also ensure adequate N nutrition early in the season before the corn roots reach the N in the ammonia band.

Table 5.
EFFECT OF KNIFE SPACING OF AMMONIA APPLIED AT VARYING RATES OF N ON CORN YIELD AT DEKALB, ILL.[1]

Knife spacing (inches)	lb N/acre		
	120	180	240
	bu/acre		
	Sidedress — 1985-1986 av.		
30	171	176	182
60	170	171	182
	Preplant — 1986[2]		
30	159	178	190
60	166	179	180

[1] Adapted from R.G. Hoeft. 1987. Effect of ammonia knife spacing on yield. In Proceedings of the Seventeenth North Central Extension-Industry Soil Fertility Workshop. St. Louis, Missouri.

[2] Applied beneath the planted row.

NITROGEN TIMING

The timing of N fertilizer applications is an important factor affecting the efficiency of fertilizer N because the interval between application and crop uptake determines the length of exposure of fertilizer N to loss processes such as leaching and denitrification. Timing N applications to reduce the chance of N losses through these processes can increase the efficiency of fertilizer N use.

Ideally, N applications should coincide with the N needs of the crop. This approach requires application of most of the N requirement for corn during a period 6 to 10 weeks after planting. Application of N during the period of maximum crop demand may not be practical or possible; other methods and times of application may be equally efficient and appropriate. The efficacy of time of application depends on soil texture, drainage characteristics of the soil, amount and frequency of rainfall or irrigation, soil temperature and, in some situations, the fertilizer N source. Nitrogen timing options usually include fall applications, spring preplant applications, sidedress or delayed applications made after planting, and split or multiple treatments added in two or more increments during the growing season.

Fall vs. Spring Applications

Fall applications of N are feasible only in areas where low winter soil temperatures retard nitrification of ammonium. This limits fall application to the northern portion of the United States. The concern with fall application is that losses of N will occur between application and crop uptake in the next growing season. This may lower crop yield and recovery of applied N, compared with spring applications. Recommendations for fall applications are to use an ammonium form of N, preferably anhydrous ammonia, and delay application until the soil temperature is below 50 degrees F.

Considerable year-to-year variation in the effectiveness of fall N application occurs, as shown in Table 6.

These data illustrate that fall N applications are usually less effective than spring applications. In general, fall-applied N is 10 to 15 percent less effective than N applied in the spring. Higher N application rates should not be used in the fall to try to make up for potential N losses. Use of a nitrification inhibitor with fall-applied N can improve the effectiveness of these treatments. Most studies show, however, that spring-applied N is more effective than inhibitor-treated fall N when conditions favoring N loss from fall applications develop. In Table 7, inhibitor-treated anhydrous ammonia was superior to anhydrous ammonia when applied in the fall, but not when applied in the spring. Spring-applied anhydrous ammonia, however, was on the average better than the fall inhibitor-treated ammonia. To increase the effectiveness of fall-applied N with an inhibitor, delay the application until soil temperatures are below 50 degrees F.

Table 6.
YIELD OF CORN AS AFFECTED BY NITROGEN RATE, TIME OF NITROGEN APPLICATION AND SOIL TYPE IN MICHIGAN, 1977-1984.[1]

	Time of application	
Nitrogen rate	*Fall*	*Spring*
lb/acre	*bu/acre*	
Loamy soils (5 experiments)		
100	118	133
150	127	154
Irrigated sandy loam soils (6 experiments)		
100	162	172
150	176	181

[1]Adapted from M.L. Vitosh. 1985. Nitrogen management strategies for corn producers. Michigan State University Extension Bulletin WQ06.

Preplant vs. Sidedress Applications

Benefits from delayed or sidedress N applications are most likely where there is a high risk of N loss between planting and crop N use. Preplant N losses occur from sandy soils through leaching and from poorly drained soils through denitrification.

Sidedress applications of N on irrigated sandy soils produce consistently greater yields than a preplant application, as shown in Table 8. In areas where rainfall greatly exceeds evapotranspiration, the same results are expected. Sidedress applications on coarse-textured/low CEC soils are usually more effective in increasing corn yields than

Table 7.
EFFECT OF N RATE, TIME OF APPLICATION, N SOURCE AND NITRIFICATION INHIBITOR ON 8-YEAR AVERAGE CORN YIELD IN OHIO.[1]

	Fall-applied			Spring-applied		
N rate	*Urea*	*AA*	*AA+NI*	*Urea*	*AA*	*AA+NI*
lb/acre	*bu/acre*					
0			56			
80	85	94	111	101	116	117
160	111	127	133	125	139	140
240	—	—	—	139	—	—
320	—	—	—	139	—	—

[1] Adapted from R.C. Stehouwer and J.W. Johnson. 1990. Urea and anhydrous ammonia management for conventional tillage corn production. J. Prod. Agri. 3:507-513.

preplant treatments containing a nitrification inhibitor.

For medium- and fine-textured soils, yields seldom differ between preplant and sidedress application. Occasionally, sidedress application can be superior to preplant application when early season rainfall is excessive. The advantage to delaying N application is to assess crop needs based on soil moisture and crop conditions. The disadvantages of delaying the major fertilizer N application are: the crop may have been under N deficiency stress before fertilizer N is applied, resulting in a yield loss; wet conditions during the sidedress application period can prevent application, and later additions may not be possible because of corn growth; and dry conditions at and after sidedressing will limit N uptake.

Split or Multiple Applications

Application of N fertilizer in several increments during the growing season can be an effective method of reducing N losses on sandy soils with high potential for N loss through leaching. Irrigation systems equipped for simultaneous application are often used to apply N in multiple applications. The timing and distribution of N additions in a multiple application system are important. To match N uptake by corn, application of some N must occur by the sixth week after planting and most of the N requirement should be applied by the tenth week after planting. Research data suggest that a well timed sidedress application can be as effective as multiple applications in irrigated corn production. A combination of sidedress applications and N additions in irrigation water may be needed to maximize corn yields on some sandy soils. Preplant additions of one-third to two-thirds of the total N requirement, with the remainder applied later, are not as effective as sidedress applications on irrigated sandy soils.

On adequately drained medium- to fine-textured soils, the potential for N loss is low and the use of delayed or multiple N applications usually will not improve corn yields. Adjusting the sidedress fertilizer N rate using the presidedress or late spring soil nitrate test is an advantage to a split application on these soils. This approach would permit adjusting for factors that affect N loss or gain and cannot be predicted.

Table 8.
EFFECT OF N RATE AND TIME OF APPLICATION ON CORN YIELD FOR AN IRRIGATED MCBRIDE SANDY LOAM SOIL IN MICHIGAN.[1]

	Time of application	
N rate	*Preplant*	*Sidedress*
lb N/acre	*bu/acre*	
0	75	75
120	149	155
180	155	161
240	157	167

[1] Adapted from M.L. Vitosh. 1969-72 Montcalm Farm Research Reports.

NITROGEN LOSSES FROM SOIL

Nitrogen (N) can be lost from the field through three principal pathways: denitrification, leaching and surface volatilization.

The form of N a farmer chooses should depend on how serious a problem he has with the above N losses. Cost of N, labor, equipment and power availability are other considerations when choosing a fertilizer source.

Denitrification occurs when nitrate N (NO_3^-) is present in a soil and not enough oxygen (O_2) is present to supply the needs of the bacteria and microorganisms in the soil. If O_2 levels are low, microorganisms strip the oxygen from the nitrate, producing N gas (N_2) or nitrous oxide (N_2O), which volatilizes from the soil. Three conditions that create an environment that promotes denitrification are wet soils, compaction and warm temperatures.

Leaching losses of N occur when soils have more incoming water (rain or irrigation) than the soil can hold. As water moves through the soil, the nitrate (NO_3^-) that is in soil solution moves along with the water. Ammonium (NH_4^+) forms of N have a positive charge and are held by the negative sites on the clay in the soil; therefore, NH_4^+ forms of N leach very little. In sands where there is very little clay, ammonium forms of N can leach. Coarse-textured sands and some muck soils are the only soils where ammonium leaching may be significant.

One way to minimize N leaching and denitrification is to minimize the time the N is in the soil before plant uptake. This cuts down on the time when conditions are favorable for losses. Most of the N is needed by corn after the plant is 3 to 4 weeks old (June 1).

Surface volatilization of N occurs when urea forms of N break down and form ammonia gases and where there is little soil water to absorb them. This condition occurs when urea forms of N are placed in the field but not in direct contact with the soil. This situation can occur when urea is spread on corn residues or 28 percent is sprayed on heavy residues of cornstalk or cover crop.

The rate of surface volatilization depends on moisture level, temperature and the surface pH of the soil. If the soil surface is moist, the water evaporates into the air. Ammonia released from the urea is picked up in the water vapor and lost. On dry soil surfaces, less urea N is lost. Temperatures greater than 50 degrees F and a pH greater than 6.5 significantly increase the rate of urea conversion to ammonia gases. Applying urea-type fertilizers when weather is cooler slows down N loss. If the surface of the soil has been limed within the past three months with 2 tons or more of limestone per acre, DO NOT apply urea-based fertilizers unless they can be incorporated into the soil.

To stop ammonia volatilization from urea, the urea must be tied up by the soil. To get the urea in direct contact with the soil requires enough rain to wash the urea from the residue or placement of urea-based fertilizer in direct contact with soil by tillage, banding or dribbling. If the residue is light (less than 30 percent cover), 0.25 to 0.5 inch of rain is enough to dissolve the urea and wash it into the soil. If the residue is heavy (greater than 50 percent cover), 0.5 inch or greater of rainfall is required.

Ammonia volatilization of N may also occur when ammonium forms of N — ammonium sulfate (AS), ammonium nitrate (AN), diammonium phosphate (DAP), monoammonium phosphate (MAP) and ammonium polyphosphate (APP) — are surface applied to calcareous soils (soil pH greater than 7.5). The extent of loss is related to the reaction products formed when ammonium fertilizers react with calcium carbonate. Ammonium fertilizers that form insoluble precipitates (AS, DAP, MAP and APP) are subject to greater ammonia volatilization losses than AN, which forms a soluble reaction product. To prevent ammonia volatilization, ammonium fertilizers should be knifed in or incorporated on calcareous soils.

SELECTING FORMS OF NITROGEN FERTILIZER

The common N fertilizers are anhydrous ammonia (82 percent N), urea (46 percent N), solutions (28 to 32 percent N), ammonium sulfate (21 percent N) and ammonium nitrate (34 percent N).

Anhydrous ammonia (82 percent) is the slowest of all N fertilizer forms to convert to nitrate N. Therefore, it would have the least chance of N loss due to leaching or denitrification. It must be injected into the soil; therefore, it would have no loss due to surface volatilization. The disadvantage of anhydrous ammonia is that it is hazardous to handle. It must be injected into the soil, and on steep slopes erosion can be a problem.

Urea (46 percent) converts to nitrate N fairly quickly, usually in less than two weeks in the spring. Denitrification on wet or compacted soils can be serious. Leaching can be a problem in coarse soils. In no-till situations, surface volatilization can be a problem if the urea is not placed in contact with the soil and the weather is dry for several days after spreading.

UAN solutions (28 to 32 percent N) are usually made up of urea and ammonium nitrate. The nitrate in this product is subject to leaching and denitrification from the time it is placed in the field. The urea components are subject to the same loss mechanisms as urea. Nitrogen solutions can be banded on the soil surface easily by dribbling. This method of application minimizes the amount that sticks to the residue and, therefore, minimizes surface volatilization but may not eliminate it.

Ammonium sulfate (21 percent) is a nitrogen source with little or no surface volatilization loss when applied to most soils. Ammonium sulfate is a good source of sulfur when it is needed. Its disadvantage is that it is the most acidifying form of N fertilizer — it requires approximately 2 to 3 times as much lime to neutralize the same amount of acidity as formed by other common N carriers.

Ammonium nitrate (34 percent) is 50 percent ammonium N and 50 percent nitrate N when added to the soil. The ammonium N quickly converts to nitrate N. For soils subject to leaching or denitrification, ammonium nitrate would not be preferred. Ammonium nitrate has no urea in it; therefore, it would be a good choice for surface application where ammonia volatilization is expected.

NITROGEN RECOMMENDATIONS FOR CORN

The following N recommendations (Table 9) for corn assume the crop is planted during the optimum planting period on mineral soils with either good natural or improved drainage.

Table 9.

Nitrogen recommendations for corn based on yield potential and previous crop.

Previous crop	*Corn yield potential (bu/acre)*					
	80	*100*	*120*	*140*	*160*	*180+*
	pounds N to apply per acre					
Corn and most other crops	80	110	140	160	190	220
Soybeans	50	80	110	130	160	190
Grass sod	40	70	100	120	150	180
Established forage legume[1]						
Average stand (3 plants/sq ft)	0	10	40	60	90	120
Good stand (5 plants/sq ft)	0	0	0	20	50	80
Annual legume cover crop[2]	50	80	110	130	160	190

[1]Any legume established for more than one year.

[2]Any legume or legume-grass mixture that has been established for less than one year. Nitrogen credit may be more or less (0 to 100 lb/acre), depending on plant species, stand, growing conditions and date of destruction.

Additional Comments

1. N fertilizer rates are based on the following relationship:

   N (lb/acre) = -27 + (1.36 x yield potential) - N credit

   or 110 + [1.36 x (yield potential - 100)] - N credit

N credits:		
	Soybeans	30
	Grass sod/pastures	40
	Annual legume cover crop	30
	Established forage legume	40 + 20 x (plants/ft^2) to maximum of 140
	Corn and most other crops	0
	Organic waste	Consult individual state recommendations

2. For corn silage, assume 1 ton/acre is equivalent to 6 bu/acre of grain.
3. For inadequately drained soils with high denitrification potentials, N should be either:
   - Applied in a split application.
   - Applied as anhydrous ammonia with a nitrification inhibitor.
   - Or concentrated in a band to minimize soil contact.
4. Corn grown on coarse-textured/low CEC soils with high leaching potentials may benefit from split or multiple N applications.
5. For soils with greater than 30 percent residue cover, the majority of applied N should be either:
   - Injected below the soil surface.
   - Dribbled in bands using N solutions.
   - Or broadcast only if the material contains no urea (i.e., ammonium nitrate or ammonium sulfate).
6. No-till corn, corn planted into cold, wet soils, corn following anhydrous ammonia applied less than 2 weeks prior to planting, and corn following spring-tilled legumes or cover crops should receive some N at planting, either:
   - 20 to 40 lb N/acre banded near the row.
   - Or 40 to 60 lb N/acre broadcast.
7. For organic soils with greater than 20 percent organic matter, adjust rates using a pre-sidedress N soil test (consult individual state recommendations) or reduce N rates by 40 lb/acre.
8. For fall applications (after October 20, well drained soils only) or early spring applications (before April 15) on wet soils, use only anhydrous ammonia with a nitrification inhibitor. Fall applications of N are not recommended on coarse-textured soils in the tri-state region. In addition, fall N is not recommended on any soil in Michigan and south of U.S. 40 in Indiana.
9. If planting is delayed past the optimum planting period, reduce N rate to reflect loss of yield potential.
10. When soils are limed and the lime is not incorporated, surface application of urea forms of nitrogen fertilizer are not recommended within one year of the lime application. Ammonium nitrate, anhydrous ammonia, ammonium sulfate or injected 28 percent solutions are suitable materials for this case.
11. Incorporation of materials with a high carbon:nitrogen ratio, such as sawdust and leaves, can cause a temporary shortage of N due to immobilization.

NITROGEN RECOMMENDATIONS FOR WHEAT

The following N recommendations for wheat (Table 10) assume that the crop is planted during the optimum planting period on mineral soils with 1 to 5 percent organic matter and either good natural or improved drainage, and that proper cultural practices are utilized.

Table 10.
Total Nitrogen Recommendations for Wheat Based on Yield Potential.

Yield potential bu/acre	*Pounds N to apply* lb N/acre
50	40
70	75
90+	110

Additional Comments

1. Recommended N rate is based on the relationship:

   N (lb/acre) = 40 + [1.75 x (yield potential - 50)]

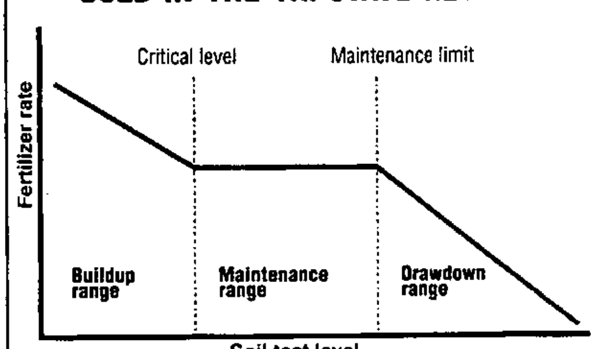
2. No credits are given for the previous crop. Consult individual state recommendations concerning credits for organic waste materials such as manure.
3. Apply 15 to 30 lb N/acre at planting and the remainder near green-up in spring; or, apply all N at planting as anhydrous ammonia plus a nitrification inhibitor, injected on 15-inch or narrower row spacing.
4. To prevent serious lodging on high organic matter soils (greater than 20 percent organic matter), reduce the N rate by 30 to 50 lb N/acre.

PHOSPHORUS AND POTASSIUM

Tri-state phosphorus (P) and potassium (K) fertilizer recommendations are based on the nutrient needs of the crop to be grown and the quantity of those nutrients available in the soil as measured by a soil test. In the tri-state region, the Bray P1 test is used to estimate P availability and the 1 normal ammonium acetate test is used to estimate K availability. Tri-state recommendations are designed to provide adequate nutrition for the crop, and to create or maintain a soil capable of providing sufficient nutrients without fertilizer addition for one or more years. Thus, the tri-state recommendations utilize a buildup and maintenance approach to fertilizer management.

The key to these recommendations is field calibration and correlation studies that have been conducted over the past 40 years. The conceptual model for these recommendations is illustrated in Figure 1. The fundamental component of the model is the establishment of a "critical level" — the soil test level above which the soil can supply adequate quantities of a nutrient to support optimum economic growth. The critical level is determined in the field and represents the results of hundreds of field experiments. There are two important concepts to keep in mind. First, some crops are more responsive to a nutrient than others, so the critical level can vary between crops. In the tri-state region, research has shown that wheat and alfalfa are more responsive to P than corn or soybeans. Thus, the critical P level for wheat and alfalfa is higher than the critical level for corn and soybeans. Second, the critical level can vary between soils. Recent research has shown that some soils, especially high clay soils in Ohio, require higher K levels to support optimum crop growth than other lower clay content soils. This information has been incorporated into the recommendations and is seen as an increase in critical level for K as the cation exchange capacity (CEC) increases.

Figure 1
Fertilizer Recommendation Scheme Used in the Tri-State Region



When soil tests are below the critical level, the soil is not able to supply the P and K requirements of the crop. The tri-state recommendations are designed to supply additional nutrients and to raise the soil test to the critical level over a four-year period. **Soil tests below the critical level should be considered as indicating a soil that is nutrient deficient for crop growth.** For deficient soils, recommended rates of fertilizer should be applied annually. Placement techniques to enhance nutrient availability, such as banding or stripping, may also be beneficial on nutrient-deficient soils. Applying 25 to 50 percent of the recommended fertilizer in a band to enhance early growth should be considered.

Above the critical soil test level, the soil is capable of supplying the nutrients required by the crop and no response to fertilizer would be expected. The tri-state recommendations use a maintenance plateau concept to make recommendations at or slightly above the critical level. The maintenance plateau is designed to safeguard against sampling or analytical variation. Recommendations for soil test values on the maintenance plateau are designed to replace the nutrients lost each year through crop removal. Because the purpose of fertilizer applications in the maintenance plateau range is to maintain fertility, no response to fertilizer in the year of application would be expected. Therefore, farmers may choose to make multiple year applications. No response to placement techniques such as banding or stripping or the use of P and K starter fertilizers would be expected in the maintenance [plat]eau region.

When soil test levels exceed the maintenance plateau level, the objective of the fertilizer recommendation is to utilize residual soil nutrients. Fertilizer recommendations are rapidly reduced from maintenance levels to zero. There is no agronomic reason to apply fertilizer when soil tests are above the maintenance plateau level.

Actual fertilizer recommendations are calculated using one of three relationships — one applicable to buildup, another for maintenance and a third for drawdown:

Tables 11 and 12 provide the critical soil test values and crop removal values used for calculating tri-state fertilizer recommendations at various soil test levels.

BUILDUP EQUATION

for P: lb P_2O_5/A to apply = [(CL - STL) x 5] + (YP x CR)

for K: lb K_2O/A to apply = [(CL - STL) x ((1 + (0.05 x CEC))] + (YP x CR) + 20

MAINTENANCE EQUATION

for P: lb P_2O_5/A to apply = YP x CR

for K: lb K_2O/A to apply = (YP x CR) + 20 (for non-forage crops)

DRAWDOWN EQUATION

for P: lb P_2O_5/A to apply = (YP x CR) - [(YP x CR) x (STL - (CL + 15))/10]

for K: lb K_2O/A to apply = (YP x CR) + 20 - [((YP x CR) + 20) x (STL - (CL + 30))/20] (for non-forage crops)

Note: The K maintenance and drawdown equation for forages, including corn silage, is:

lb K_2O/A to apply = [(YP x CR) + 20] - [((YP x CR) +20) x (STL - CL)/50]

where:

CL = critical soil test level (ppm)

STL = existing soil test level (ppm)

YP = crop yield potential (bu per acre for grains, tons per acre for forages)

CR = nutrient removed per unit yield (lb/unit)

CEC = soil cation exchange capacity (meq/100g)

Table 11.
CRITICAL SOIL TEST LEVELS (CL) FOR VARIOUS AGRONOMIC CROPS.

