A PROGRESS REVIEW OF IOWA'S AGRICULTURAL-ENERGY-ENVIRONMENTAL INITIATIVES:

Nitrogen Management in Iowa

Technical Information Series 22

Iowa Department of Natural Resources
Larry J. Wilson, Director
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A Joint Report From the Integrated Farm Management Demonstration Project,
the Model Farms Demonstration Project, and
the Big Spring Basin Demonstration Project

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December 1991

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SUMMARY

Since 1982, a consortium of state and federal organizations have implemented an array of programs to improve the environmental performance of agriculture in Iowa. One of the primary objectives was to improve nitrogen (N) management because nitrate contamination of water supplies has become a growing problem. The consortium developed a comprehensive demonstration, education, and research program to address this problem, building on efforts initiated in 1981 in the Big Spring basin. Some of the major projects that evolved include: the Big Spring Basin Demonstration Project (BSBDP); the Integrated Farm Management Demonstration Project (IFMDP), including the Integrated Crop Management (ICM) project; and the Model Farms Demonstration Project. A primary research goal was to develop or calibrate a soil test specifically for N management. Legislative action, particularly the Iowa Groundwater Protection Act, provided various directives, fiscal support, and additional initiatives, such as the Leopold Center for Sustainable Agriculture and requirements for private pesticide applicator training. The approach of the projects carried over into other mainstream programs, as well.

Promoting improved, integrated farm management has been the major emphasis of the projects, which make use of known technologies where major improvements in N-management could be implemented immediately. These proven approaches improve both the profitability and the environmental performance of crop production. Iowa's programs have utilized a large and varied network of on-farm demonstration and implementation projects. These were coupled with an aggressive marketing and information delivery plan to accelerate voluntary adoption. The magnitude of the consortium's educational and marketing programs has successfully initiated adoption of improved N-management techniques. The marketing scheme recognizes that altering agricultural management is a sociological process as well as a technical one, and is designed to expand program impacts beyond the cooperating farmers. Demonstrations have been conducted in every county to provide local credibility of the benefits of improved N-management techniques.

The results of N-management programs can be evaluated from two perspectives; results of individual projects and impacts on the state and regional scale. Individual projects show significant improvements in N management. In the BSBDP, 52% of the 200 area farmers report reducing fertilizer nitrogen (FN) rates since 1981. Farm inventories show they reduced FN applied to corn by 21%, resulting in a reduction of N-loading in the basin of >1 million pounds per year. These reductions have meant cost savings of about $200,000 per year to area farmers. In the IFMDP-ICM project, 48 farmers in Butler County reduced their FN use by over 240,000 lbs in 1989, with no reductions in yields. In sum, they increased their net return by over $500,000/year through integrated crop management improvements. Various statewide demonstration efforts using the nitrate-soil test reduced nitrogen applications by 62% in 1989 (on

23 sites), following drought conditions, and by 21% in 1990 (on 41 sites), with no difference in yields relative to usual N rates. Sixty to seventy percent of samples processed by the ISU Soil Test Lab suggest that some reductions in nitrogen use might be feasible.

While management changes on individual project farms have been substantial, this directly includes only 2-3% of Iowa farms. With the outreach and marketing programs, including field days, local activities, and various media coverage, project results have been distributed to all parts of the state. But are such marketing efforts carrying over to neighbors and other farmers? Are these efforts affecting measurable improvements in farm management statewide that will afford environmental improvements? Two sources of information, surveys of farmers' attitudes and farm-management practices, and standard state and national data on nitrogen use, indicate success.