Crop	*Critical soil test levels*				
	P	*K at CEC*[1]			
		5	*10*	*20*	*30*
	ppm (lb/acre)	ppm (lb/acre)			
Corn	15 (30)[2]	88 (175)	100 (200)	125 (250)	150 (300)
Soybean	15 (30)	88 (175)	100 (200)	125 (250)	150 (300)
Wheat	25 (50)	88 (175)	100 (200)	125 (250)	150 (300)
Alfalfa	25 (50)	88 (175)	100 (200)	125 (250)	150 (300)

[1] Critical level for ppm K = 75 + (2.5 x CEC) for all crops

[2] Values in parentheses are lb/acre.

Note: A CEC of 15 is used to calculate the K_2O recommendation for calcareous soils (soils with pH equal to or greater than 7.5 and a calcium saturation of 80 percent or greater) and organic soils (soils with an organic matter content of 20 percent or greater or having a scooped density of less than 0.8 grams per cubic centimeter).

Table 12.
NUTRIENTS REMOVED IN HARVESTED PORTIONS OF AGRONOMIC CROPS.

Crop	*Unit of yield*	*Nutrient removed per unit of yield*	
		P_2O_5	*K_2O*
		lb /unit	
Corn			
Feed grain	bushel	0.37	0.27
Silage	ton	3.30	8.00
Soybeans	bushel	0.80	1.40
Wheat			
Grain	bushel	0.63	0.37
Straw	bushel	0.09	0.91
Alfalfa	ton	13.00	50.00

PHOSPHORUS AND POTASSIUM FERTILIZER PLACEMENT AND TIMING

Most soil test report forms do not provide information on how farmers should apply their fertilizer. To be used efficiently, P and K fertilizers should be applied properly and at the appropriate time. Because the choices of application depend greatly on the fertilizer material used and the equipment available, it is up to the farmer to see that the fertilizer is properly applied. When plants are small, soil test levels low, soil surface residues high and soil temperatures cold, starter fertilizers become very important for optimum plant growth. For well established crops such as forage legumes, topdressing is the normal recommended practice.

Starter Fertilizers

In many instances, applying some or all of the fertilizer needed with the planting unit improves fertilizer efficiency. If starter fertilizer is used, apply 20 to 40 lb of N, P_2O_5 and/or K_2O per acre in a band 2 inches to the side and 2 inches below the seed. The total amount of salts (N + K_2O) should not exceed 100 lb per acre for corn or 70 lb per acre for 30-inch-row soybeans.

The amount of P_2O_5 added in the band is non-limiting except that most P fertilizers are combined with N such as diammonium phosphate (DAP), monoammonium phosphate (MAP) and ammonium polyphosphate (APP). When these fertilizers are used as a starter, do not band more than 40 lb N per acre on corn and 20 lb N per acre on 30-inch-row soybeans. Nitrogen and P are the most important major nutrients for early plant growth, particularly in no-till production systems. On high P testing soils (greater than 30 ppm P), N is the most important nutrient for corn and should not be omitted from the starter in high residue no-till systems unless at least 40 to 60 lb N per acre has been broadcast applied prior to emergence. It is not necessary to include K in the starter fertilizer unless the soil test K levels are very low (less than 75 ppm K).

For drilled soybeans, wheat and forage legumes, it is unlikely that any P can be banded beside and below the seed at planting time because most new drills do not have fertilizer attachments. In this situation, all nutrients should be broadcast before planting. Only on extremely low P testing soils (less than 10 ppm P) will this create any significant P deficiency problems.

Fertilizer with the Seed

The general practice of applying fertilizer in contact with seed is not recommended. Band placement to the side and below the seed is usually superior to any other placement. Some farmers, however, have grain drills or planters that place fertilizer in contact with the seed. In this case, caution should be used to prevent seed or seedling injury from fertilizer salts. For corn, do not place more than 5 lb N + K_2O per acre in contact with the seed on low CEC soils (CEC less than 7) and no more than 8 lb N + K_2O per acre when the CEC is greater than 8. Soybean seed is very sensitive to salt injury; consequently, all fertilizer for drilled soybeans should be broadcast before planting. For small grain seedings, do not drill more than 100 lb of plant nutrients (N + P_2O_5 + K_2O) per acre in contact with the seed. Do not apply more than 40 lb N per acre as urea in contact with small grain seed. Young germinating seeds and seedlings are very sensitive to salt injury. Dry weather will accentuate the injury.

When seeding forage legumes, do not place more than 100 lb P_2O_5 and 50 lb K_2O per acre in contact with the seed. If the fertilizer is placed 1 to 1½ inches below the seed, the seeding time fertilizer may include all of the P and up to 150 lb K_2O per acre. Broadcast and incorporate any additional fertilizer requirements before seeding. For established legumes, all fertilizer requirements should be topdressed in the fall before plants go dormant (approximately October 1) or after the first cutting in the spring.

Phosphorus Recommendations

TABLES 13-17 PROVIDE ACTUAL P_2O_5 FERTILIZER RATE RECOMMENDATIONS DERIVED FROM THE EQUATIONS GIVEN ON PAGE 11.

Table 13.
PHOSPHATE (P_2O_5) RECOMMENDATIONS FOR CORN.

Soil test	Yield potential — bu per acre				
	100	120	140	160	180
ppm (lb/acre)	——lb P_2O_5 per acre——				
5 (10)[1]	85	95	100	110	115
10 (20)	60	70	75	85	90
15-30 (30-60)[2]	35	45	50	60	65
35 (70)	20	20	25	30	35
40 (80)	0	0	0	0	0

[1] Values in parentheses are lb/acre.
[2] Maintenance recommendations are given for this soil test range.

Table 16.
PHOSPHATE (P_2O_5) RECOMMENDATIONS FOR WHEAT.

Soil test	Yield potential — bu per acre				
	50	60	70	80	90
ppm (lb/acre)	——lb P_2O_5 per acre——				
15 (30)[1]	80	90	95	100	105
20 (40)	55	65	70	75	80
25-40 (50-80)[2]	30	40	45	50	55
45 (90)	15	20	20	25	30
50 (100)	0	0	0	0	0

[1] Values in parentheses are lb/acre.
[2] Maintenance recommendations are given for this soil test range.

Table 14.
PHOSPHATE (P_2O_5) RECOMMENDATIONS FOR CORN SILAGE.

Soil test	Yield potential — tons per acre				
	20	22	24	26	28
ppm (lb/acre)	——lb P_2O_5 per acre——				
5 (10)[1]	115	125	130	135	140
10 (20)	90	100	105	110	115
15-30 (30-60)[2]	65	75	80	85	90
35 (70)	35	40	40	45	45
40 (80)	0	0	0	0	0

[1] Values in parentheses are lb/acre.
[2] Maintenance recommendations are given for this soil test range.

Table 17.
PHOSPHATE (P_2O_5) RECOMMENDATIONS FOR ALFALFA.

Soil test	Yield potential — tons per acre				
	5	6	7	8	9
ppm (lb/acre)	——lb P_2O_5 per acre——				
15 (30)[1]	115	130	140	155	165
20 (40)	90	105	115	130	140
25-40 (50-80)[2]	65	80	90	105	115
45 (90)	35	40	45	50	60
50 (100)	0	0	0	0	0

[1] Values in parentheses are lb/acre.
[2] Maintenance recommendations are given for this soil test range.

Table 15.
PHOSPHATE (P_2O_5) RECOMMENDATIONS FOR SOYBEANS.

Soil test	Yield potential — bu per acre				
	30	40	50	60	70
ppm (lb/acre)	——lb P_2O_5 per acre——				
5 (10)[1]	75	80	90	100	105
10 (20)	50	55	65	75	80
15-30 (30-60)[2]	25	30	40	50	55
35 (70)	10	15	25	25	30
40 (80)	0	0	0	0	0

Values in parentheses are lb/acre.
Maintenance recommendations are given for this soil test range.

Potassium Recommendations

Tables 18-22 provide actual K_2O fertilizer rate recommendations derived from the equations given on page 11.

Table 18.

Potash (K_2O) recommendations for corn at various yield potentials, cation exchange capacities (CEC's) and soil test levels.

Yield potential	bu/ acre	100	120	140	160	180
Soil test K		lb K_2O per acre				
ppm (lb/acre)	CEC	5 meq/100g				
25 (50)[1]		125	130	135	140	145
50 (100)		95	100	105	110	115
75 (150)		65	70	75	80	85
88-118 (175-235)[2]		45	50	60	65	70
130 (260)		20	20	20	25	25
140 (280)		0	0	0	0	0
	CEC	10 meq/100g				
25 (50)		160	165	170	175	180
50 (100)		120	125	135	140	145
75 (150)		85	90	95	100	105
100-130 (200-260)[2]		45	50	60	65	70
140 (280)		25	25	30	30	35
150 (300)		0	0	0	0	0
	CEC	20 meq/100g				
50 (100)		195	200	210	215	220
75 (150)		145	150	160	165	170
100 (200)		95	100	110	115	120
125-155 (250-310)[2]		45	50	60	65	70
165 (330)		25	25	30	35	35
175 (350)		0	0	0	0	0
	CEC	30[3] meq/100g				
75 (150)		235	240	245	250	255
100 (200)		170	175	185	190	195
125 (250)		110	115	120	125	130
150-180 (300-360)[2]		45	50	60	65	70
190 (380)		25	25	30	30	35
200 (400)		0	0	0	0	0

1 Values in parentheses are lb/acre.
2 Maintenance recommendations are given for this soil test range.
3 For Michigan, do not use CEC's greater than 20 meq/100g.

Table 19.

Potash (K_2O) recommendations for soybeans at various yield potentials, cation exchange capacities (CEC's) and soil test levels.

Yield potential	bu/ acre	30	40	50	60	70
Soil test K		lb K_2O per acre				
ppm (lb/acre)	CEC	5 meq/100g				
25 (50)[1]		140	155	170	180	195
50 (100)		110	125	135	150	165
75 (150)		80	90	105	120	135
88-118 (175-235)[2]		60	75	90	105	120
130 (260)		25	30	35	40	[illegible]
140 (280)		0	0	0	0	
	CEC	10 meq/100g				
25 (50)		175	190	205	215	230
50 (100)		135	150	165	180	195
75 (150)		100	115	130	140	155
100-130 (200-260)[2]		60	75	90	105	120
140 (280)		30	40	45	50	60
150 (300)		0	0	0	0	0
	CEC	20 meq/100g				
50 (100)		210	225	240	255	270
75 (150)		160	175	190	205	220
100 (200)		110	125	140	155	170
125-155 (250-310)[2]		60	75	90	105	120
165 (330)		30	40	45	50	60
175 (350)		0	0	0	0	0
	CEC	30[3] meq/100g				
75 (150)		250	265	280	290	300
100 (200)		185	200	215	230	245
125 (250)		125	140	155	165	180
150-180 (300-360)[2]		60	75	90	105	120
190 (380)		30	40	45	50	60
200 (400)		0	0	0	0	0

1 Values in parentheses are lb/acre.
2 Maintenance recommendations are given for this soil test range.
3 For Michigan, do not use CEC's greater than 20 meq/100g.

Table 20.

POTASH (K_2O) RECOMMENDATIONS FOR WHEAT AT VARIOUS YIELD POTENTIALS, CATION EXCHANGE CAPACITIES (CEC's) AND SOIL TEST LEVELS.

Yield potential	bu/ acre	50	60	70	80	90
Soil test K		lb K_2O per acre				
ppm (lb/acre)	CEC	5 meq/100g				
25 (50)[1]		115	120	125	130	130
50 (100)		85	90	95	95	100
75 (150)		55	60	60	65	70
88-118 (175-235)[2]		40	40	45	50	55
130 (260)		15	15	15	20	20
140 (280)		0	0	0	0	0
	CEC	10 meq/100g				
25 (50)		150	155	160	160	165
50 (100)		115	115	120	125	130
75 (150)		75	80	85	85	90
100-130 (200-260)[2]		40	40	45	50	55
140 (280)		20	20	25	25	25
150 (300)		0	0	0	0	0
	CEC	20 meq/100g				
50 (100)		190	190	195	200	205
75 (150)		140	140	145	150	155
100 (200)		90	90	95	100	105
125-155 (250-310)[2]		40	40	45	50	55
165 (330)		20	20	25	25	25
175 (350)		0	0	0	0	0
	CEC	30[3] meq/100g				
75 (150)		225	230	235	235	240
100 (200)		165	165	170	175	180
125 (250)		100	105	110	110	115
150-180 (300-360)[2]		40	40	45	50	55
190 (380)		20	20	25	25	30
200 (400)		0	0	0	0	0

1 Values in parentheses are lb/acre.
2 Maintenance recommendations are given for this soil test range.
3 For Michigan, do not use CEC's greater than 20 meq/100g.

Table 21.

POTASH (K_2O) RECOMMENDATIONS FOR CORN SILAGE AT VARIOUS YIELD POTENTIALS, CATION EXCHANGE CAPACITIES (CEC's) AND SOIL TEST LEVELS.

Yield potential	tons/ acre	20	22	24	26	28
Soil test K		lb K_2O per acre[3]				
ppm (lb/acre)	CEC	5 meq/100g				
25 (50)[1]		260	275	290	300	300
50 (100)		225	245	260	275	290
75 (150)		195	210	230	245	260
88 (175)[2]		180	195	210	230	245
110 (220)		100	110	115	125	135
130 (260)		25	30	30	35	35
140 (280)		0	0	0	0	0
	CEC	10 meq/100g				
25 (50)		295	300	300	300	300
50 (100)		255	270	285	300	300
75 (150)		220	235	250	265	280
100 (200)[2]		180	195	210	230	245
120 (240)		110	120	125	135	145
140 (280)		35	40	40	45	50
150 (300)		0	0	0	0	0
	CEC	20 meq/100g				
50 (100)		300	300	300	300	300
75 (150)		280	295	300	300	300
100 (200)		230	245	260	280	295
125 (250)[2]		180	195	210	230	245
145 (290)		110	120	125	135	145
165 (330)		35	40	40	45	50
175 (350)		0	0	0	0	0
	CEC	30[4] meq/100g				
75 (150)		300	300	300	300	300
100 (200)		300	300	300	300	300
125 (250)		245	260	275	290	300
150 (300)[2]		180	195	210	230	245
170 (340)		110	120	125	135	145
190 (380)		35	40	40	45	50
200 (400)		0	0	0	0	0

1 Values in parentheses are lb/acre.
2 Maintenance recommendations are given for this soil test level.
3 Potash recommendations should not exceed 300 lb per acre.
4 For Michigan, do not use CEC's greater than 20 meq/100g.

Table 22.

POTASH (K_2O) RECOMMENDATIONS FOR ALFALFA AT VARIOUS YIELD POTENTIALS, CATION EXCHANGE CAPACITIES (CEC's) AND SOIL TEST LEVELS.

Yield potential	tons/ acre	5	6	7	8	9
Soil test K		lb K_2O per acre[3]				
ppm (lb/acre)	CEC	5 meq/100g				
25 (50)[1]		300	300	300	300	300
50 (100)		300	300	300	300	300
75 (150)		285	300	300	300	300
88 (175)[2]		270	300	300	300	300
110 (220)		150	175	205	230	260
130 (260)		40	50	55	65	70
140 (280)		0	0	0	0	0
	CEC	10 meq/100g				
25 (50)		300	300	300	300	300
50 (100)		300	300	300	300	300
75 (150)		300	300	300	300	300
100 (200)[2]		270	300	300	300	300
120 (240)		160	190	220	250	280
140 (280)		55	65	75	85	95
150 (300)		0	0	0	0	0
	CEC	20 meq/100g				
50 (100)		300	300	300	300	300
75 (150)		300	300	300	300	300
100 (200)		300	300	300	300	300
125 (250)[2]		270	300	300	300	300
145 (290)		160	190	220	250	280
165 (330)		55	65	75	85	95
175 (350)		0	0	0	0	0
	CEC	30[4] meq/100g				
75 (150)		300	300	300	300	300
100 (200)		300	300	300	300	300
125 (250)		300	300	300	300	300
150 (300)[2]		270	300	300	300	300
170 (340)		160	190	220	250	280
190 (380)		55	65	75	85	95
200 (400)		0	0	0	0	0

1 Values in parentheses are lb/acre.
2 Maintenance recommendations are given for this soil test level.
3 Potash recommendations should not exceed 300 lb per acre.
4 For Michigan, do not use CEC's greater than 20 meq/100g.

SECONDARY NUTRIENTS

Calcium (Ca), magnesium (Mg) and sulfur (S) are the three secondary nutrients required by plants. They are less likely to be added as fertilizer than the macronutrients (N-P-K). Most soils in Indiana, Michigan and Ohio will adequately supply these nutrients for plant growth. The standard soil test measures the relative availability of Ca and Mg in soils. There is no accurate soil test for S at this time. A plant analysis is the best diagnostic tool for confirming S availability.

If the exchangeable Ca level is in excess of 200 ppm, no response to Ca is expected. If the soil pH is maintained in the proper range, then the added Ca from lime will maintain an adequate level for crop production.

The required soil exchangeable Mg level is 50 ppm or greater. Low levels of Mg are commonly found in eastern Ohio and southern Indiana and on acid sandy soils in Michigan. High levels of exchangeable K tend to reduce the uptake of Mg. Therefore, if the ratio of Mg to K, as a percent of the exchangeable bases, is less than 2 to 1, then Mg is recommended for forage crops. Most Mg deficiencies can be corrected by maintaining proper soil pH using lime high in Mg. The ratio of Ca to Mg should be considered when lime is added to a soil. If the ratio, as a percent of the exchangeable bases, is 1 to 1 or less (less Ca than Mg), a high calcium/low magnesium limestone should be used. Most plants grow well over a wide range of Ca to Mg soil ratios.

Excessive use of K fertilizers can greatly reduce the uptake of Ca and Mg. High K/low Mg forages can cause grass tetany, milk fever, hypocalcemia and other health problems for ruminant animals. For these reasons, the tri-state K recommendations for alfalfa and corn silage do not follow the maintenance plateau concept above the critical K soil test level. Potassium recommendations above the critical level are less than crop removal so as to discourage luxury consumption of K and improve Mg uptake.

Sulfur is taken up as sulfate by plants. Sulfate sulfur is supplied primarily by microbial decomposition of soil organic matter. Sulfate is a negative ion and easily leaches in soils. Most soils in Indiana, Michigan and Ohio will adequately supply needed sulfur for plant growth. Sandy soils low in organic matter that are subject to excessive leaching may not supply adequate sulfur. Crops such as wheat and alfalfa that grow rapidly at cool temperatures when mineralization of S is slow are most likely to be S deficient. If elemental sulfur is used, it should be applied at least 2 months before the crop is planted. This would allow time for the S to be converted to the plant-available sulfate form by the soil bacteria. Sulfur should be added in the sulfate form if added less than 2 months before plant uptake.

MICRONUTRIENTS

Micronutrients are required by plants in small amounts. Those essential for plant growth are boron (B), chloride (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo) and zinc (Zn).

Most soils in Michigan, Indiana and Ohio contain adequate quantities of micronutrients. Field crop deficiencies of Cl, Mo and Fe have not been observed in this region of the United States. Some soils, however, may be deficient in B, Cu, Mn and Zn, and deficiencies can

Table 23.
CROP AND SOIL CONDITIONS UNDER WHICH MICRONUTRIENT DEFICIENCIES MAY OCCUR.

Micronutrient	Soil	Crop
Boron (B)	Sandy soils or highly weathered soils low in organic matter	Alfalfa and clover
Copper (Cu)	Acid peats or mucks with pH < 5.3 and black sands	Wheat, oats, corn
Manganese (Mn)	Peats and mucks with pH > 5.8, black sands and lakebed/depressional soils with pH > 6.2	Soybeans, wheat, oats, sugar beets, corn
Zinc (Zn)	Peats, mucks and mineral soils with pH > 6.5	Corn and soybeans
Molybdenum (Mo)	Acid prairie soils	Soybeans

cause plant abnormalities, reduced growth and even yield loss. When called for, micronutrient fertilizers should be used judiciously and with care. Some micronutrient fertilizers can be toxic if added to sensitive crops or applied in excessive amounts. Table 23 lists the soil and crop conditions under which micronutrient deficiencies are most likely to occur.

Table 24.
NUTRIENT SUFFICIENCY RANGES FOR CORN, SOYBEANS, ALFALFA AND WHEAT.

Element	Corn Ear leaf sampled at initial silking	Soybeans Upper fully developed leaf sampled prior to initial flowering	Alfalfa Top 6 inches sampled prior to initial flowering	Wheat Upper leaves sampled prior to initial bloom
	Percent (%)			
Nitrogen	2.90-3.50	4.25-5.50	3.76-5.50	2.59-4.00
Phosphorus	0.30-0.50	0.30-0.50	0.26-0.70	0.21-0.50
Potassium	1.91-2.50	2.01-2.50	2.01-3.50	1.51-3.00
Calcium	0.21-1.00	0.36-2.00	1.76-3.00	0.21-1.00
Magnesium	0.16-0.60	0.26-1.00	0.31-1.00	0.16-1.00
Sulfur	0.16-0.50	0.21-0.40	0.31-0.50	0.21-0.40
	Parts per million (ppm)			
Manganese	20-150	21-100	31-100	16-200
Iron	21-250	51-350	31-250	11-300
Boron	4-25	21-55	31-80	6-40
Copper	6-20	10-30	11-30	6-50
Zinc	20-70	21-50	21-70	21-70
Molybdenum	—	1.0-5.0	1.0-5.0	—

DIAGNOSING MICRONUTRIENT DEFICIENCIES

Both soil testing and plant analysis can be useful in diagnosing micronutrient deficiencies. Soil testing for micronutrients has become a widely accepted practice in recent years. Micronutrient soil tests, however, are not as reliable as tests for soil acidity (pH) or for phosphorus (P) and potassium (K). For this reason, plant analysis is also very important in diagnosing micronutrient deficiencies. Combining plant analysis with soil tests provides more accurate assessment of the micronutrient status of crops and soils.

Plant analysis can be used in two ways. One is to monitor the crop's micronutrient status; the other is to diagnose a problem situation. By monitoring, plant analysis can point out an existing or potential problem before visual symptoms develop. Table 24 is a guide to interpreting the adequacy of primary, secondary and micronutrients in specific plant tissues sampled at the suggested times. These sufficiency ranges should not be used when other plant parts are sampled or when samples are taken at different times.

If you suspect a nutrient deficiency problem, don't wait for the suggested sampling time to get a plant analysis. Collect plant samples from both problem and normal-appearing plants. Take whole plants if the plants are small; take leaf samples if the plants are large. Corresponding soil samples should also be taken from each area to help confirm the deficiency.

MICRONUTRIENT PLACEMENT AND AVAILABILITY

Table 23 lists the soil and crop conditions under which micronutrient deficiencies are most likely to occur. When these conditions exist and soil or plant tissue analysis confirms a need, micronutrient fertilizers should be soil or foliar applied. Micronutrients banded with starter fertilizers at planting time are usually more effective over a longer period of growth than foliar-applied micronutrients. Most soil-applied micronutrients, with the exception of boron for alfalfa and clover, should be banded with the starter fertilizer for efficient uptake. Boron applications for alfalfa and clover should be broadcast with other fertilizers or sprayed on the soil surface. Broadcast applications of 5 to 10 lb Zn per acre may be used to alleviate Zn-deficient soils. Broadcast applications of Mn, however, are not recommended because of high soil fixation. Residual carryover of available Mn in deficient soils is very limited. Therefore, Mn fertilizers should be applied every year on these soils. Foliar-applied micronutrients are more frequently used when deficiency symptoms are present or suspected and when banded soil applications are not practical.

Soil acidification with sulfur or aluminum sulfate to improve micronutrient uptake is usually not practical.

large fields. Some starter fertilizers are acid-forming and may improve the uptake of both applied and native soil forms of micronutrients when deficiencies are slight. When micronutrient deficiencies are moderate or severe, starter fertilizers alone will not overcome the deficiency.

SELECTING MICRONUTRIENT SOURCES

The three main classes of micronutrient sources are inorganic, synthetic chelates and natural organic complexes. Inorganic sources consist of oxides, carbonates and metallic salts such as sulfates, chlorides and nitrates. Sulfates of Cu, Mn and Zn are the most common metallic salts used in the fertilizer industry because of their high water solubility and plant availability. Oxides of Zn are relatively water insoluble and thus must be finely ground to be effective in soils. Broadcast applications of Zn oxides should be applied at least 4 months before planting to be effective. Oxysulfates are oxides that are partially acidulated with sulfuric acid. Studies have shown granular Zn oxysulfates to be about 35 to 50 percent water-soluble and immediately available to plants. Metal-ammonia complexes such as ammoniated Zn sulfate are also used by the fertilizer industry. Such complexes appear to decompose in soils and provide good agronomic effectiveness.

Chelates can be synthetic (manufactured) or natural organic decomposition products such as organic acids and amino acids, but they all contain known chemical bonds that increase micronutrient solubility. Synthetic chelates usually have higher stability than natural chelates. Chelates such as Zn-EDTA are more stable in soils than Zn citrate or Zn-ammonia complexes and thus are more effective in correcting Zn deficiency.

Natural organic micronutrient complexes are often produced by reacting metal inorganic salts with organic byproducts, mainly those of the wood pulp industry. Lignosulfonates, phenols and polyflavonoids are common natural organic complexes. These complexes are often quite variable in their composition and are less effective than the synthetic chelates.

Selecting a micronutrient source requires consideration of many factors, such as compatibility with N-P-K fertilizers, convenience in application, agronomic effectiveness and cost per unit of micronutrient.

Table 25 lists several commonly used micronutrient fertilizer sources. The inorganic sulfates are generally preferred to oxide forms of micronutrients when blending with N-P-K fertilizers because of their greater water solubility and greater effectiveness. Zinc and Mn oxides, however, are acceptable sources of micronutrients when finely ground. Finely ground materials may present segregation problems when used with granular fertilizers, so the use of a fertilizer sticker is highly recommended. Zinc EDTA, a synthetic chelate, has been found to be more effective than Zn sulfate in Michigan and Ohio field trials and may be used at one-fifth the rate of Zn sulfate. Natural organic chelates and complexes such as Zn citrate or Zn lignosulfonate are considered less effective than true (100 percent) synthetic chelates and should be used at the same rate as inorganic sources. Chelated Mn reactions in soil are quite different from chelated Zn reactions. Manganese chelates, when applied to soil, are usually ineffective because of high levels of available Fe in our soils (Fe replaces the Mn in soil-applied Mn chelates). Therefore, they are unacceptable sources of Mn when soil applied. Foliar applications of Zn chelates are effective sources and should be used at their labeled rates.

Table 25.
MICRONUTRIENT SOURCES COMMONLY USED FOR CORRECTING MICRONUTRIENT DEFICIENCIES IN PLANTS.

Micronutrient	Common fertilizer sources
Boron (B)	Sodium tetraborate (14 to 20% B) Solubor® (20% B) Liquid boron (10%)
Copper (Cu)	Copper sulfate (13 to 35% Cu) Copper oxide[1] (75 to 89% Cu)
Manganese (Mn)	Manganese sulfate (23 to 28% Mn) Manganese oxysulfates (variable % Mn)
Zinc (Zn)	Zinc sulfate (23 to 36% Zn) Zinc-ammonia complex (10% Zn) Zinc oxysulfates (variable % Zn) Zinc oxide[1] (50 to 80% Zn) Zinc chelate (9 to 14% Zn)

® Registered trade name of U.S. Borax.
[1] Granular oxides are not effective sources of micronutrients.

Table 26.
MANGANESE FERTILIZER RECOMMENDATIONS FOR RESPONSIVE CROPS GROWN ON MINERAL SOILS.[1]

Soil test Mn[2]	Soil pH 6.3	6.5	6.7	6.9	7.1	7.3	7.5+
ppm	*lb Mn per acre*[3]						
2	2	4	5	6	7	9	10
4	2	3	4	5	7	8	9
8	0	2	3	4	5	6	8
12	0	0	0	3	4	5	6
16	0	0	0	0	2	4	5
20	0	0	0	0	0	2	4
24	0	0	0	0	0	0	2

1 Recommendations are for band applications of soluble inorganic Mn sources with acid-forming fertilizers. Broadcast applications of Mn fertilizer are not recommended.

2 0.1 N HCl extractable Mn

3 Recommendations are calculated from the following equation and rounded to the nearest pound:

$XMn = -36 + 6.2 \times pH - 0.35 \times ST$

Where XMn = lb Mn per acre
pH = soil pH
ST = ppm Mn soil test

Table 27.
MANGANESE FERTILIZER RECOMMENDATIONS FOR RESPONSIVE CROPS GROWN ON ORGANIC SOILS.[1]

Soil test Mn[2]	Soil pH 5.8	6.0	6.2	6.4	6.6	6.8	7.0+
ppm	*lb Mn per acre*[2]						
2	2	4	5	7	9	10	12
4	1	3	5	6	8	10	11
8	0	1	3	5	7	8	10
12	0	0	2	4	6	7	9
16	0	0	1	3	4	6	8
20	0	0	0	1	3	5	6
24	0	0	0	0	2	4	5
28	0	0	0	0	1	2	4
32	0	0	0	0	0	1	3
36	0	0	0	0	0	0	1

1 Recommendations are for band applications of soluble inorganic Mn sources with acid-forming fertilizers. Broadcast applications of Mn fertilizer are not recommended.

2 0.1 N HCl extractable Mn

3 Recommendations are calculated from the following equation and rounded to the nearest pound:

$XMn = -46 + 8.38 \times pH - 0.31 \times ST$

Where XMn = lb Mn per acre
pH = soil pH
ST = ppm Mn soil test

MICRONUTRIENT RECOMMENDATIONS

Tables 26-29 give recommended rates of soil-applied inorganic sources of micronutrients based on soil type, soil test and pH. These rates are recommended only for the responsive crops listed in Table 23. The micronutrient soil tests recommended for use in Michigan, Ohio and Indiana are 0.1 N HCl for Mn and Zn and 1.0 N HCl for Cu using a 1 to 10 soil-to-extractant ratio. Micronutrient availability in both mineral and organic soils is highly regulated by soil pH. The higher the soil pH, the higher the soil test should be before a deficiency is eliminated. The higher the soil pH and the lower the soil test, the more micronutrient fertilizer is needed to correct a deficiency. Copper deficiency in Michigan, Ohio and Indiana has been observed only on black sands and organic soils. Because of the extreme Mn and Cu deficiency problems and often excess N mineralization in organic soils, wheat and oat plantings are not recommended on these soils.

Boron recommendations for Michigan, Ohio and Indiana are not based on any soil test — they are based on soil type and the responsiveness of the crop. Boron is recommended annually at a rate of 1 to 2 pounds per acre broadcast applied on established alfalfa and clover grown on sandy soils. Boron applications on fine-textured high clay soils have not proven to be beneficial.

Molybdenum deficiency of soybeans has been found on certain acid soils in Indiana and Ohio. Most molybdenum deficiencies can be corrected by liming soils to the proper soil pH range. The recommended molybdenum fertilization procedure is to use ½ ounce of sodium molybdate per bushel of seed as a

Table 28.
Zinc fertilizer recommendations for responsive crops grown on mineral and organic soils.[1]

Soil test Zn^2	Soil pH 6.6	6.8	7.0	7.2	7.4	7.6+
ppm	*lb Zn per acre*[3]					
1	1	2	3	4	5	6
2	0	1	2	3	4	5
4	0	0	1	2	3	4
6	0	0	1	2	3	4
8	0	0	0	1	2	3
10	0	0	0	0	1	2
12	0	0	0	0	0	1

[1] Recommendations are for band applications of soluble inorganic Zn sources. Synthetic Zn chelates may be used at one-fifth this rate. For broadcast applications, use 5 to 10 lb Zn/acre.

[2] 0.1 N HCl extractable Zn

[3] Recommendations are calculated from the following equation and rounded to the nearest pound:
$XZn = -32 + 5.0 \times pH - 0.4 \times ST$
Where XZn = lb Zn per acre
pH = soil pH
ST = ppm Zn soil test

Table 29.
Copper recommendations for corn grown on organic soils.[1]

Soil test Cu^2	Copper recommendation
ppm	*lb Cu per acre*[3]
1	4
4	4
8	3
12	2
16	1
20+	0

[1] Recommendations are for band applications of soluble inorganic Cu sources. For broadcast applications, use 5 to 10 lb Cu/acre.

[2] 1.0 N HCl extractable Cu

[3] Recommendations are calculated from the following equation and rounded to the nearest pound:
$XCu = 6.3 - 0.3 \times ST$
Where XCu = lb Cu per acre
ST = ppm Cu soil test

planter box treatment or 2 ounces of sodium molybdate per acre in 30 gallons of water as a foliar spray. Extreme care should be used when applying molybdenum because 10 ppm of Mo in forage may be toxic to ruminant animals.

Table 30 gives foliar micronutrient recommendations for responsive crops listed in Table 23. Foliar rates of suggested sources should be based on the size of the plant — use higher rates for larger plants and lower rates with smaller plants. Use 20 to 30 gallons of water for sufficient coverage of the foliage to ensure good uptake of the micronutrient. When foliar sprays of chelates are used, follow the labeled rate — using too much can cause foliar injury and reduced uptake. At reduced rates, chelate foliar sprays are usually less effective than the suggested inorganic sources.

Table 30.
Common micronutrient fertilizer sources and suggested rates for foliar application.[1]

Micronutrient	lb of element per acre	Common fertilizer sources
Boron (B)	0.1-0.3	Sodium borate (20 %B) Boric acid (17%B)
Copper (Cu)	0.5-1.0	Copper sulfate (13 to 25% Cu)
Manganese (Mn)	1.0-2.0	Manganese sulfate (28% Mn)
Zinc (Zn)	0.3-0.7	Zinc sulfate (36% Zn)
Molybdate (Mo)	0.01-0.07	Ammonium molybdate (49%) Sodium molybdate (46%)

[1] Use sufficient water (20 to 30 gallons) to get good coverage of foliage.

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March 21, 1998

Dear

You have been selected to participate in a pesticide usage survey conducted by OSU Extension at Clermont County as a part of East Fork/Little Miami River water quality program. Our goal is to collect the pesticide use data to determine the risk and benefit information associated with pesticides used in fruit production.

I have divided chemicals into four categories that include fungicides, insecticides/miticides, herbicides, and fertilizers. Please take some of your valuable time to list the amount of pesticides and fertilizers you used on your fruit farm in 1997. I have provided you with four surveys that cover apples, grapes, brambles, and strawberries. The results from this survey will help us develop a cost-effective plan to maintain the water quality in East Fork and Little Miami River watershed.

To reward you for completing the survey, OSU Extension at Clermont county will give you a choice of one Extension publication on fruit production. Your choices include "Ohio Commercial Small Fruit Spray Guide," "Ohio Commercial Tree Fruit Spray Guide,", and the ever popular "Midwest Small Fruit Pest Management Handbook." In Addition, your names will be entered into a drawing for a $50 cash prize. Please remember that we will only have 35 fruit growers all together.

The deadline for returning the survey will be April 25. I look forward to your completed surveys. If you have any questions about the survey, please let me know. I will be more than happy to answer your questions.

Sincerely yours,

Gary Gao, Ph.D.
Horticulture Extension Agent

cc: John Grimes, OSU Extension-Highland County
Tony Nye, OSU Extension-Clinton County

Survey of Ohio Apple, Peach, and Pear Orchard Pesticide Use in 1997

Name of the Farm Operation:______________________ Farm Manager:______________

Farm Address:___________________________ City and Zip Code:______________

Phone:____________________ Best Time to Call:________________________________

Fruit Crop Production Represented in Farm Operation

Crop	Acreage	Crop	Acreage
Apples		Pears	
Blackberries		Plumes and Prunes	
Blueberries		Raspberries	
Cherries		Strawberries	
Grapes		Other fruits	
Peaches and Nectarines			

Fungicide Usage on Apples, Peaches, and Pears in 1997

Fungicides	Rate /100 gal	Rate /Acre	Your Rate/100 gal	Your Rate/Acre	Frequency (i.e. 5 times)	Total Amount
Bayleton 50DF	0.5-2 oz	2-8 oz				
Benlate 50WP	2-3 oz	8-12 oz				
Captan 50WP	1 lb	4 lb				
Mancozeb 80 WP	12 oz	3 lb				
Nova 40WP	1.25 -2 oz	5-8 oz				
Polyram 80WP	1.5 oz	6 lb				
Rubigan EC	3 fl. oz	8-12 fl. oz				
Streptomycin 17W	0.5 lb	2 lb				
Sulfur 95WP	2-3 lb	8-12 lb				
Thiram 65WP	2 lb	8 lb				
Topsin-M 70 WSB	4-6 oz	1-1.5 lb				
Ziram 76DF	2 lb	6-8 lb				
Other, specify						
Other, Specify						

Insecticide/Miticide Usage on Apples, Peaches, and Pears in 1997

Insecticides/Miticides	Rate /100 gal	Rate /Acre	Your Rate/100 gal	Your Rate/Acre	Frequency (i.e. 5 times)	Total Amount
Agri-Mek 0.15 EC	2.5-5 fl oz	8 fl oz				
Ambush 25 WP		6.4-25.6 oz				
Ambush 2 EC		6.4-25.6 fl oz				
Apollo SC or Savey 50 WP	1-2 fl oz	4-8 fl oz 3 oz				
Asana XL 0.66 EC	2-5.8 fl oz	4.8-16.5 fl oz				
Carozol SP	4-8 oz	1-4 lb				
Diazinon 50 WP	1 lb	4 lb				
Dimethoate 4EC Dimethoate 25WP Dimethoate 2.76 EC	0.5-1 pt 1-2 lb 0.75-1.5 pt	2-4 pt 4-8 lb 3-6 pt				
Guthion 50 WP	0.5-0.75 lb	2-3 lb				
Imidan 70WP	0.75 lb	2.1-5.3 lb				
Lannate LV (2.4SL) Lannate 90SP	0.75 pt 0.25 lb	3 pt 1 lb				
Lorsban 4EC Lorsban 50 WP	0.5-1 pt 8-12 oz	2-4 pt 2-3 lb				
Sevin 50 WP Sevin 80S Sevin 4F Sevin XLR (4EC)	1 lb 0.67 lb 0.5 pt 0.5 pt	4 lb 2.67 2 qt 2 qt				
Thiodan 50 EC Thiodan 3 EC	1 lb 0.67 qt	4 lb 2.67 lb				
Other, Specify						
Other, Specify						
Other, Specify						

Herbicide Usage on Apples, Peachs, and Pears in 1997

Herbicides	Rate /Acre	Your Rate/Acre	Frequency (i.e. 5 times)	Total Amount
Casoron 4G or Norosac	100-150 lb			
Devrinol 50DF Devrinol 10-G	8 lb 40 lb			
Goal 1.6 E	2.5-10			
Gramoxone (2.5 lb/gal)	2-3 pt/10 -20 gal			
Karmex DF (80% a.i.)	4 lb			
Kerb 50	2lb-8 lb			
Poast 1.5 E	1.2-2.5 pt/25 gal			
Princep 4L	2-4 qt			
Prowl 3.3 EC	2.4-4.8 qt/20 gal			
Roundup Roundup 1-2% Roundup 33%	1-5 qt Hand held Wiper or wick			
Sinbar (80%)	2-4 lb/20 gal			
Surflan A.S.(4 lb/gal) Surflan G (0.5 a.i./lb)	2-6 qt 2.4-7.1 lb			
Touchdown 6E	5 1/3/10 to 30 gal			
Other, Specify				
Other, Specify				

Fertilizer Usage on Apples, Peaches, and Pears in 1997

Nitrogen Actual Nitrogen/Acre	Phosphate lbs/Acre (P_2O_5)	Potash lbs/Acre (K_2O)	Lime	Elemental Sulfur	Other Nutrients

Survey of Ohio Brambles (Raspberries and Blackberries) Pesticide Use in 1997

Name of the Farm Operation:________________________ Farm Manager:________________
Farm Address:______________________________ City and Zip Code:__________________
Phone:_____________________ Best Time to Call:___________________________________

Fruit Crop Production Represented in Farm Operation

Crop	Acreage	Crop	Acreage
Apples		Pears	
Blackberries		Plumes and Prunes	
Blueberries		Raspberries	
Cherries		Strawberries	
Grapes		Other fruits	
Peaches and Nectarines			

Fungicide Usage on Brambles (Raspberries and Blackberries) in 1997

Fungicides	Rate /100 gal	Rate /Acre	Your Rate/100 gal	Your Rate/Acre	Frequency (i.e. 5 times)	Total Amount
Aliette 80 WDG	2.5 lb	2.5-5 lb				
Benlate 50WP	6 oz	12 oz				
Copper hydroxide 50WP	2 lb	4 lb				
Liquid Lime and Sulfur	10 gal	20 gal				
Ridomil 2E		< 3 lb ai				
Rovral 50WP	0.5-1 lb	1-2 lb				
Ronilan 50 WP	0.5-1 lb	1-2 lb				
Other, specify						
Other, Specify						

Insecticide/Miticide Usage on Brambles (Raspberries and Blackberries) in 1997

Insecticides/Miticides	Rate /100 gal	Rate /Acre	Your Rate/100 gal	Your Rate/Acre	Frequency (i.e. 5 times)	Total Amount
Align	8-10.5 oz	8 oz				
Cythion 5EC	0.75 qt	1.5 qt				
Dipel 2X	0.25-0.5 oz	0.5-1.0 lb				
Diazinon 50 WP Diazion AG500 (4E)	2-4 lb 1 pt	4-8 lb 2 pt				
DiPel 2X	0.25-5 lb	0.5-1 lb				
Guthion 50 WP Guthion 2 S	4 oz 0.5 pt	8 oz 1 pt				
Malathion 8F at	1-2 pt	2-4 qt				
Methoxychlor 50 WP	1-1.5 lb	2-3 lb				
Neemix	0.25-1 gal	0.5-2 gal				
Pyrelin EC	0.5-1.0 qt	1-2 qt				
Sevin 50 WP Sevin 80S	2-4 lb 1.25 lb	4-8 lb 2.5 lb				
Other, Specify						
Other, Specify						

Herbicide Usage on Brambles (Raspberries and Blackberries) in 1997

Herbicides	Rate /Acre	Your Rate/Acre	Frequency (i.e. 5 times)	Total Amount
Casoron or Norosac 4G	100 lb			
Devrinol 50DF	8 lb/20 gal			
Fusilade 1E	1-1.5 qt			
Gallery 75DF	0.66-1.33 lb			
Gramoxone (2.5 lb/gal)	2-3 qt/50 -100 gal			
Karmex (Diuron 80%)	2-3 lb in 24-40 gal			
Poast 1.5 EC	1.5-2.5 pt/10-20 gal			
Princep (simazine 80%)	2.5-5.0 lb in 25-40 gal			
Prism	13-34 fl oz			
Roundup (glyphosate 3 lb/gal)	1-5 qt/10-40 gal			
Sinbar (terbacil 80%)	1-2 lb			
Solicam (norflurazon 80%)	2.5-5 lb			
Snapshot 80DF	2.5-5.0 lb			
Surflan (oryzalin 4AS)	2.0 to 6.0 qt/20-40 gal			
Touchdown 6E	5.33/10-30 gal			
Other, Specify				
Other, Specify				

Fertilizer Usage on Brambles (Raspberries and Blackberries) in 1997

Nitrogen Actual Nitrogen/Acre	Phosphate lbs/Acre (P_2O_5)	Potash lbs/Acre (K_2O)	Lime	Elemental Sulfur	Other Nutrients

Survey of Ohio Grape Pesticide Use in 1997

Name of the Farm Operation:______________________ Farm Manager:________________
Farm Address:______________________________ City and Zip Code:________________
Phone:___________________ Best Time to Call:________________________________

Fruit Crop Production Represented in Farm Operation

Crop	Acreage	Crop	Acreage
Apples		Pears	
Blackberries		Plumes and Prunes	
Blueberries		Raspberries	
Cherries		Strawberries	
Grapes		Other fruits	
Peaches and Nectarines			

Fungicide Usage on Grapes in 1997

Fungicides	Rate /100 gal	Rate /Acre	Your Rate/100 gal	Your Rate/Acre	Frequency (i.e. 5 times)
Bayleton 50DF	0.5-2 oz	2-8 oz			
Benlate 50WP	2-3 oz	8-12 oz			
Captan 50WP	1 lb	4 lb			
Ferbam 76 WP	1.5 lb	3.0 lb			
Fixed Copper and Lime (Abound F)	5.5-7.7 fl oz	11-15.4 fl oz			
Mancozeb 80 WP	12 oz	3 lb			
Nova 40WP	1.25 -2 oz	5-8 oz			
Procure 50WS	2-4 oz	4-8 oz			
Ridomil MZ 72 Ridomil MZ-58	1-1.25 lb 0.5-1 lb	2-2.5 lb 1.5-2 lb			
Rovral 50WP	0.75-1 lb	1.5-2 lb			
Rubigan EC	3 fl. oz	8-12 fl. oz			
Sulfur 95WP	2-3 lb	8-12 lb			
Thiram 65WP	2 lb	8 lb			
Ziram 76DF	2 lb	6-8 lb			
Other, specify					
Other, Specify					

Insecticide/Miticide Usage on Grapes in 1997

Insecticides/Miticides	Rate /100 gal	Rate /Acre	Your Rate/100 gal	Your Rate/Acre	Frequency (i.e. 5 times)
Diazinon 50 WP Diazion AG500 (4E)	1 lb 0.5-1.0 pt	2 lb 1-2 pt			
Guthion 50 WP Guthion 2 S	0.75-1.0 lb 1.2 - 2 qt	1.5-2 lb 3-4 qt			
Imidan 70WP	0.67-1.06 lb	1.33-2.13 lb			
Kelthane 35 WP Kelthane 50 WP	1-1.33 lb 0.5-1 lb	1.5-3.5 lb 1-2.5 lb			
Methoxychlor 50 WP	3 lb	6 lb			
Penncap-M	1 qt	2 qt			
Provaso Solupak 75 WP		0.75-1.0 oz			
Sevin 50 WP Sevin 80S	2 lb 1.25 lb	4 lb 2.5 lb			
Thiodan 50 EC Thiodan 3 EC	1 lb 0.67 qt	2 lb 1.33 qt			
Vendex 4L Vendex 50 WP	0.5-1.0 pt 0.5-1.0 lb	1-2.5 pt 1-2.5 lb			
Other, Specify					
Other, Specify					

Herbicide Usage on Grapes in 1997

Herbicides	Rate /Acre	Your Rate/Acre	Frequency (i.e. 5 times)
*Casoron 4G or Norosac	100-150 lb		
Devrinol 50DF	8 lb/20 gal		
Goal 1.6 E	2.5-10 qt/100 gal		
Gramoxone (2.5 lb/gal)	2-3 pt/30 -100 gal		
Karmex DF (80% a.i.)	2-4 lb/25-50 gal		
Kerb 50	2lb-8 lb/20-50 gal		
Poast 1.5 EC	1.2-2.5 pt/20 gal		
Princep (80%)	2.5-6.0 lb/20 gal		
Prowl 4 EC	2-4 qt/20 gal		
Roundup (3 lb acid/gal)	1-4 qt/10-40 gal		
Surflan A.S.(4 lb/gal)	2-6 qt/20-60 gal		
Other, Specify			
Other, Specify			

Fertilizer Usage on Grapes in 1997

Nitrogen Actual Nitrogen/Acre	Phosphate lbs/Acre (P_2O_5)	Potash lbs/Acre (K_2O)	Lime	Elemental Sulfur	Other Nutrients

Survey of Ohio Strawberry Pesticide Use in 1997

Name of the Farm Operation:______________________ Farm Manager:______________
Farm Address:__________________________ City and Zip Code:______________
Phone:________________ Best Time to Call:______________________________

Fruit Crop Production Represented in Farm Operation

Crop	Acreage	Crop	Acreage
Apples		Pears	
Blackberries		Plumes and Prunes	
Blueberries		Raspberries	
Cherries		Strawberries	
Grapes		Other fruits	
Peaches and Nectarines			

Fungicide Usage on Strawberries in 1997

Fungicides	Rate /100 gal	Rate /Acre	Your Rate/100 gal	Your Rate/Acre	Frequency (i.e. 5 times)	Frequency (i.e. 5 times)
Aliette 80 WDG	2.5 lb	2.5-5 lb				
Benlate 50WP	8 oz	1 lb				
Captan 50WP	2 lb	4 lb				
Ridomil 2E		< 3 lb ai				
Rovral 50WP	8-12 oz	16-24 oz				
Sulfur 95WP	2-3 lb	8-12 lb				
Syllit 65 WP	0.75-1 lb	1.5-2 lb				
Thiram 65WP	2.5 lb	5 lb				
Topsin M 70WSB	0.375-0.5 lb	0.75-1 lb				
Other, specify						
Other, Specify						

Insecticide/Miticide Usage on Strawberries in 1997

Insecticides/Miticides	Rate /100 gal	Rate /Acre	Your Rate/100 gal	Your Rate/Acre	Frequency (i.e. 5 times)	Total Amount
Agri-Mek 0.15EC	8 fl oz	16 fl oz				
Danitol 2.4 EC	8-10.6 fl oz	10.76 fl oz				
Diazinon 50 WP Diazion AG500 (4E)	1 lb 1.0 pt	2 lb 2 pt				
Brigade 10 WP	3.2 oz-16 oz	6.4-32 oz				
Guthion 50 WP Guthion 2 S	0.5 lb 1 pt	1.0 lb 2 pt				
Kelthane 35 WP Kelthane 50 WP	1-1.33 lb 0.5-1 lb	2-6.75 lb 1-4.75 lb				
Methoxychlor 50 WP	3 lb	6 lb				
Sevin 50 WP Sevin 80S	2 lb 1.25 lb	4 lb 2.5 lb				
Thiodan 50 EC Thiodan 3 EC	1 lb 1.3 qt	2 lb 2.6 qt				
Vendex 4L Vendex 50 WP	1.0 pt 1 lb	2 pt 2 lb				
Other, Specify						
Other, Specify						

Herbicide Usage on Strawberries in 1997

Herbicides	Rate /Acre	Your Rate/Acre	Frequency (i.e. 5 times)	Total Amount
Dacthal (DCPA 75%)	8-12 lb/50 gal			
Devrinol 50DF	8 lb/20 gal			
Gramoxone (2.5 lb/gal)	1.5 pt/20 -100 gal			
Poast 1.5 EC	1.5 pt/25 gal			
Sinbar (terbacil 80%)	2-6 oz			
Other, Specify				
Other, Specify				

Fertilizer Usage on Strawberries in 1997

Nitrogen Actual Nitrogen/Acre	Phosphate lbs/Acre (P_2O_5)	Potash lbs/Acre (K_2O)	Lime	Elemental Sulfur	Other Nutrients

THE OHIO STATE UNIVERSITY EXTENSION

Ohio State University Extension
Clermont County
P.O. Box 670
1000 Locust Street
Owensville, OH 45160-0670

Phone 513-732-7070
Fax 513-732-7060

March 25, 1998

Dear

You have been selected to participate in a pesticide usage survey conducted by OSU Extension at Clermont County as a part of East Fork/Little Miami River water quality program. Our goal is to collect the pesticide use data to determine the risk and benefit information associated with pesticides used in vegetable production.

I have divided chemicals into four categories that include fungicides, insecticides/miticides, herbicides, and fertilizers. Please take some of your valuable time to list the amount of pesticides and fertilizers you used on your vegetable farm in 1997. I have provided you with a four-page survey. The results from this survey will help us develop a cost-effective plan to maintain the water quality in East Fork and Little Miami River watershed.

To reward you for completing the survey, OSU Extension at Clermont county will give you a copy of the 1998 "Ohio Vegetable Production Guide," a must-have bulletin for vegetable producers. In Addition, your names will be entered into a drawing for a $50 cash prize. Please remember that we will only have 41 vegetable growers all together.

The deadline for returning the survey will be April 25. I look forward to your completed surveys. If you have any questions about the survey, please let me know. I will be more than happy to answer your questions.

Sincerely yours,

Gary Gao, Ph.D.
Horticulture Extension Agent

cc: John Grimes, OSU Extension-Highland County
Tony Nye, OSU Extension-Clinton County

Survey of Ohio Vegetable Pesticide Use in 1997

Name of the Farm Operation:______________________ Farm Manager:________________

Farm Address:___________________________ City and Zip Code:__________________

Phone:____________________ Best Time to Call:________________________________

Vegetable Crop Production Represented in Farm Operation

Crop	Acreage	Crop	Acreage
Asparagus and Rhubarb		Onions: Bulbs and Greens	
Beans		Parsley	
Beets		Peas	
Broccoli, Brussels Sprouts, Cabbage		Peppers	
Carrots and Parsnip		Potatoes	
Celery		Radishes, Turnips, Rutabagas (Swede Turnips), and Kohlrabi	
Cucumbers		Spinach and Swiss Chard	
Eggplant		Pumpkins and Squash (Summer and Winter)	
Endive and Escarole		Sweet Corn	
Greens: Mustard, Turnip, Collard, Kale		Tomatoes	
Lettuce		Other	
Muskmelon and Watermelon		Other	

Fertilizer Usage on Vegetable Crops in 1997

Nitrogen Actual Nitrogen/Acre	Phosphate lbs/Acre (P_2O_5)	Potash lbs/Acre (K_2O)	Lime	Elemental Sulfur	Other Nutrients

Fungicide Usage (Rate and Frequency) on Vegetable Crops in 1997

Fungicides	Beans	Peppers	Pumpkins	Sweet Corns	Tomatoes	Others (please specify)
Example: Bravo 720	**1.4 pt/A 3 times**					
Aliette 80WDC						
Apron 25W, or 50W						
Basic Copper 53						
Bayleton 50DF						
Benlate 50WP						
Botran 75W						
Bravo 720, 500, or 90 DG						
Captan 50WP						
Dithane F45 or M45						
Echo						
Fixed Copper						

Maneb 75 DF						
Manzate 200 DF						
Penncozeb						
Ridomil PC, MZ, C70W, or 50 W						
Ronilan 50 DF						
Rovral 50 W, 4F						
Terranil 6 L						
Thiram						
Topsin-M85 WDG						
Ziram 76DF						
Other, specify						

Insecticide/Miticide Usage (Rate and Frequency) on Vegetable Crops in 1997

Insecticides/Miticides	Beans	Peppers	Pumpkins	Sweet Corns	Tomatoes	Others (please specify)
Example: Diazinon 50 WP	**2 lb/Acre 3 times**					
Agri-Mek 0.15 EC						
Baythroid 2 EC						
Danitol 2.4 EC						
Diazinon 50 WP Diazinon AG 500						
Guthion 50 WP Sniper 50 W Gowan Azinphos-M 50 W						
Kelthane MF (4EC)						
Kryocide (96%) a.i.						
Lannate LV (2.4SL) Lannate 90SP						
Malathion 5 EC Malathion 8 EC						
Methoxychlor 4L Methoxychlor 2 EC						
Penncap-M 2F						

Sevin 50 WP Sevin 80S Sevin 4F Sevin XLR (4EC)						
Thiodan 50 WP Thiodan 3 EC						
Other, Specify						
Other, Specify						
Other, Specify						

Sencor 4 L Lexone 4 L						
Trific 60DF						
Tillam 6 E						
Other, Specify						
Other, Specify						

Herbicide Usage (Rate and Frequency) on Vegetable Crops in 1997

Herbicides	Beans	Peppers	Pumpkins	Sweet Corns	Tomatoes	Others (please specify)
Example: Dacthal 75W	**6 lb/acre 3 times**					
Aatrex 80 W						
Basagram						
Commond 4 EC						
Curbit						
Dacathal W 75						
Devrinol 50 WP						
Dual 8 E Dual II						
Eptem 7E						
Frontier 6.0						
Gramoxone Extra						
Lasso 4 EC						
Poast (0.2-0.3 a.i./A)						
Roundup Roundup 1-2% Roundup 33%						

Ohio State University Extension
Clermont County
P.O. Box 670
1000 Locust Street
Owensville, OH 45160-0670
Phone 513-732-7070
Fax 513-732-7060

March 25, 1998

Dear

You have been selected to participate in a pesticide usage survey conducted by OSU Extension at Clermont County as a part of East Fork/Little Miami River water quality program. Our goal is to collect the pesticide use data to determine the risk and benefit information with ornamental plant production, lawn care, golf course, tree and shrub care, recreation parks, institutional parks and grounds maintenance.

I have divided chemicals into four categories that include fungicides, insecticides/miticides, herbicides, and fertilizers. Please take some of your valuable time to list the amount of pesticides and fertilizers you used at your business, institution, or customers' properties in 1997. I have provided you a survey with three tables. The results from this survey will help us develop a cost-effective plan to maintain the water quality in East Fork and Little Miami River watershed.

To reward you for completing the survey, OSU Extension at Clermont county will give you a choice of ONE Extension publication on turfgrasses or ornamental plants, to first 50 people that return completed surveys. Your choices include "Insect and Mite Control on Woody Ornamentals and Herbaceous Perennials," "Controlling Weeds in Nurseries and Landscape Plantings," and "Management of Turf Pests." In Addition, your names will be entered into a drawing of cash prizes of $100, $75, $50, and $25.

The deadline for returning the survey will be April 25. I look forward to your completed surveys. If you have any questions about the survey, please let me know. I will be more than happy to answer your questions.

Sincerely yours,

Gary Gao, Ph.D.
Horticulture Extension Agent

cc: John Grimes, OSU Extension-Highland County
Tony Nye, OSU Extension-Clinton County

Survey of Pesticide Use on Turf, Ornamentals, and Industrial Vegetation

Your Name:____________________ Business or Institution Name:__________________________
Business or Institution: Address:____ City and Zip Code:__________________
Business or Institution Township:_____________
Business Phone:___________________ Best Time to Call:_________________________

Horticultural Information About Your Business or Institution

Types of Operation	Total Acreage Under Management	Acreage for Weed Control	Acreage for Insect/Mite Control	Acreage for Disease Control	Acreage with Fertilizer Application
Greenhouses					
Nurseries					
Sod Farm					
Tree Farm					
Parks/Recreation					
Institutions/Business Parks					
Grounds Maintenance					
Lawn Care					
Tree/Shrub Protection					
Golf Courses					
Industrial Vegetation Control					
Other					

Survey of Pesticides (Fungicides, Insecticides/Miticides, and Herbicides) Usage in 1997 at Your Business or Institution, or Customers's Properties

Type of Turf Area or Ornamental Plants Treated	Acre or 1000 Square Feet (Please Circle One) Treated	Name of the Pesticide Used	Concentration of Pesticides i.e. % a.i., lb/gal	Formulation of Pesticides WP, DF, G, E, EC, L, others	Quantity of Undiluted Pesticide (lb, oz, pt, qt, gal, etc)	Volume or Quantity per Application (lb, oz, pt, qt, gal, etc)	Number of Applications	Who Applied the Pesticides Self or Custom Applied	Pest Target
List	List	List	List	List	List	List	List	List	List
Examples: Pine Trees Chrysanthemums Maples Fairways Home Lawns Parks	 1 Acre 1 Acre 5 Acres 50 Acres 100 Acres 25 Acre	 Dimethoate Diazion Malathion Orthene Chlorpyrifos 2,4-D	 2 lb/gal 50% 57% 75% 50% 3.8 lb/gal	 EC WP EC S WSP EC	 2.0 qts/100 gal 1.0 lb/100 gal 1.5 qts/100 gal 2.75 lb/acre 1.0 lb/acre 4 qts/Acre	 10 lb 1.0 500 gallon 188.0 lb 100 lb 12 lb	 1 1 2 3 1 1	 Custom Custom Custom Self Custom Self	 Bagworm Thrips Aphids Sod Webworm Chinch Bug Boradleaf Weeds

Survey of Pesticides (Fungicides, Insecticides/Miticides, and Herbicides) Usage in 1997 at Your Business or Institution, or Customers's Properties (Contiuned)

Type of Turf Area or Ornamental Plants Treated	Acre or 1000 Square Feet (Please Circle One) Treated	Name of the Pesticide Used	Concentration of Pesticides i.e. % a.i., lb/gal	Formulation of Pesticides WP, DF, G, E, EC, L, others	Quantity of Undiluted Pesticide (lb, oz, pt, qt, gal, etc)	Volume or Quantity per Application (lb, oz, pt, qt, gal, etc)	Number of Applications	Who Applied the Pesticides Self or Custom Applied	Pest Target
List	List	List	List	List	List	List	List	List	List

Survey of Fertilizer Usage in 1997 at Your Business or Institution, or Customers's Properties

Type of Turf Area or Ornamental Plants Treated	Acre or 1000 Square Feet (Please Circle One) Treated	Type of the Fertilizer (Name and the Analysis)	Nitrogen (lbs of actural N per Acre or 1000 Square Feet	Phosphus (lbs of P_2O_5 per Acre or 1000 Square Feet	Potassium (lbs of K_2O per Acre or 1000 Square Feet)	Number of Applications Per Year	Lime (tons/acre or lbs/1000 square feet)	Elemental Sulphur (lbs/acre or square feet)	Other Micronutrients
List	List	List	List	List	List	List	List	List	List
Example: Lawns	2 Acres	24-6-12	2 lb/1000 sq ft	0.5 lb/1000 sq ft	1 lb/1000 sq ft	3	None	None	Iron Sulphate

THE OHIO STATE UNIVERSITY EXTENSION

Ohio State University Extension
Clermont County
P.O. Box 670
1000 Locust Street
Owensville, OH 45160-0670

Phone 513-732-7070
Fax 513-732-7060

November 27, 1998

Dear

A pesticide usage survey conducted by OSU Extension at Clermont County was sent to you about one month ago. This survey is a part of East Fork/Little Miami River water quality program. Our goal is to assess the pesticide and fertilizer usage by homeowners like you in your yard and garden in Clermont County. We received 50 excellent responses from residents in our county. However, we would definitely like a few more. I still have 50 Ohio-Line CDS in my office for those that turn in complete and detailed responses. The OhioLine CD has several thousand OSU Extension Fact Sheets and many Bulletins with great pictures on landscaping and gardening. It makes a great Christmas gift for a gardening friend.

This pesticide usage information will help us design effective educational programs to improve our water quality in a pro-active manner. The results from this survey will also help us develop a cost-effective plan to maintain the water quality in East Fork and Little Miami River watershed.

I have divided yard and garden chemicals into four categories that included Weed Killers (Herbicides), Insect Killers (Insecticides/Miticides), Disease Control Chemicals (Fungicides), and Fertilizers. Please take some of your valuable time to list the brand names and amounts of pesticides and fertilizers you used in your yard and garden in 1998. Please be as specific as possible. I also provided you with a list of some commonly available pesticides and fertilizers in local garden Centers.

The deadline for returning the survey will be December 28, 1998. I look forward to your completed surveys. If you have any questions about the survey, please let me know. I will be more than happy to answer your questions.

Sincerely yours,

Gary Gao, Ph.D.
Horticulture Extension Agent

1998 Survey of Pesticide Use in Home Garden, Landscape, and Lawn

Your Name:____________________________
Address:_______________________________
City and Zip Code:_______________________

Home Township:_________________________

May we contact you for additional information? Yes____ No____

Home Phone:( )--________--__________
Best Time to Call:_______________________

Information About Your Garden, Landscape, and Home Lawn

Size of Your Yard (Please mark one)

A. Less than 1/4 acre (Please specify square footage)_______
B. 1/4 - ½ Acre______
C. ½ - 1 Acre______
D. 1 - 2 Acres______
E. 2 - 3 Acres______
F. Larger than 3 Acres (please specify acreage)______

Type and Area of Ornamental Plants or Lawn Under Management

Types of Plants	Total Area (Acre or 1000 Square Foot)	Total Area with any Input of Fertilizer, or Weed Killer, Insect Killer or Fungicides	Apply Pesticides Yourself or Hire Commercial Companies to Do the Work (Please List Company Name)?
Trees			
Shrubs			
Vegetables			
Fruits			
Flower Beds			
Lawn			
Other			

Usage of Weed Killers(Herbicides), Insect Killers (Insecticides/Miticides), and Disease Control Chemicals (Fungicides) in Your Garden, Landscape, and Lawn in 1998*

Type of Turf Area or Ornamental Plants Treated	Area Treated (Please Specify Acre or Sq. Ft.)	Brand Name of the Pesticide Used	Rate of Application (Please be Specific)	Amount Applied	Frequency of Pesticide Application	Who (Self or Commercial Company) Applied the Pesticides?
List	List	List	List	List	List	List
Examples: Pine Lawn	1000 sq. ft. 20,000 sq. ft.	Dragon Sevin Liquid Preen	2 qt./100 g. of water 2.0 lbs active Ingredients /Acre	3 qt. 0.9 lb.	3 1	Self Self

*Mention of any commercial trade names here does not constitute any endorsement or nor any condemnation.

Survey of Fertilizer Usage in Your Garden, Landscape, and Lawn in 1998

Type of Turf Area or Ornamental Plants Treated	Area Treated	Brand Name of Fertilizer	Fertilizer Analysis	Amount per Acre or 1000 Square Feet	Frequency of Application	Total Amount Applied
List	List	List	List	List	List	
Example: Vegetable Garden Lawns	1000 sq. ft. 8000 sq. ft	Shultz's Plant Food Plus Miracle Gro Lawn Food	10-15-10 36-6-6	2 lb./100 ft. row 8 lb./1000 sq. ft.	1 3	16 lbs. 160 lbs.

*Mention of any commercial trade names here does not constitute any endorsement or nor any condemnation.

A Partial List of Common Weed Killers and Preventers (Herbicides), Insect/Mite Killers (Insecticides/Miticides), and Fungicides/Bactericides (for Disease Control), and Fertilizers*

Weed Killers and Preventers	Active Ingredient(s)
Bonide (Spot Weed Killer)	2,4 D, MCPP, Dicamba
Dragon Lawn Weed Killer	2,4 D, MCPP, Dicamba
Dragon Liquid Edger	Sodium Cacodylate, Dimethylarsinic Acid
Dragon Total Vegetation Killer	Prometon
Finale	Glufosinate-ammonium
Ortho Weed-B-Gon	2,4 D, MCPP
Ortho Lawn and Weed Killer 2	MCPP, 2,4 D, Dicamba
Preen	Trifluralin
Preen for Ground Covers	s-ethyldipropylehio carbamate
Round Up	Glyphosate
Round Fence and Yard Edger	Glyphosate
Scotts' Starter and Halts	Siduron and 16-21-4
Scotts' Turf Builder and Halts	Pendimethalin/28-3-4
Insect/Mite Killers (Insecticides/Miticides)	
Dragon Lindane Borer Spray	Lindane
Dragon Systemic Rose and Flower Care	Disulfoton
Dragon 25% Diazinon Insect Spray	Diazinon
Dragon 50% Malathion Insect Spray	Malathion
Dragon Horticultural Oil	Petroleum Oil
Dragon Sevin 10% Dust	Sevin
Dragon Sevin Liquid	Sevin
Dragon Easy Sevin for Vegetables	Sevin

*Mention of any commercial trade names here does not constitute any endorsement or nor any condemnation.

A Partial List of Common Weed Killers and Preventers (Herbicides), Insect/Mite Killers (Insecticides/Miticides), and Fungicides/Bactericides (for Disease Control), and Fertilizers*

Insect/Mite Killers (Insecticides/Miticides)	
Ortho Isotox Insect Killer Formula IV	Acephate and Hekakis
Ortho Lawn and Garden Insect Control	Dursban
Ortho Diazion Soil & Turf Insect Control	Diazinon
Scotts' Grub EX	Imidacloprid
Scotts' Grub EX plus Fertilizer	Imidacloprid and 24-2-3
Fungicides/Bactericides (for Disease Control)	
Dragon Daconil 2787	Chlorothalonil
Ortho Multiple Purpose Fungicide	Chlorothalonil
Ortho Rose Pride Funginex	Triforine
Combination Sprays	
Dragon Fruit Tree Spray	Captan, Malathion, Methoxychlor, Sevin
Ortho Rose Pride Orthenex Insect and Disease Control	Orthene and Vendex
Fertilizers	
Dragon Bone Meal	6-12-0
Dragon Dried Blood	12-0-0
Miracid Soil Acidifier Plant Food	30-10-10
Stern's Miracle Gro Quick Start	4-12-4
Stern's Miracle Gro Lawn Food	36-6-6
Shultz's Plant Food Plus	10-15-10
Shultz's Bloom Plus	5-30-5
Shultz's All Bloom Plus	10-15-10

*Mention of any commercial trade names here does not constitute any endorsement or nor any condemnation.

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Pesticides in Residential Areas—Protecting the Environment

OSU EXTENSION FACTS

No. 7461

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This fact sheet presents factors that affect pesticide loss to the aquatic environment, discusses toxicity of pesticides, and offers advice for reducing the environmental impact of the pesticides used in residential areas.

A well-maintained, healthy lawn and lush ornamentals increase property values, help prevent erosion, conserve water, deaden sound, supply oxygen, and increase aesthetic and recreational values. But landscaping requires intensive care, such as watering, fertilizing, mowing, and pest control. Protecting the environment also requires care because some pesticides, specifically insecticides, herbicides, and fungicides, may be washed from lawn areas to surface and ground waters.

Public concern generally focuses on the use of pesticides and fertilizers on large tracts of agricultural land. But, for the urban and suburban environment, residential use may be a greater concern. Pesticides, fertilizers, and other active materials are used extensively in the urban, suburban, and residential environment. Studies have shown that, after a heavy summer rain, nitrates and pesticides increase dramatically in streams and lakes near areas of urban or suburban development.

Use of pesticides and fertilizers in residential areas is very different from agricultural uses. In residential areas, chemicals are applied to smaller areas, but applications may be heavier and more frequent. Some lawns, for example, receive 10 or more pesticide applications per season, and two or three times as much nitrogen as a typical field crop. In 1987, more than $31 million was spent on lawn fertilizers and over $25 million on lawn pesticides in Oklahoma.[1]

Pesticide Movement

Pesticides are designed to stay in place to control the target pest, then degrade into harmless products. However, some pesticides can move from the site of application to the surrounding area. Pesticides leave the target

Recommendations

1. Always read the label before purchasing a pesticide. Read it again before applying.
2. Do not apply pesticides when rain is imminent. Pesticides need time to dry and work.
3. Do not spray pesticides when it is windy.
4. Note the temperature range specified on the label. High temperature may increase evaporative loss or cause plant injury.
5. Use the correct amount of water. If too much water is used, the pesticide may not work properly and may be more likely to run off.
6. Calibrate your sprayer. Too little won't work. Too much may damage the environment.
7. Use Integrated Pest Management (IPM) to control pests.
8. To protect ground water, select pesticides with low leaching potential.
9. To protect streams and lakes, consider runoff potential.
10. Where possible, substitute low-toxicity, short-lived chemicals for high-toxicity and long-lived chemicals.
11. Finally, use care when handling chemicals and disposing of the leftover material.

area by degradation or breakdown, evaporation to the atmosphere, leaching to ground water, and runoff to surface water.

Runoff is the most direct route to surface ponds, lakes, or streams. Even if no body of water is visible, runoff may reach a water body by way of ditches, storm sewers, or underground drainage pipes. This is a concern particularly in subdivisions where numerous manicured lawns are treated with pesticides and fertilizers. Runoff from such areas can upset nearby ecosystems and threaten wildlife. Pesticides differ in their relative runoff potential, as shown in the following tables.

Leaching is the extraction of chemicals from soil by water moving through the soil. Most pesticide chemicals degrade rapidly in soil. But, if they are highly leachable, they may reach ground water before they are degraded. In rainy periods or when there is excessive irrigation, leachable chemicals are likely to move to ground water. The tables show the relative leaching potential of commonly used chemicals.

Degradation is the time it takes a pesticide to degrade (break down into simpler substances). Degradation rate is measured by half-life—the time it takes for half of the active ingredient to break down. For example, half-life of the insecticide Sevin is 10 days. Therefore, one ounce of active ingredient would degrade to a half ounce in 10 days. In another 10 days, only one-fourth ounce (half of a half ounce) would remain, and so on. Materials with a shorter half-life are less persistent than those with a longer half-life. Tables 1 through 3 show the degradation rate, expressed as half-life in soil, for some commonly used pesticides.

Evaporation (or volatilization) is the loss of pesticide to the atmosphere. In most cases, this is not a big concern for water quality, although some evaporated pesticide may return to earth on dust particles or in rainfall. Evaporation can also contribute to air pollution. Perhaps the biggest concern is that evaporative loss reduces the effectiveness of the pesticide, requiring extra pesticide treatments with more handling, rinsings, and disposal problems.

Integrated Pest Management for Residential Areas

Integrated Pest Management (IPM) uses biological principles, cultural practices, and some chemicals to control pest populations with minimal environmental impact.

- Select adapted plant materials, considering resistance to commonly occurring pests.
- Select high-quality seed or sod, free of weeds, insects, and disease.
- Use proper planting and establishment techniques to minimize perennial weeds and other problems.
- Manage fertility with soil tests to maintain vigorous growth without excess fertilizer.
- Identify status and abundance of pests.
- Adjust cultural practices, such as mowing, fertilization, irrigation, aerification, and dethatching.
- Use mechanical alternatives, such as hand pulling or cultivation, instead of a pesticide.
- Use spot treatments instead of broadcast application.

Impact of Pesticides on Aquatic Organisms

Pesticides in the environment are generally a concern because they kill organisms other than the target insect, weed, or disease organism. Toxicity varies by species and may be either acute or chronic. **Acute toxicity** is fast-acting, affecting organisms directly. **Chronic toxicity** is more subtle. It results from low-level, frequent exposure, and its effects may not be recognized until much later.

Acute toxicity is measured by testing the chemical on a population of organisms, such as invertebrates, fish, or birds. Toxicity is reported as the median lethal dose (LD_{50}) or the median lethal concentration (LC_{50}). LD_{50} is the dose (mg of chemical/kg of body weight) that will kill 50 percent of the designated organisms in a specified period of time, usually 24 to 96 hours. The lower the LD_{50} or LC_{50}, the more dangerous the chemical. Toxicity of some commonly used pesticides to mallard ducks, fish, and aquatic invertebrates is shown in the tables.

Bioaccumulation

Bioaccumulation is the concentrating effect that occurs when many microscopic organisms, contaminated by pesticides, are eaten by organisms higher in the food chain. For example, DDT sprayed on insects accumulated in small mammals, birds, and people. The concentration of pesticides in the tissue of organisms at the top of the food chain may be far greater than the concentration in the water or surrounding environment. Accumulated pesticide may kill the higher organism, or it may have more subtle effects, such as reducing the organisms reproductive capabilities. Today's pesticides do not bioaccumulate.

Reducing Environmental Impact

Pesticide formulation, application timing, and application method can affect runoff and leaching. For example, if it rains, wettable powder formulations are much more likely to be washed off a surface than are emulsified

Table 1. Characteristics of commonly used insecticides.

Insecticides	Relative Runoff Potential[4]	Relative Ground Water Leaching Potential[4]	Half-life in Days[4,11]	Relative Toxicity[a,b]		
				Mallards	Fish[c]	Invertebrates
Affirm (Abamectin)				medium	medium	
Amdro (Hydramethylnon)	large	very small	10	very low	high[e]	
Baygon (Propoxur)				high	medium	
Cygon (Dimethoate)	small	medium	7	high	medium	
Diazinon (Diazinon)	medium	large	30	very high	high	
Dursban (Chlorpyrifos)	large	small	30	medium	very high[d]	
Dylox (Trichlorfon)	small	large	27	high	high	
Ficam/Turcam (Bendiocarb)			5			
Kelthane (Dicofol)	large	small	60		high	
Malathion (Malathion)	small	small	1	low	very high[e]	
Methoxychlor (Methoxychlor)			120	very low	very high	high
Oftanol (Isofenphos)			150			
Omite (Propargite)	large	small	56	very low	high[e]	
Orthene (Acephate)	small	small	3	medium	very low	
Pentac (Dienochlor)					high	
Pyrethrins (Pyrethrins)				very low	very high	
Rotenone (Rotenone)				very low	very high	very low
Sevin (Carbaryl)	medium	small	10	very low	medium	medium
Tempo (Cyfluthrin)			30	very low	very high	

[a]Toxicity to mallard ducks[2,5,8,10] is based on LD_{50}:
- very low = more than 2,000mg/kg
- low = 500 to 2,000
- medium = 50 to 500
- high = 10 to 50
- very high = less than 10mg/kg

[b]Toxicity to fish[5,7,9] and aquatic invertebrates[2,9] is based on 48- or 96-hour LC_{50}:
- very low = more than 100mg/l
- low = 10 to 100
- medium = 1 to 10
- high = 0.1 to 1
- very high = less than 0.1mg/l

[c]Fish toxicity based on catfish and bluegill

[d]Catfish are less sensitive

[e]Bluegill are less sensitive

concentrate formulations.[4] Timing is important because effectiveness varies with growth stage and pest population. Spraying for a pest that is not present can waste chemicals and threaten the environment. Likewise, some application methods, such as spot treatment, may be better than broadcast spay.

Pesticide selection can be adjusted to avoid known problems. For example, if soils are sandy or ground water is near the surface, a pesticide with low leaching potential is desirable. If a pond with fish or ducks is nearby, the chemical's runoff potential and its specific toxicity should be considered.

Care in application and disposal. Improper handling of chemicals, indiscriminant spraying, and dumping are serious concerns. Do not apply more pesticide than allowed by the product's label, and never pour pesticide in a storm sewer or other channel.

Water management. Over-watering lawns can leach pesticides below the reach of plant roots. This increases the chance of contaminating ground water, particularly if the chemical has high leaching potential.

Identify your pests and use Integrated Pest Management (IPM) [see box on page 2]. Exploring the options for pest control may require expert advice, as well as personal research. For information about pest identification and IPM, visit your County Extension Office.

Table 2. Characteristics of commonly used herbicides.

Herbicide	Relative Runoff Potential[4]	Relative Ground Water Leaching Potential[4]	Half-life in Days[4,11]	Relative Toxicity[a,b]		
				Mallards	Fish[c]	Invertebrates
Arsonate/Bueno (MSMA Soluble Salt)	large	small	100		very low	
Balan (Benefin)	large	small	30	very low	very high	
Banvel (Dicamba Soluble Salt)	small	large	14	low	low	very low
Betasan (Bensulide)	large	small	120			
Dacamine/Weedar (2, 4-D)	small	medium	10		very low[f]	
Dacthal [DCPA (Chlorthaldimethyl)]	large	small	100		very low	
Devrinol (Napropamide)	large	medium	70			
Dicamba (Dicamba)				low	low	
Endothal (Endothall)			7			
Kerb (Pronamide)	large	small	60			
Mecoprop (MCPP) Soluble Amine Salt	small	large	21		low	
Montar/Phytar 560/ Rad-E-Cate						
Pendimethalin (Pendimethalin)	large	small	90	very low	high	
Ronstar (Oxadiazon)			60	low	medium	
Roundup/Kleenup (Glyphosate Amine Soluble Salt)	large	small	47		very low	medium
Sencor (Metribuzin)	medium	large	40	very low	medium	medium

[a]Toxicity to mallard ducks[2,5,8,10] is based on LD_{50}:

very low =	more than 2,000mg/kg
low =	500 to 2,000
medium =	50 to 500
high =	10 to 50
very high =	less than 10mg/kg

[b]Toxicity to fish[5,7,9] and aquatic invertebrates[2,9] is based on 48- or 96-hour LC_{50}:

very low =	more than 100mg/l
low =	10 to 100
medium =	1 to 10
high =	0.1 to 1
very high =	less than 0.1mg/l

[c]Fish toxicity based on catfish and bluegill

[d]Catfish are less sensitive

[e]Bluegill are less sensitive

[f]2,4-D butoxyethanol ester has medium to high toxicity to fish

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Table 3. Characteristics of commonly used fungicides.

Fungicide	Relative Runoff Potential[4]	Relative Ground Water Leaching Potential[4]	Half-life in Days[4,11]	Relative Toxicity[a,b]		
				Mallards	Fish[b]	Invertebrates
Banner (Propiconazole)	medium	medium	110		medium	
Bayleton (Triadimefon)	medium	medium	26		low	
Benlate/Tersan (Benomyl)	large	small	240	low	very high[e]	
Bordeaux Mix (Bordeaux Mix)						
Captan (Captan)			3	very low	very high[e]	
Carbamate (Ferbam)	medium	medium	17			
Cyprex (Dodine Acetate Soluble Salt)	large	small	20[11]	low		
Daconil (Chlorothalonil)	large	small	30	very high	very high	very high
Dithane/Manzate (Mancozeb)	large	small	70		medium	
Dithane (Maneb)	medium	small	70[11]			
Dyrene (Anilazine)	small	small	1	very low	high	
Folpet (Folpet)				low	medium	
Funginex (Triforine)	medium	small	21		very low	
Fungo/Topsin (Thiophanate-methyl)	small	medium	10[11]			
Karathane (Dinocap)	medium	small	5	low	medium	
Koban/Terrazole/Truban (Etrazol/Etridiazole)	large	small	103[11]			
Ornalin/Vorlan (Vinclozolin)	medium	medium	20			
Pipron (Piperalin)	medium	small	30			
Rubigan (Fenarimol)	medium	small	360	very low	high	
Subdue (Metalaxyl)	small	medium	70		low	
Terraclor/Trufcide (PCNB)	large	small	21	very low		

[a]Toxicity to mallard ducks[2,5,8,10] is based on LD_{50}:
- very low = more than 2,000mg/kg
- low = 500 to 2,000
- medium = 50 to 500
- high = 10 to 50
- very high = less than 10mg/kg

[b]Toxicity to fish[5,7,9] and aquatic invertebrates[2,9] is based on 48- or 96-hour LC_{50}.
- very low = more than 100mg/l
- low = 10 to 100
- medium = 1 to 10
- high = 0.1 to 1
- very high = less than 0.1mg/l

[c]Fish toxicity based on catfish and bluegill

[d]Catfish are less sensitive

[e]Bluegill are less sensitive

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The Oklahoma Cooperative Extension Service
Bringing the University to You!

The Cooperative Extension Service is the largest, most successful informal educational organization in the world. It is a nationwide system funded and guided by a partnership of federal, state and local governments that delivers information to help people help themselves through the land-grant university system.

Extension carries out programs in the broad categories of agriculture, natural resources and environment; home economics; 4-H and other youth; and community resource development. Extension staff members live and work among the people they serve to help stimulate and educate Americans to plan ahead and cope with their problems.

Some characteristics of the Cooperative Extension system are:

- The federal, state and local governments cooperatively share in its financial support and program direction.
- It is administered by the land-grant university as designated by the state legislature through an Extension director.
- Extension programs are nonpolitical, objective and based on factual information.
- It provides practical, problem-oriented education for people of all ages. It is designated to take the knowledge of the university to those persons who do not or cannot participate in the formal classroom instruction of the university.
- It utilizes research from university, government and other sources to help people make their own decisions.
- More than a million volunteers help multiply the impact of the Extension professional staff.
- It dispenses no funds to the public.
- It is not a regulatory agency, but it does inform people of regulations and of their options in meeting them.
- Local programs are developed and carried out in full recognition of national problems and goals.
- The Extension staff educates people through personal contacts, meetings, demonstrations and the mass media.
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CLERMONT COUNTY ENGINEER
SNOW AND ICE CONTROL
COST AND MATERIAL TRACKING

1996-97

EVENT	DATE	LABOR	OVERTIME	SALT	MAINT	FUEL	MISC	TOTAL		COST/MI.		TONS OF SALT	TONS OF SALT/MI
1	12/18/96	1,410	0	2,343	0	138	0	3,891	JH	$10.18		107	0.279
2	12/19/96	1,836	0	1,390	96	138	24	3,483	JH	$9.12		63	0.165
3	12/20/96	444	99	340	0	94	0	977	JH	$2.56		15	0.040
4	12/22/96	0	1,089	1,617	0	138	21	2,865	JH	$7.50		74	0.192
												0	0.000
5	1/9/97	1,920	1,197	11,110	5,361	482	118	20,168	JH	$52.80		505	1.322
6	1/10/97	1,896	360	4,464	0	283	20	7,022	JH	$18.38		203	0.531
												0	0.000
7	1/15/97	1,086	0	1,322	0	52	0	2,461	TB	$6.44		60	0.157
8	1/16/97	1,770	18	3,773	0	232	0	5,793	TB	$15.16		172	0.449
												0	0.000
9	1/24/97	1,334	0	2,970	60	136	0	4,500	MP	$11.78		135	0.353
10	1/26/97	0	2,089	3,696	209	119	0	6,113	MP	$16.00		168	0.440
												0	0.000
11	1/27/97	866	21	3,071	438	283	0	4,679	JH	$12.25		140	0.365
12	1/28/97	1,100	165	3,132	0	166	26	4,589	JH	$12.01		142	0.373
												0	0.000
13	2/8/97	0	3,402	5,566	453	359	19	9,799	TB	$25.65		253	0.662
												0	0.000
14a	2/13/97	0	1,782	6,538	0	166	119	8,606	JH(MP)	$22.53		297	0.778
14b	2/14/97	1,846	196	2,153	0	273	0	4,467	MP	$11.69		98	0.256
15	2/16/97	0	1,764	3,671	245	273	0	5,952	MP	$15.58		167	0.437
TOTAL		$15,508	$12,181	$57,154	$6,861	$3,311	$347	$95,363	AVG/event:	$15.60		2,598	6.801
	notes:	MAINT includes truck repair/parts, mechanic labor and tow charges											
		SALT includes salt and calcium chloride							[redacted]				
		1996-97 based on 382 miles of road											

1997-98

EVENT	DATE	LABOR	OVERTIME	SALT	MAINT	FUEL	MISC	TOTAL		COST/MI.		TONS OF SALT	TONS OF SALT/MI
1	11/15/97	0	2,043	3,300	333	138	0	5,814	MP	$15.06		138	0.356
2	11/16/97	0	216	264	0	14	0	494	MP			11	0.028
3	12/5/97	672	1,337	2,986	0	273	17	5,285	MP	$13.69		124	0.322
4	12/6/97	0	1,044	1,386	0	273	0	2,703	MP			58	0.150
5	12/8/97	768	1,791	3,762	186	437	31	6,975	JH	$18.07		157	0.406
6	12/11/97	96	36	22	0	28	0	182	JH			1	0.002
7	12/12/97	192	45	44	0	32	0	313	JH			2	0.005
8	12/29/97	96	1,818	2,222	512	251	113	5,012	JH	$12.98		93	0.240
9	12/30/97	96	486	3,099	512	251	0	4,443	JH	$11.51		129	0.334
10	12/30/97	2,130	135	3,070	25	245	0	5,605	JH	$14.52		128	0.331
11	12/30/97	1,764	1,026	6,285	150	245	29	9,499	JH	$24.61		262	0.678
12	12/31/97	1,086	0	2,986	0	138	0	4,210	TB	$10.91		124	0.322
13	12/31/97	0	1,584	2,813	135	245	0	4,776	JH	$12.37		117	0.304
14	11/17/98	0	1,229	2,789	0	273	0	4,290	MP	$11.11		116	0.301
15	11/18/98	0	311	594	0	39	0	944	MP			25	0.064
16	11/19/98	0	1,206	2,960	173	245	0	4,584	JH	$11.87		123	0.320
17	2/4/98	10,794	4,641	26,103	10,617	3,035	277	55,467	MP/JH	$143.70		1,088	2.818
**MB	2/4-2/8	1,728	0	0	429	53	0	2,210	MP			0	0.000
18	2/6/98	0	522	132	0	27	0	681	MP			6	0.014
19	2/7/98	0	414	154	0	19	0	587	MP			6	0.017
20	2/8/98	0	378	132	0	25	0	535	MP			6	0.014
21	3/4/98	192	1,269	1,986	72	185	0	3,704	JH	$9.60		83	0.214
22	3/10/98	1,566	0	4,147	0	184	0	5,897	TB	$15.28		173	0.448
23	3/21/98	0	1,278	2,750	0	61	0	4,089	MP	$10.59		115	0.297
												0	0.000
TOTAL		21,180	22,808	73,985	13,143	6,714	467	138,296	AVG/event:	$22.39		3,083	7.986
	notes:	1997-98 based on 386 miles of road							[redacted]				
		total towing charges for event 17 were est. $3075 (included in MAINT cost)											
		**MB indicates cost for repairing/replacing mailboxes for event 17											
17 Detail	2/4/98	2,004	482	6,270	1,490	546	0	10,791	MP				
	2/4/98	1,632	882	2,970	3,320	546	200	9,550	JH				
	2/5/98	1,740	411	4,257	1,539	546	33	8,525	MP				
	2/5/98	1,824	1,350	2,772	1,583	546	0	8,075	JH				
	2/6/98	1,728	1,202	5,280	2,685	556	44	11,494	MP				
	2/6/98	1,868	315	4,554		297	0	7,032	JH				
		10,794	4,641	26,103	10,617	3,035	277	55,467					

H

Pesticides in Ground Water

OSU EXTENSION FACTS

No. 7459

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Ground water is a major source for Oklahoma's residential, industrial, and agricultural water uses. Like surface waters, ground water can be contaminated by human activities. Pesticides are a particular concern since they are so widely used. Using too much pesticide, selecting the wrong pesticide, or applying a pesticide incorrectly not only wastes money, but may also degrade the environment. Since clean-up can be very difficult and expensive, it is better to avoid ground water contamination through careful selection and application.

This fact sheet discusses the factors that cause ground water contamination by pesticides and provides information to help agricultural producers select pesticides that are least likely to leach to ground water.

Ground water contamination can result from point sources, where concentrated chemicals are manufactured, stored, or handled; or nonpoint sources, such as cropland, industrial sites, lawns, or golf courses, where diluted chemicals are applied over large areas. Most point sources are governed by federal and state regulations and their control is beyond the scope of this fact sheet.

Nonpoint source ground water contamination, unlike point source contamination, occurs over wide areas and usually involves low concentrations. A nonpoint-source problem could arise from repeated use of the same pesticide over many years, frequent use of the same material within a season, or high application rates in a single year.

Ground water contamination depends on the rate at which the chemical moves through the soil, the rate at which it degrades to inactive materials, and the depth to ground water.

How Do Chemicals Reach Ground Water?

Chemicals are carried by water through the soil into ground water through the processes of infiltration, leaching, and percolation. Leaching dissolves and extracts minerals, salts, fertilizers, and pesticides from the soil so that they can be carried by percolating water.

Infiltration and percolation. As shown in Figure 1, rainfall or irrigation water can enter the soil (infiltration) and move downward (percolation), or it can run off the surface. Some of the water that infiltrates returns to the atmosphere through evapotranspiration—the combination of direct evaporation from the soil surface and transpiration by plants.

Infiltration and percolation rates are determined primarily by soil texture. Coarse-textured soils, such as sands, have high infiltration and percolation rates, whereas fine-textured soils, such as clays, have low infiltration and percolation rates. Most soils are layered so that the surface may be sandy or silty and the subsoil loamy or clayey and vice versa. Thus, a soil could have high infiltration but low percolation. Percolation is also referred to as internal drainage or permeability.

Leaching. Leaching occurs when precipitation or irrigation water extracts chemicals from the soil and dissolves

Figure 1. The water cycle.

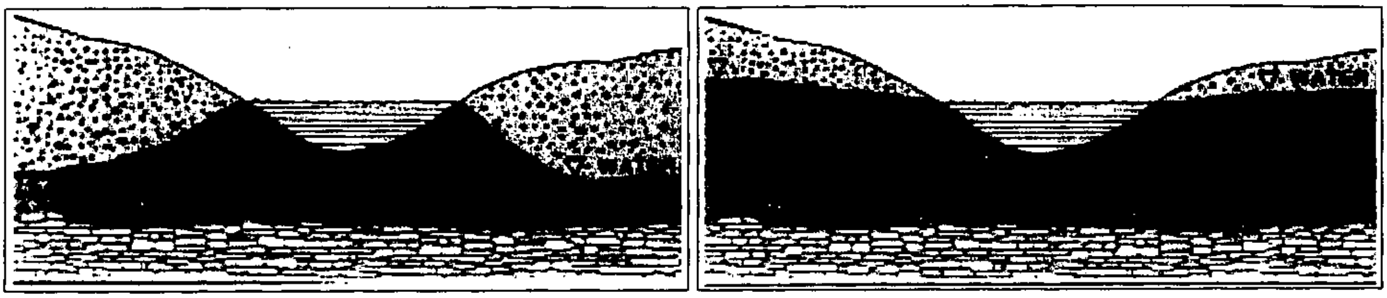

Figure 2. When the water level in the stream is higher than the water table of the alluvial aquifer (left), water flows from the stream to the ground water. More commonly, alluvial aquifers provide water to the stream (right).

them in the soil solution. The rate of leaching is determined by how tightly the chemical is bound to soil particles, the amount of water infiltrating the soil, and the rate of percolation.

Run-in. Run-in is transport to ground water by a direct route, such as an open well, a test hole, or a sink hole. A sink hole is a natural surface depression in the landscape and is commonly found in karst (limestone or gypsum) geology. The presence of a sink hole is recognized as a surface depression that does not hold water. Generally, a tunnel or fractured bedrock located beneath a sink hole acts as a drainage pipe to remove water. Contamination that enters a sink hole can move quickly to drinking water supplies some distance away. Back siphoning of pesticides into a well or careless disposal of chemicals or containers near a well, test hole, or sink hole is also a serious threat to ground water.

Alluvial aquifers. Alluvial aquifers associated with rivers are particularly susceptible to contamination. This type of aquifer generally consists of coarse, water-bearing sands and gravels near the land surface. Water moves rapidly in an alluvial aquifer, and there may be significant exchange between the alluvial aquifer and the river as shown in Figure 2. A stream that intersects an alluvial aquifer may lose water to the aquifer if the stream is at a higher elevation than the water level in the aquifer. More commonly, a stream receives its water from the alluvial aquifer. Contamination can, therefore, move from the aquifer to a stream or vice versa, depending on weather conditions.

Pesticide Leaching Potential

Table 1 is an excerpt from the Pesticide Parameter Database (adapted from Hornsby 1991), which is available from the County Extension Office. The Relative Leaching Potential Index (RLPI) in the Pesticide Parameter Database is determined by a chemical's water solubility, absorption (or binding) characteristics, degradation rate, and volatility. In selecting a pesticide, the RLPI should be considered along with the soil's leaching potential to determine whether or not ground water contamination is likely.

Absorption characteristics. Pesticide adsorption on soils is quantified by the soil's Organic Carbon Partition Coefficient (K_{oc}). The K_{oc} describes the relative affinity or attraction of the pesticide to soil material and, therefore, its mobility in soil. Pesticides with small K_{oc} values are more likely to leach than those with high K_{oc} values. Table 1 shows the wide range of K_{oc} values for some commonly used pesticides. Estimates of K_{oc} are found in the Pesticide Parameter Database.

Water solubility. A chemical's water solubility is often viewed as an indicator of its mobility in water. Water solubility and adsorption to soil particles, for most compounds, are inversely related, i.e., the higher the solubility, the less likely the pesticide will adsorb to soil particles. However, this rule has exceptions. Some highly soluble pesticides bind tightly and irreversibly to soil particles, and, therefore, are at low risk to leaching. For example, the herbicides paraquat and glyphosate (Roundup®) are two pesticides with high solubility and high K_{oc}. Water solubility can be obtained from the 1989 SCS Water Quality Reference Handbook.

Water solubility greater than 30 ppm indicates that significant mobility is possible if the K_{oc} is low. The Environmental Protection Agency (EPA) considers chemicals with solubility greater than 30 ppm and K_{oc} values less than 100 to be a concern in sandy soils.

Pesticide degradation. Pesticides break down or decompose through chemical reactions in the soil, sunlight (photo-decomposition), and microbial activity. Generally, sunlight and chemical reactions result in partial breakdown, whereas complete degradation is often possible through the action of soil microorganisms. Intermediate breakdown products may have characteristics different from the parent compound. They can also be toxic to plants and animals, but more often are non-toxic.

Degradation rate is quantified in terms of Degradation Half-life ($T_{1/2}$), the time required for 50 percent of the pesticide to decompose to products other than the original pesticide. The half-life ($T_{1/2}$) of selected pesticides are shown in Table 1. A more complete list of $T_{1/2}$ is available in the Pesticide Parameter Database. The longer the half-life, the higher the probability that the pesticide will show up in ground water. A half-life greater than 21 days is considered a critical value by the EPA.

Microbial activity accounts for most pesticide break-

Table. 1. Example of part of the Pesticide Parameter Database showing chemical characteristics.

Common Name	Trade Name	Org. Carbon Part. Coef. K_{oc}, ml/g	Degrad. Half-life $T_{1/2}$, days	RLPI	RRPI	Lifetime HALEQ ppb	Aquatic Tox. LC_{50} mg/L
Herbicides:							
Alachlor	Lasso	170	15	113	113	0.4	1.4
Atrazine	Many	100	60	17	17	3	4.5
Chlorsulfuron	Glean	40 (pH 7)	160	3 (pH 7)	3 (pH 7)	400	>250
Glyphosate	Roundup	24000 E	47	>2000	1	700	8.3
Metolachlor	Dual	200	90	22	22	100	2
Metribuzin	Lexone,Sencor	60	40	15	15	200	76
Paraquat	Graxomone	1000000 E	1000 E	>2000	1	30	15
Picloram	Tordon	16	90	2	2	500	4
Trifluralin	Treflan	8000	60	1330	2	5	0.041
2,4-D amine	Many	20	10	20	20	70	100
Insecticides:							
Aldicarb	Temik	30	30	10	10	10	0.56
Carbaryl	Sevin	300	10	300	300	700	114
Carbofuran	Furadan	22	50	4	4	40	0.38
Diazinon	Many	1000 E	40	250	25	0.6	0.09
Parathion, ethyl	Many	5000 E	14	>2000	14	2	1.43
Fungicides/Nematicides:							
Benomyl	Benlate	1900	240	79	2	400	0.17
Fenamiphos	Nemacur	100	50 E	20	20	2	0.11
Metalaxyl	Ridomil, Subdue	50	70	7	7	400	>100
Propiconazole	Tilt	1000 E	110	91	9	100	1.3
Triadimefon	Bayleton	300	26	115	115	200	14

K_{oc} - Organic Carbon Adsorption Coefficient.
$T_{1/2}$ - Half-life is a measure of persistence of the pesticide in the soil.
RLPI- Relative Leaching Potential Index.
RRPI- Relative Runoff Potential Index.
E - Estimated value.
pH - Reported at pH 7, value varies with pH .
HALEQ - Concentration at which long-term exposure is a concern.
LC_{50} - Concentration lethal to 50 percent of the test species.

down in soil, but chemical processes also are effective. The rate of degradation varies with the type of pesticide, soil temperature, moisture content, pH, and availability of oxygen. The effectiveness of microbes is also dependent on the concentration of the pesticide, history of prior pesticide use, and the existing plant cover. In general, microbial breakdown is slower in cool, dry soils than in warm, moist soils. Also, because microbe populations are typically small below the root zone, pesticide degradation rates are lower in aquifers than near the soil surface.

Volatilization. Volatilization, or evaporation, reduces the total amount of pesticide available for movement to ground water. Volatilization increases with air temperature and the vapor pressure of the pesticide formulation. It occurs more rapidly in wet than in dry soils. To minimize volatilization loss, volatile pesticides are normally incorporated in the soil and are generally not applied at high temperatures. Volatility information can be obtained from product literature.

Soil Leaching Potential

Soils information is the second part of the information needed to determine the potential for ground water contamination. A soil's leaching potential can be inferred from the county soil survey information. Important soil characteristics include texture and permeability, organic matter content, slope, and landscape position. A list of soils identified in your county and the corresponding leaching potential values is available at the County Extension Office. Table 2 contains an example of the soil leaching and surface runoff potential for some Caddo County soils.

Soil permeability. The permeability of soil is an important factor in determining chemical leaching rates. Permeability is a function of soil texture, structure, and pore space. Highly permeable, coarse, sandy soils have large pores that allow water and pesticides to move rapidly between soil particles during rainfall or irrigation. In medium and fine-textured soils, water moves more slowly, allowing more time for pesticide adsorption and degradation. Each layer of the soil can have a different permeability, but the overall permeability is determined by the most restrictive layer. The county soil survey provides information on permeability.

Soil permeability can be enhanced by the presence of macropores, large channels produced by plant roots,

Table 2. Soil leaching and surface runoff potential of some Caddo County soils. (Proposed by USDA-SCS).

Soil Map Symbol	Soil Name	Soil Leaching Potential[1]	Surface Loss Potential[1]
AgD	Acme (gypsum outcrops)	L	H
CoB,CoC,CoD,CoD2,CrD3	Cobb	M	M
Cs,Cy	Cyril	H	L
DaD3,DnD,DnE	Darnell	L	M
LuD,LuE	Dill	M	M
DoB,DuD	Dougherty	H	L
EfD,EuB,EuC	Eufaula	H	L
FoA	Foard	M	M

[1]L = Low potential, M = Medium potential, H = High potential (Corresponds to SCS ratings: Nominal, Intermediate, and High).

earthworms, soil cracks, and the burrowing of smaller animals. Forests, pastures, no-till cropland, and other areas with undisturbed soils are known to develop systems of macropores that increase infiltration and percolation and speed the transport of chemicals to the ground water. For this reason, pesticide selection and management is particularly important for no-till crops.

Soil organic matter. Soil organic matter helps to bind pesticides, particularly those with high K_{oc}, and promotes degradation. The large surface area of organic matter promotes pesticide adsorption and provides an excellent environment for microbial activity. Some of the benefits of high organic matter soils may be offset, however, because higher application rates may be needed for pest control with soil applied products.

Soil texture. Permeability and chemical adsorption are both affected by soil texture. Texture is determined by the reactive proportion of sand, silt, and clay. Clayey soils have extremely small particles with disproportionately large surface area that adsorb pesticides and other organics. Many clays also have high cation exchange capacity, and therefore adsorb positively charged pesticides in particular. Clayey soils also have low permeability. Thus, clayey soils restrict the downward movement of water and pesticide. Sandy soils, on the other hand, have particles with relatively small surface area, low cation exchange capacity, and high permeability. Sandy soils do not readily adsorb pesticides and provide little barrier to ground water contamination. Silty soils are intermediate in properties between sands and clays with respect to both permeability and pesticide adsorption.

Soil pH. The pH of the soil is a measure of its degree of acidity or alkalinity. Soil pH affects the degradation rate of pesticides and the adsorption characteristics and mobility of ionic pesticides. For example, basic pesticides, such as Atrazine, are more strongly absorbed and less mobile in acid soils (pH less than 7) than in neutral or alkaline soils. Acidic pesticides, such as 2,4-D and Glean®, are negatively charged and are more mobile in neutral or alkaline soils (pH greater than or equal to 7). Soil pH has little or no effect on the mobility of non-ionic pesticides.

Slope and landscape position. Movement of water and pesticides through a soil is also affected by slope and landscape position. Flat areas or concave slopes where runoff occurs are more prone to leaching than convex slopes that have higher runoff rates. The higher runoff rates mean less infiltration and a lessened potential for leaching. Further, soils in flat concave positions may accumulate water from other areas, enhancing water intake and increasing the leaching potential.

Recommendations

Preventing ground water contamination of pesticides depends largely on good management. The following practices can reduce the risk of pesticide contaminating ground water.

1. Read and follow label directions.
2. Evaluate leaching potential of alternative pesticides, using information in this publication.
3. If a high potential for leaching exists, consider toxicities.
4. If leaching potential is high and toxicity is a concern, consider using a different pesticide, using non-chemical alternatives, or altering application procedures to reduce the opportunity for leaching to ground water.

Reference

Hornsby and Audustigin (Eds). 1991. Pesticide Parameter Database. *In:* Handbook on Managing Pesticides for Crop Production and Water Quality. Univ. of Florida.

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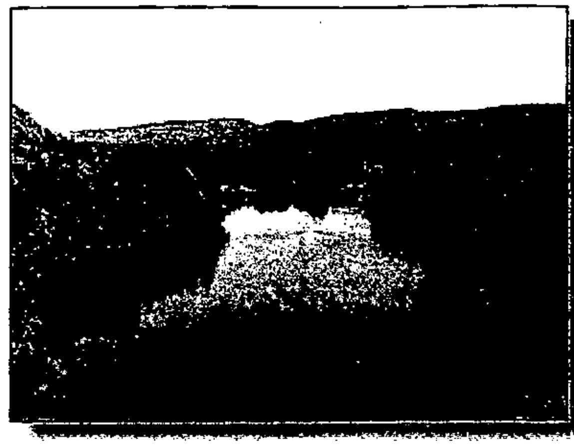
ECONOMIC RESEARCH SERVICE
United States Department of Agriculture

Agriculture and Water Quality



"Connecticut River," by R.E. MacIntyre Sr.

What is the status of U.S. water quality?

There has been significant improvement in the quality of U.S. water resources since 1972, due mainly to reductions in pollution from industrial and municipal point sources brought about by the Clean Water Act. However, water quality problems remain, and many of these are the result of nonpoint source pollution from agriculture.
(Note: Point sources typically discharge pollutants directly to waters from a pipe, and include industrial facilities, municipal sewage treatment plants, combined sewer over-flows, and confined livestock operations. In contrast, nonpoint sources deliver pollutants to waters from diffuse origins. Nonpoint sources include urban runoff, agricultural soil erosion and runoff of chemicals from agricultural fields, leaching of agricultural chemicals into groundwater, and atmospheric deposition of contaminants from air pollution.)

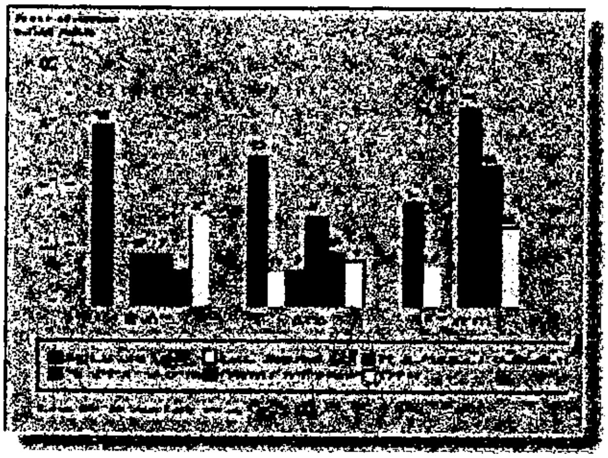


Figure 1. Sources and extent of U.S. surface water quality impairment.

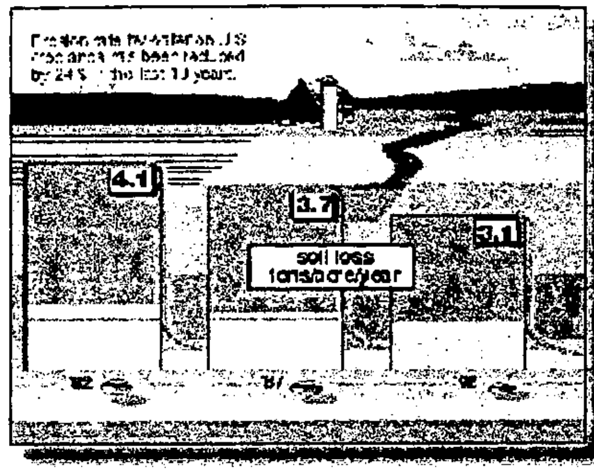
The most recent Environmental Protection Agency (EPA) Water Quality Inventory (1995), based on assessments by the States, reports that over one-third of surveyed U.S. rivers, lakes (excluding the Great Lakes), and estuaries do not fully support a healthy aquatic community or human activities all year round. According to the Inventory, agriculture is the leading source of impairment for the Nation's rivers (affecting 60% of the impaired river miles), the leading source of impairment in lakes (affecting 50% of impaired lake acres, not including the Great Lakes), and the third leading source of impairment of estuaries (affecting 34% of impaired estuary acres) **(Figure 1)**. Agriculture was also judged to be the leading source of impairment of wetland water quality. While the status of groundwater quality in the U.S. is not well known, of 38 States reporting overall groundwater quality, 29 judged their groundwater quality to be good or excellent. When degradation of groundwater quality does occur, it is typically a localized problem and agriculture is often a source. Of 49 States reporting sources of groundwater contamination, agriculture was cited as a source in 44. The Great Lakes continue to suffer serious pollution, but agriculture is not one of the leading sources.

How does agriculture affect water quality? - *Physical dimensions.*

Agricultural production involves many activities and practices that can adversely affect the quality of surface and groundwater. Sediment from eroding land can affect surface water, and nutrients from fertilizers and manure, pesticides, and salts from irrigation can affect both surface water and groundwater.

Sediment: Tilling the soil and/or leaving it without vegetative cover for some period of time results in accelerated soil erosion. Varying proportions of sediment from eroding fields may be delivered to surface waterbodies depending on topography, distance, and land cover. Sediment harms waterbodies when present in excessive amounts by clouding the water and coating the leaves of plants, both of which deprive them of sunlight needed for growth. The deposition of sediment reduces the useful life of reservoirs, clogs ditches and irrigation canals, blocks navigation channels, resulting in increased dredging costs. By raising stream beds and burying streamside wetlands, sediment can increase the likelihood and severity of floods. In addition, suspended sediment can increase the cost of water treatment for municipal and industrial water users. *According to EPA, siltation is one of the leading pollution problems in U.S. rivers and streams, and among the top four problems in lakes and estuaries.*

Figure 2. Reductions of sheet and rill erosion on U.S. croplands.



According to the 1992 National Resources Inventory, soil loss from wind erosion and sheet and rill erosion on cropland dropped from a total of 3.1 billion tons on 421 million acres in 1982 to 2.1 billion tons on 382 million acres in 1992 **(Figure 2)**. Annual sheet and rill erosion on cropland declined from 1.7 billion tons to 1.2 billion tons on 382 million acres in 1992, while annual wind erosion on cropland dropped from 1.4 billion tons to 0.9 billion tons. Most of these reductions occurred on highly erodible land targeted since 1985 under several USDA conservation programs. While controlling both sheet and rill and wind erosion helps sustain long-term soil productivity, controlling sheet and rill erosion is more important in reducing the amount of soil, pesticides, fertilizer, and other substances that move into the Nation's surface waters.

Nutrients: The application of fertilizers and/or manure to agricultural land increases the chance that nutrients will run off into surface waters or leach into groundwater. The two primary agricultural nutrients that play a role in water quality are nitrogen and phosphorus. Nitrogen, primarily found in the soil as nitrate, is soluble and easily transported by surface runoff, in tile drainage, or by leachate. Phosphorus, primarily in the form of phosphate, is only moderately soluble and, relative to nitrate, is not very mobile in soils or groundwater. An excessive amount of nitrogen or phosphorus in surface waters can cause algae to grow at an accelerated rate. An abundance of algae results in cloudy water, which prevents aquatic plants from receiving sunlight for photosynthesis. When the algae die, they are decomposed by bacteria, depleting the oxygen dissolved in the water. This is the process of eutrophication which can result in clogged pipelines, fish kills, and reduced recreational opportunities. *According to EPA, nutrient pollution is the leading cause of water quality impairment in lakes and estuaries and the third leading cause in rivers.*

Above a certain concentration, nitrate is also a concern for drinking water. Based on the human health effects of nitrate and nitrite, EPA has established a maximum contaminant level (MCL) of 10 mg/L for nitrate, and 1 mg/L for nitrite in public drinking systems. Nitrates or nitrites above the MCL can be a factor in causing methemoglobinemia ("blue-baby syndrome"), which prevents the transport of oxygen in the bloodstream of infants, and may be a cancer risk to humans due to nitrosamine formation. From its 1988-90 national survey of drinking water wells, EPA found nitrate in more than half of the 94,600 community water system wells (CWS) and almost 60 percent of the 10.5 million rural domestic wells, making nitrate the most frequently detected chemical in well water. *However, only 1.2 percent of the CWS's and 2.4 percent of the rural domestic wells were estimated to contain levels above the MCL.* Consequently, about 3 million people (including 43,500 infants) using water from CWS's and about 1.5 million people (including 22,500 infants) using rural wells are exposed to nitrate at levels above the MCL. Higher findings for rural domestic wells are expected since they are closer to farmland and are generally shallower than wells used by CWS's, making them more susceptible to contamination. More recently, the U.S. Geological Survey (USGS) found that the MCL was exceeded in about 1 percent of CWS's, but 9 percent of rural domestic wells (Mueller et. al, 1995). The difference with EPA's findings is probably due to different sampling strategies. USGS found that about 21 percent of wells under agricultural land exceeded the MCL in selected watersheds, with particularly high proportions exceeding the MCL in the Northern Plains and the Pacific regions.

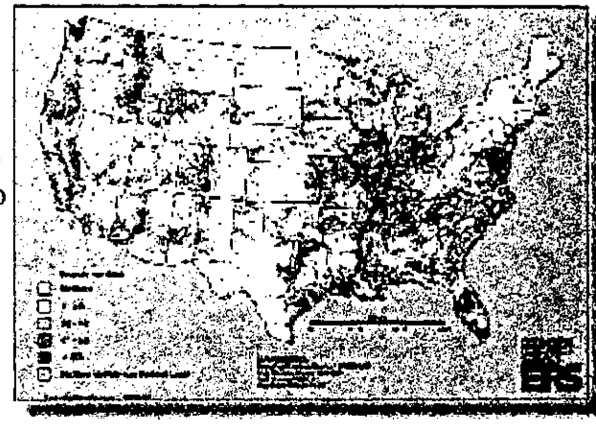


Figure 3. Residual nitrogen from agricultural sources including manure.

Residual nitrogen on cropland (nitrogen from both commercial and manure sources in excess of plant needs) is an indicator of potential nitrate availability for runoff to surface water or leaching to groundwater. Regions with relatively high residual nitrogen include the Corn Belt, parts of the Southeast, and the intensively irrigated areas of the West **(Figure 3)**. However, residual nitrogen by itself does not necessarily result in water quality problems. For example, warm, moist soil conditions in the Southeastern States tend to volatilize residual nitrogen to the atmosphere, and vegetative buffers capture excess nitrogen before it reaches water systems. Therefore, nitrate levels in surface and groundwater in the Southeast tend to be low, even though residual nitrogen may be high.

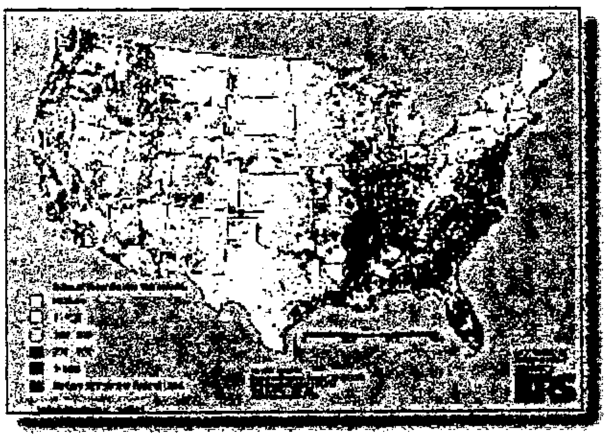


Figure 4. Groundwater vulnerability index for nitrogen from agriculture including manure.

To better assess the potential for groundwater contamination by nitrates, a groundwater vulnerability index for nitrogen was developed by Kellogg, Maizel, and Goss (1992). The index is a function of soil leaching potential, nitrate leaching potential, precipitation, and nitrogen fertilizer use. According to the index, regions with the greatest potential for nitrate contamination of groundwater include parts of the Lower Mississippi River, Southeast, and intensively irrigated portions of the West, reflecting areas of relatively large nitrogen fertilizer use and/or areas with soils prone to leaching **(Figure 4)**. A similar index is not yet available for surface water.

Pesticides: Well over 500 million pounds (active ingredient) of pesticides with different levels of toxicity, solubility, and persistence, are annually applied to agricultural crops to control pests, fungus, and disease. Some pesticides can travel far from where they are applied, and may harm freshwater and marine organisms, damaging recreational and commercial fisheries. Pesticides in drinking water supplies can pose a risk to human health. EPA has established enforceable drinking water standards for 13 currently used pesticides, and more are pending. The presence of regulated pesticides above specified levels in water supplies requires additional treatment, placing added costs on water utilities and their customers. EPA's 1988-90 survey of drinking water wells found that 10 percent of the community water system wells (CWS's) and 4 percent of rural domestic wells contained at least one pesticide. Pesticides or their transformation products have been detected in the groundwaters of 43 States (Barbash and Resek, 1995). *However, EPA estimated that less than 1 percent of the CWS's and rural domestic wells had concentrations above MCL's or Lifetime Health Advisory Levels (the maximum concentration of a water contaminant that may be consumed safely over an average lifetime).* Problems were found more frequently in shallow wells in agricultural areas. A sampling of wells in corn- and soybean-growing areas in the Midwest found 28 percent of wells had detectable levels of selected pesticides and metabolites, but none exceeded the MCL. Atrazine was the most frequently detected compound (Kolpin, Burkart, and Thurman, 1993).

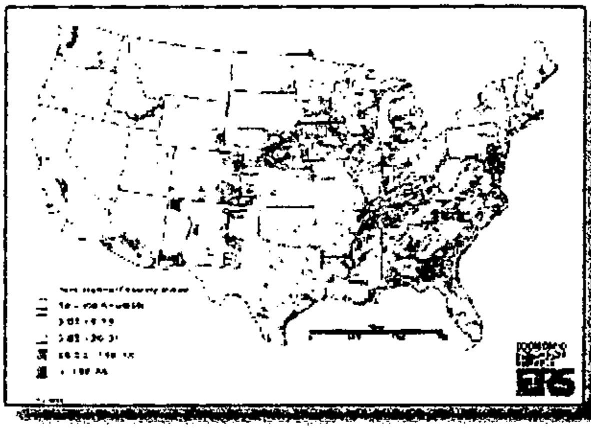


Figure 5. Groundwater vulnerability index for pesticides from agriculture weighted by persistence and toxicity.

Groundwater vulnerability to pesticides varies geographically, depending on soil leaching potential, pesticide leaching potential, application rates, precipitation, and the persistence and toxicity of the pesticides used. These factors are incorporated in an index developed by USDA's Natural Resources Conservation Service (**Figure 5**). Areas with sandy, highly leachable soils, such as central Nebraska and the blueberry barrens of Maine, have high vulnerability ratings. Highly vulnerable areas characterized by heavy applications of generally toxic materials on fruit and vegetable crops include the San Joaquin Valley in California, Florida, and southern Arizona. In contrast, the Corn Belt, despite the widespread use of chemicals, particularly herbicides, has a lower rating than other areas because the predominant soils are not prone to leaching.

Salinity: Irrigation return flows can carry dissolved salts, as well as nutrients and pesticides into surface or groundwater. Dissolved salts and other minerals can have significant impacts on surface- and groundwater quality. Increased concentrations of naturally occurring toxic minerals, such as selenium and boron, can harm aquatic wildlife and degrade recreation opportunities. Increased levels of dissolved solids in public drinking water supplies can increase water treatment costs, force the development of alternative water supplies, and reduce the life spans of water-using household appliances. Increased salinity levels in irrigation water can reduce crop yields or damage soils so that some crops can no longer be grown.

How does agriculture affect water quality? - *Economic dimensions.*

Estimating the economic effects of agriculture on U.S. water quality is complicated by the lack of organized markets, and thus prices, for environmental quality. Nevertheless, economists have conducted numerous studies on the value of water quality over the years. Most of these studies have focused on specific sites or "local" water quality issues. Relatively few studies have looked at the costs of water pollution or the benefits of pollution reduction on a nationwide scale, and none have included costs to all classes of water users. However, the results of these studies suggest that the annual benefits from improving water quality could total tens of billions of dollars. A 1995 ERS study estimated that water quality benefits from erosion control on cropland alone could total over $4 billion per year (Hrubovcak, LeBlanc, and Eakin, 1995). This estimate included damages or costs to navigation, reservoirs, recreational fishing, water treatment, water conveyance systems, and industrial and municipal water use.

ERS has also estimated the economic benefits to water quality from two of USDA's primary conservation programs: the Conservation Reserve Program and the conservation compliance provision. As a result of reducing soil erosion by 700 million tons per year (an average of 19 tons per acre) of which approximately 60 percent is wind erosion and the remaining 40 percent is sheet and rill erosion, the CRP generates $437 million annually in benefits to water users, or approximately $12 per acre (Ribaudo, 1989). This estimate does not include the water quality benefits from reduced use of nutrients and pesticides on the land CRP removes from crop production. The conservation compliance provision, on the other hand, produces average erosion reductions of approximately 10 tons per acre, providing annual water quality benefits of approximately $14 per acre (USDA, ERS, 1994). A higher proportion of the erosion reductions attributable to conservation compliance are from sheet and rill erosion which plays a larger role in water quality impairment compared with wind erosion. As with the CRP, the water quality benefits of conservation compliance reflect only reductions in water quality damages due to sediment. High concentrations of the pesticide atrazine in some water supplies in the Midwest have prompted concerns that public water utilities will have to install expensive water treatment systems in order to meet Safe Drinking Water Act requirements. If all the treatment plants withdrawing from surface sources upgrade their treatment systems to remove pesticides, it has been estimated that annual treatment costs would increase by an estimated $400 million per year (Ribaudo and Bouzaher, 1994).

Outbreaks of cryptosporidia, a parasite found in the feces of some animals and that causes gastrointestinal illness, are causing growing concern over the safety of water supplies in areas with large numbers of cattle. This organism has been implicated in gastroenteritis outbreaks in Milwaukee, Wisconsin (400,000 cases and 100 deaths in 1993) and in Carrollton, Georgia (13,000 cases in 1987). The cost of the Milwaukee outbreak is estimated to exceed $54 million (*Health and Environment Digest*, 1994). While the source of the organism in these outbreaks was never determined, the fact that it has been found in many dairy herds has brought some attention to this sector, especially given the proximity of dairies to population centers.

Dissolved salts and other minerals are an important cause of pollution in the Southern Plains, arid Southwest, and southern California. Total damages from salinity in the Colorado River range from $310 million to $831 million annually, based on the 1976-85 average levels of river salinity. These include damages to agriculture ($113 - $122 million, households ($156 - $638 million), utilities ($32 million), and industry ($6 - $15 million) (Lohman, Milliken, and Dorn, 1988).

What is being done to reduce U.S. agricultural water pollution?

Clearly, agricultural production is responsible for a significant share of remaining impairment of U.S. water resources. Some may ask, "Why does this occur? Don't farmers realize the harm they are doing?" Agricultural pollution of water resources occurs not because farmers seek to harm the environment. Rather, agricultural nonpoint source pollution is a classic case of what economists refer to as a market failure. Because property rights to the environment are not clearly defined, there is no market price associated with using water resources as a receptor for eroded soil, excess nutrients, pesticide residues, etc. Consequently, farmers are not compelled to factor the offsite costs of erosion or chemical runoff and leaching into their production decisions. These costs are "external" to their operation. Economists refer to these effects as "externalitites." In addition, oftentimes farmers are unaware of the offsite effects their production decisions cause. As a result, farmers adopt production systems that have higher erosion and/or chemical application rates, causing more water pollution, than is socially optimal.

To reduce agricultural nonpoint pollution of water resources, society, acting through government, can (1) restrict certain production options such as banning the use of highly leachable pesticides in vulnerable areas, (2) invest in research and development to find alternative production options that are less environmentally damaging, or (3) adjust the anticipated costs or benefits of certain production options through education, technical assistance, and by taxing inputs or by offering subsidies for practice adoption. To some extent all these approaches have been used in the U.S. to deal with agricultural water pollution. USDA has preferred not to employ regulatory approaches to deal with nonpoint source pollution associated with agricultural lands. USDA's preference for voluntary approaches is based on the inherent difficulty in regulating nonpoint sources of pollution, and on the belief that when educated about the problems, and provided technical and financial assistance, farmers will make improvements in production practices to achieve conservation and environmental goals. In passing the Federal Agriculture Improvement and Reform Act of 1996 (1996 Act), Congress reaffirmed its preference for dealing with agricultural resource problems using voluntary approaches through the turn of the century. However, the Environmental Protection Agency (EPA) does regulate animal waste discharges from large confined livestock operations under the Clean Water Act, and an increasing number of States regulate pesticide use and are using land use controls such as zoning, land acquisition, and easements targeted to areas deemed important for protecting water resources.

USDA Programs

USDA's approach to water quality is twofold. First, in response to a Presidential initiative for enhancing water quality in the 1990 Federal budget, the USDA Water Quality Program (WQP) was established. The WQP focuses on providing agricultural producers with education, technical assistance, and financial assistance to respond voluntarily to water quality concerns and State water quality requirements in selected project areas. The WQP also has strong technology development/transfer and database development elements. Second, USDA administers a broad range of conservation programs that have a wider availability than the WQP and for which water quality is but one of several goals. In reality, there is a great deal of overlap between the conservation programs and the WQP. In 1996 USDA spent a total of $3.2 billion on resource conservation and environmental programs.

USDA's Water Quality Program (WQP)

In 1990, USDA made a commitment to protect the Nation's waters from contamination by agricultural chemicals and waste products by establishing the Water Quality Program. The initiative integrates the combined expertise of four Federal departments (USDA, EPA, Interior, and Commerce) to promote the use of environmentally- and economically-sound farm production practices, and to develop improved chemical and biological pest controls. In 1996 the WQP was in its seventh year, with annual expenditures ranging from $83 to $116 million.

The WQP strives to (1) determine the precise nature of the relationship between agricultural activities and water quality; and (2) develop, and induce the adoption of, technically and economically effective agrichemical management and agricultural production strategies that protect surface- and groundwater quality. The WQP contains three major components: (1) research and development; (2) education, technical, and financial assistance; and (3) database development and evaluation. Originally intended as a 5-year program, USDA funding for limited program activities is projected beyond 1999.

WQP research has improved our understanding of the relationship between water quality and production practices in the Midwest. In particular, the *Management System Evaluation Area (MSEA)* efforts have resulted in a number of improvements in nitrogen management, herbicide management, crop management, and irrigation water management. The MSEA findings are improving USDA's ability to provide farmers with information on practices that are sound from economic, agronomic, and environment standpoints.

The *Hydrologic Unit Area* and *Demonstration Projects*, which target education, technical, and financial assistance in areas with known agricultural pollution problems, have shown progress in:

- *Nitrogen management.* Through 1993, nitrogen management practices (including cover and green manure crops) have been implemented on 1 million acres, about 46 percent of the 5-year goal for the 90 DP and HUA projects. Annual nitrogen reductions averaged almost 42 pounds per acre on land receiving treatments.
- *Phosphorus management.* Phosphorus management practices, including those for managing field

applications of animal waste, had been implemented on about 850,000 acres by 1993, which is nearly 100 percent of the 5-year goal (USDA, NRCS, 1995). Annual phosphorus reductions averaged about 40 pounds per acre. Predominant phosphorus management practices include nutrient management, use of cover and green manure crops, and conservation tillage.
- *Pesticide management.* Through 1993, 501,000 acres had been treated with pesticide management practices (USDA, NRCS, 1995), nearly 43 percent of the 5-year goal of the 90 projects. Practices include scouting, improved application/timing, mechanical control of pests, use of host crops and predators for pest control, and crop rotations. Pesticide reductions averaged nearly 0.6 pound per acre active ingredient (AI) in 1993. The significance of the chemical reductions in many projects is limited by inadequate knowledge of pre-project application rates.
- *Erosion and sediment control.* Erosion and sediment control practices have been installed on over 1 million acres (USDA, NRCS, 1995). Over 50 different conservation practices are being used to abate erosion and sediment delivery in the project areas, some of which are innovative and not included in the NRCS technical manual. Practices include rotations, crop residue use, conservation tillage, cover and green manure crops, and pasture and hayland planting.
- *Water management.* In 1993, the HUA's and DP's implemented irrigation water management practices on 119,000 acres, reducing average annual application of irrigation water by 11 inches per acre (USDA, NRCS, 1995). Irrigation application efficiency on treated fields increased by 18 percent.

Agricultural Conservation Program (ACP)

In operation from 1936 to 1996, ACP provided financial assistance to agricultural producers to help solve a wide range of agricultural conservation and environmental problems, including water quality. With several important exceptions, ACP funds were not targeted to specific geographic areas. ACP cost-shared up to 75 percent of the total cost of implementing an approved practice, with a maximum of $3,500 per recipient per year. While used to primarily address soil erosion and water conservation issues over most of its history, beginning in the 1980's a growing proportion of ACP funds were devoted to water quality practices. Cost-share expenditures on practices whose primary purpose was water quality rose from $13.4 million in 1988 to $44.2 million in 1994, or from 7.1 percent of ACP expenditures to 23.1 percent. By 1994, almost all of USDA's water quality cost-share funds came from ACP.

In 1990, Integrated Crop Management (ICM) was instituted by USDA as a trial practice under ACP. The goal of ICM was to promote more efficient use of pesticides and fertilizers by subsidizing substitute technologies. ICM provided 75-percent cost sharing, not exceeding $7 per acre for most field crops or $14 per acre for horticultural and specialty crops. Cost sharing was made available for up to 3 years for practices including pest scouting services, soil testing, or the rental of specialized machinery. In 1992, ICM was included as an eligible practice under the Water Quality Incentive Projects (discussed below), where it received a flat incentive payment of up to $10 per acre for field crops and $20 per acre for specialty crops. From 1990 to 1993, ICM was implemented on about 830,000 acres.

The Federal Agriculture Improvement and Reform Act of 1996 (1996 Act) consolidated the functions of ACP into the new Environmental Quality Incentive Program (EQIP).

Water Quality Incentive Projects (WQIP)

WQIP was created by the Food, Agriculture, Conservation and Trade Act of 1990, and was administered as a practice under ACP. The goal of WQIP was to reduce agricultural pollutants by subsidizing farm management practices that restore or enhance water resources affected by agricultural nonpoint source pollution. Areas eligible for WQIP included: watersheds identified by States as being impaired by nonpoint source pollution under Section 319 of the Clean Water Act; areas identified by State agencies for environmental protection and so designated by the Governor; and areas where sinkholes could convey runoff directly into groundwater. A total of 242 projects were started during FY 93-95. Eligible producers entered into 3- to 5-year agreements with USDA to implement approved management practices on their farm, as part of an overall water quality plan, in return for an incentive payment. The WQIP supported 39 different practices for protecting water quality. WQIP was also consolidated into EQIP by the 1996 Act.

Colorado River Salinity Control Program (CRSCP)

CRSCP, jointly administered by USDA and the U.S. Department of the Interior, was started in 1984 to identify salt source areas in the Colorado River basin; assist landowners and farm operators in installing practices to reduce salinity in the Colorado River; carry out research, education, and demonstration activities; and monitor and evaluate the activities being performed. The Colorado River is the primary source of water for over 18 million people in Arizona, California, Colorado, Nevada, New Mexico, Utah, Wyoming, and Mexico. Its water is also used for irrigated agriculture, generating hydroelectric power, and industrial purposes. Farmers could receive cost-sharing to install improved irrigation systems designed to increase irrigation efficiency and to reduce the movement of salt into the groundwater. Once an application was approved, landowners entered into a contract for 3 to 10 years. Besides agreeing to build and install the salinity control project, the landowner also agreed to operate and maintain the project for as long as 25 years. Through 1994, 150,000 acres had been treated, out of 360,000 acres originally identified as needing treatment. The program has conserved about 300,000 acre-feet of water, and salt loadings were down 191,223 tons per year, 38 percent of the total reduction believed possible. Salt levels at the three monitoring stations have remained below the limits instituted under the Clean Water Act, thus satisfying the program's goal. Like ACP and WQIP, CRSCP was consolidated into EQIP under the 1996 Act.

Environmental Quality Incentives Program (EQIP)

EQIP was established by the 1996 Act as a new program to consolidate and better target the USDA cost-sharing programs: ACP, WQIP, CRSCP, and the Great Plains Conservation Program (GPCP). After October 1, 1996, the end of the EQIP phase-in period, ACP, WQIP, CRBSCP, and GPCP will be terminated. The objective of EQIP is to encourage farmers and ranchers to adopt practices that reduce environmental and resource problems. Half of the available funds for EQIP will be targeted at practices relating to livestock production. EQIP must be carried out to maximize environmental benefits provided by the program per dollar expended. During 1996-2002, USDA will provide technical assistance, education, cost-sharing, and incentive payments to producers who enter into 5 to 10-year contracts specifying EQIP conservation plans. The program will be available to farmers and ranchers who own or operate land on which crops or livestock are produced including cropland, pasture, and rangeland.

EQIP conservation plans will indicate changes farmers will make to cropping systems, grazing management, manure, nutrient, pest, or irrigation management, and/or land use changes to improve soil, water, and related natural resources including grazing lands, wetlands, and wildlife habitat.. Producers that implement land management practices (e.g. nutrient management, tillage management, grazing management) can receive technical assistance, education, and incentive payments. Producers that implement structural practices (e.g. animal waste management facilities, terraces, filterstrips) can receive technical assistance, education, and cost-sharing of up to 75 percent of the projected cost of the practice(s). However, large confined livestock operations, subject to definition by USDA, will be ineligible for cost sharing to construct animal waste management facilities. An evaluation and selection process will be used to target priority project areas and specific problems within those areas in order to maximize environmental benefits per dollar expended.

Program funding for EQIP will be $200 million annually through 2002 except for fiscal year 1996 when funding is $130 million. In general the total amount of cost-share and incentive payments paid to a producer under EQIP may not exceed $10,000 for any fiscal year or $50,000 for a multi-year contract. However, USDA may pay a producer more if it is determined it to be essential to the purposes of the program.

Conservation Technical Assistance (CTA)

Conservation Technical Assistance provides technical assistance to farmers for soil and water conservation and water quality practices, and is administered by NRCS. CTA provides technical assistance to farmers adopting practices under USDA conservation programs and to other producers who ask for assistance in adopting approved NRCS practices. In 1995, the CTA program spent $7.6 million on water quality-related assistance, apart from those activities directly related to the Water Quality Program. This includes assistance provided to programs run by agencies other than USDA.

Conservation Compliance

Conservation compliance was established by the Food Security Act of 1985 primarily for the purpose of reducing soil erosion. Under conservation compliance, farmers who grow crops on highly erodible land are required to implement an approved soil conservation plan to remain eligible for an array of farm program payments. NRCS provides technical assistance for planning and implementing the practices, and some-cost share assistance may be available through other programs. While not intended as a pollution prevention program, the magnitude of erosion reductions brought about will result in sizable water quality benefits as indicated above. Although some farmers perceive it as regulation, the conservation compliance provision is not regulatory since it applies only to those who participate in farm programs, and farm program participation is voluntary.

Conservation Reserve Program (CRP)

The Conservation Reserve Program was established by the Food Security Act of 1985 as a voluntary long-term cropland retirement program. USDA provides CRP participants with an annual per-acre rent and half the cost of establishing a permanent land cover (usually grass or trees) in exchange for retiring highly erodible or other environmentally sensitive cropland for 10-15 years. CRP enrollment reached 36.4 million acres in 1995 as a result of acreage accepted in 13 discrete signup opportunities. At its peak, the CRP reduced soil erosion by nearly 700 million tons per year, or 19 tons per acre. This was a 22-percent reduction in U.S. cropland erosion (USDA, ERS, 1994). While estimates of the water quality benefits of the CRP are significant as presented above, as a general approach for improving water quality, retiring whole cropland fields is relatively expensive. Even though the water quality benefits are "guaranteed" as long as the land is retired, land retirement probably cannot be justified on the basis of water quality benefits alone. However, there are areas where the benefits of retiring cropland undoubtedly outweigh the costs. These could include riparian areas, wellhead recharge areas, and drainage areas around particularly valuable reservoirs. Since 1991, CRP has placed a high priority on enrolling these areas. Beginning in the Fall of 1996, a continuous enrollment opportunity CRP signup will be held for these partial-field practices.

Wetland Reserve Program (WRP)

The WRP was authorized by the Food, Agriculture, Conservation and Trade Act of 1990, and provides easement payments and restoration cost-shares to landowners who return prior converted or farmed wetlands to wetland condition. Easement payments cannot exceed the fair market value of the land, less the value of permitted uses, such as hunting or fishing leases or managed timber harvest. The enrollment goal of the WRP is 975,000 acres The WRP is primarily a habitat protection program, but converting cropland back to wetland function also has water quality benefits. Some benefits arise from reduced chemical use on former cropland, but the greatest potential benefits come from the ability of the wetland to filter sediment and agricultural chemicals from runoff and to stabilize stream banks. The Wetland Reserve Program is not targeted on a watershed basis. Water quality benefits would be enhanced by targeting enrollment to watersheds in greatest need of protection from agricultural runoff.

USDA Support of Non-USDA Programs

USDA supports several water quality projects sponsored under non-USDA programs. USDA has provided accelerated technical and financial assistance to farmers in the upland areas of the 21 EPA National Estuary Program projects through CTA and ACP. USDA also provides the same support to several multi-agency regional programs to manage and protect water resources. These include the Chesapeake Bay Program, Great Lakes National Program, Gulf of Mexico Program, Lake Champlain Program, and Land and Water 201 Program. USDA's support for the National Estuary Program and regional programs totaled $15.1 million in 1995.

In addition, USDA is assisting EPA's Clean Lakes Program by targeting some Small Watershed Program flood-control projects to Clean Lakes Program projects. USDA is providing program support in many of EPA's Section 319 watershed projects. Some of the HUA and WQIP projects were targeted to watersheds identified under Section 319. USDA technical assistance for Section 319 projects totaled $300,000 in 1995.

EPA Programs

The primary Federal water quality law, the Clean Water Act (CWA), addresses both point and nonpoint sources of pollution. Pollution from point sources are subject to effluent limits enforced through the National Pollutant Discharge Elimination System (NPDES) permits. With respect to agriculture, large confined animal operations (over 1,000 animal units) fall under the NPDES system. Over 6,000 operations are large enough to require an NPDES permit. However, enforcement has been a problem, and many facilities lack permits (Westenbarger and Letson, 1995).

Water pollution from nonpoint sources, including agriculture, is subject to Section 319 of the CWA. Section 319 calls for control of nonpoint source pollution, but does not provide direct authorities to regulate these sources. Because of the diverse and site-specific nature of nonpoint source pollution, States are given primary responsibility. State and local governments develop nonpoint source control plans that can include regulatory measures but mostly emphasize voluntary actions. The Nonpoint Source Program, established by Section 319, authorizes grants to States for developing and promoting nonpoint source management plans. States have established a number of watershed projects under this program that involve many local, State, and Federal stakeholders. EPA's role is to provide program guidance, technical support, and limited funding. Through 1995, EPA had provided over $274 million in grants to such projects, of which $107 million was for agriculture.

The Coastal Zone Management Act Reauthorization Amendments (CZARA) added important nonpoint source (NPS) water pollution requirements to the Coastal Zone Management Act. This is the first federally mandated program requiring specific measures to deal with agricultural nonpoint sources. CZARA requires that each State with an approved coastal zone management program submit to EPA and to the National Oceanic and Atmospheric Administration a program to "implement management measures for nonpoint source pollution to restore and protect coastal waters." A list of economically achievable measures for controlling agricultural NPS pollution is part of each State's management plan. States can first try voluntary incentive mechanisms, but must be able to enforce management measures if voluntary approaches fail. Implementation of plans is not required until 1999. In general, annual costs of CZARA management measures have been estimated to be less than $5,000 per farm for most farm sizes. Exceptions are grazing management measures for larger farms in the West, and manure management measures on larger dairy farms (Heimlich and Barnard, 1995).

The Safe Drinking Water Act (SDWA) requires the EPA to set standards for drinking-water quality and requirements for water treatment by public water systems. The SDWA authorized the Wellhead Protection Program in 1986 to protect supplies of groundwater used as public drinking water from contamination by chemicals and other hazards, including pesticides, nutrients, and other agricultural chemicals. The program is based on the concept that land-use controls and other preventive measures can protect groundwater. Currently, 39 States have an EPA-approved wellhead protection program.

The Comprehensive State Ground Water Protection Program (CSGWPP), established in 1991, coordinates all Federal, State, tribal, and local programs that address groundwater quality. States have the primary role in designing and implementing CSGWPP's in accordance with local needs and conditions. EPA has approved programs in 5 States, and plans from an additional 13 States are under review.

EPA also administers some regional programs targeted at particular water bodies. EPA's National Estuary Program helps States to develop and carry out basin-wide, comprehensive programs to conserve and manage their estuary resources. The Clean Lakes Program authorizes EPA grants to States for lake classification surveys, diagnostic/feasibility studies, and for projects to restore and protect lakes.

State Programs

Some 44 States have passed laws or instituted programs that either protect water quality directly, or indirectly, by affecting some aspect of agricultural production associated with nonpoint source pollution (Ribaudo and Woo, 1991; Gadsby, 1996; Jackson, 1996). Some of these laws are in response to Federal laws such as the Clean Water Act, while others are in response to chronic problems such as nitrates or pesticides in groundwater. States use a variety of approaches for addressing water quality problems: controls on inputs or practices, controls on land use, economic incentives, and education programs.

Input controls are primarily directed at pesticides and nutrients. Most States require certification of pesticide applicators. Some States restrict where particular chemicals can be used, usually in response to observed groundwater problems. Nutrient management plans are required in 16 States, usually in areas affected by groundwater contamination. Chemigation is banned or tightly controlled in 19 states.

Practices for controlling soil erosion to address water quality problems are required in 18 States. In most, best management practices (BMP's) are required if a complaint is filed by a citizen or government agency. Some States require erosion control plans on cropland, but actual implementation of BMP's is contingent on the availability of cost-share funds.

As animal operations become larger, more States are looking at ways of protecting the environment from animal waste. Large confined animal operations can present major water quality problems at the local level. As indicated above, large operations (greater than 1,000 animal units) are subject to the NPDES point-source permits of the Clean Water Act. However, these permits address only storage of manure on the site, and not disposal. Pennsylvania is the first State to pass a comprehensive nutrient management law aimed at concentrated animal operations. Animal operations with over two animal units per acre of land available for spreading must have a farmlevel nutrient management plan that demonstrates that waste is being safely collected and disposed of.

Land-use laws that affect agriculture are being used by municipalities, counties, and other local governments. Land-use controls include zoning, land acquisition, and easements targeted to areas deemed critical for protecting water resources. Zoning ordinances are used in many areas, especially around the rural-urban fringe, to ban confined animal operations.

Economic incentives for water quality primarily take the form of cost-sharing, with 27 States having cost-share programs for soil conservation and other practices. Tax credits are used to a much lesser degree. (Many States have fertilizer taxes, but these are typically used to generate revenue rather than to significantly reduce fertilizer use.)

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For more information...

This page is only an introduction to the effects of agriculture on water quality. Below are some additional sources of information.

ERS Resources

Linkable publications in this section are in Adobe Acrobat PDF format. You can download and get help using the Adobe Acrobat Reader to view and print a document. This format is used to preserve the content and layout used in the printed publication.

- *Voluntary Incentives for Reducing Agricultural Nonpoint Source Water Pollution, AIB-716, May 1995.* Data from selected study areas are used to evaluate the success of existing incentive programs to control agricultural nonpoint source pollution. Because profitability drives production decisions, these programs tend to be most successful when they promote inexpensive changes in existing practices.

- *The Benefits of Protecting Rural Water Quality: An Empirical Analysis, AER-701, January 1995.* The use of nonmarket valuation methods to estimate the benefits of protecting or improving rural water quality from agricultural sources of pollution are explored. Two case studies show how these valuation methods can be used to include water-quality benefits estimates in economic analyses of specific policies to prevent or reduce water pollution.

- *Agricultural Resources and Environmental Indicators, AH-705, December 1994.* This report identifies trends in land, water, and commercial input use, reports on the condition of natural resources used in the agricultural sector, and describes and assesses public policies that affect conservation and environmental quality in agriculture. The following three AREI chapters specifically relate water resources:
    - Chapter 2.1, Water Use and Pricing in Agriculture.
    - Chapter 2.2, Water Quality.
    - Chapter 6.5, USDA's Water Quality Program.

- *Atrazine: Environmental Characteristics and Economics of Management, AER-699, September 1994*. Atrazine is an important herbicide in the production of corn and other crops in the U.S. Recent findings indicate that elevated amounts of atrazine are running off fields and entering surface-water resources. The costs and benefits of an atrazine ban, a ban on pre-plant and pre-emergent applications, and a targeted ban to achieve a surface-water standard are examined.

- *Estimating Water Quality Benefits: Theoretical and Methodological Issues, TB-1808, September 1992*. Knowledge of the benefits and costs to water users is required for a complete assessment of policies to create incentives for water quality-improving changes in agricultural production. A number of benefit estimation methods are required to handle the varying nature of water quality effects.

Other Internet Resources

- Stream Water Quality in the Conterminous United States -- Status and Trends of Selected Indicators During the 1980's, Richard A. Smith, Richard B. Alexander, and Kenneth J. Lanfear. This is an HTML version of a paper published in the National Water Summary 1990-91 -- Stream Water Quality, U.S. Geological Survey Water-Supply Paper 2400.

- USGS Water Resources of the United States. The water resources home page of the U.S. Geological Survey, Department of the Interior.

- Chesapeake Bay: Measuring Pollution Reduction. U.S. Geological Survey page covering extent, reduction, and monitoring of nutrient pollution of Chesapeake Bay.

- National Water-Quality Assessment (NAWQA) Program. The U.S. Geological Survey's NAWQA home page. The NAWQA Program is designed to describe the status and trends in the quality of the Nation's ground- and surface-water resources and to provide a sound understanding of the natural and human factors that affect the quality of these resources.

- United States Environmental Protection Agency - Office of Water. EPA's Office of Water home page.

- Water Quality Inventory (1995). EPA's Water Quality Inventory 305B report to Congress for 1994.

- Rangeland Hydrology, Non-point Source Pollution and Water Quality. A page maintained by the University of California Cooperative Extension Service dealing with Western rangelands, grazing, and water quality.

- Colorado Water Knowledge. Page maintained by Colorado State University specializing in Colorado water issues.

- Water Pollution Prevention and Control, United States Code, Title 33, Chapter 26. U.S. Code courtesy of Cornell Law School.

- National Drinking Water Regulations, United States Code, Title 42, Chapter 6A, Subchapter XII, Part B, Para. 300g-1. U.S. Code courtesy of Cornell Law School.

- Water Quality Information Center: A service of the National Agricultural Library, Agricultural Research Service, U. S. Department of Agriculture, in cooperation with the University of Maryland, providing access to information related to water resources and agriculture.

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