Statewide surveys indicate about 50% of farmers cooperating in the demonstration projects have reduced FN rates for corn since 1985, while 39% of their neighbors and only 15-25% of other farmers have reduced FN use; about 4% of cooperators but 13% of the other farmers have increased rates. The independent data on statewide FN use, standardized to a crop acreage basis, show Iowa producers have reduced nitrogen use since 1985, despite declining fertilizer prices and contrary to trends in the adjacent cornbelt region. Reductions are calculated relative to 1985 rates and to regional time-series trends. Since 1986, these reductions total over 800 million lbs-N, for use on corn, with no decline in yields. These reductions equate to cost savings for Iowa farmers of over $120 million and an energy savings equivalent to over 200 million gallons of diesel fuel. When reductions and savings are calculated from total FN sales records, the savings are even greater, equalling about 1,230 million lbs-N and a savings of over $184 million.

The savings for 1989 and 1990 are used as a conservative estimate of the benefits of Iowa's agricultural-environmental programs. For these years N use was reduced, relative to 1985 rates and regional trends by 440 to 540 million pounds, with a cost savings of $65 to $80 million for the two-year period. Estimates for other input reductions and efficiencies promoted by the programs suggest a total savings of about $100 million. From 1981 through 1990, about $11 million in state and federal funds, including $9.6 million in oil-overcharge funds, have been allocated to these programs. These projects have provided an eight-to ten-fold "payback" to the state, based on the 1989-1990 savings alone. The special oil-overcharge funding terminates in 1992, however, and continued progress improving N-use will likely lose momentum without further support.

While significant achievements can be noted in reducing overall environmental loading from agricultural practices in Iowa, there are substantial improvements yet to be made. For major reductions to take place continued program support will be required, as will major efforts by Iowa agri-business to provide services to farmers that promote adoption of more efficient nitrogen use. Farmers took 10-15 years to adapt to using purchased FN, even though research clearly showed this would increase production and profitability. As we attempt to refine N-management, generally reducing FN use for environmental and economic efficiency, it is difficult to expect a more rapid rate of change. Similarly, it took many years of incremental increases in N-loading before the impacts of nitrate on Iowa's water resources were wholly apparent. It will take continued positive changes in N-management and equally many years for water-quality improvements to be apparent beyond the local scale, as well.

Aggressive demonstration, education, and marketing programs are necessary if we are to rely on voluntary adoption of more efficient N-management practices. Based on state surveys, considerable refinements are still feasible through use of realistic yield goals and appropriate crediting for rotation and manure benefits. Further refinement of new soil test methods will be needed. Past estimates suggesting that nitrogen use in Iowa could be reduced by $100 million per year clearly seem feasible.

INTRODUCTION

Since 1982, the state of Iowa has implemented a large array of programs to improve the environmental performance of agriculture. These new initiatives, while continuing Iowa's traditionally strong efforts in soil conservation, have also focused on reducing the effects of nutrients, pesticides, sediment, and animal waste on surface-water and groundwater quality. Improved nitrogen management has been one primary objective of the programs because of the extensive regional problems with nitrate contamination of water supplies that has evolved over time in Iowa, and other corn-belt states (Hallberg, 1986, 1987, 1989; Keeney, 1986). Nitrogen (N) management was also targeted because assessments of farm management showed clear opportunities to enhance the efficiency and profitability of Iowa farmers through improved N-management. This paper reviews the results of Iowa's nitrogen management programs.

PROGRAM HISTORY

Groundwater studies and agronomic research in the late 1970's showed significant regional losses of nitrogen into the environment related to the extent of intensive row-crop production in Iowa (Baker and Johnson, 1981; Baker and Laflen, 1983; Hallberg and Hoyer, 1982; Hallberg et al., 1983; Hallberg, 1987). These studies indicated the losses were largely the result of inefficiencies in nitrogen management; some inefficiencies simply had not been recognized and some were inherent in modern crop production. But the studies also showed significant improvements were possible, simply through more efficient, integrated management (e.g., Blackmer, 1986; Cerrato and Blackmer, 1990; Killorn et al., 1988; Oberle and Keeney, 1990a,b).

Iowa farmers and the public were also concerned with mitigating agriculture's impact on the environment. Surveys showed that farmers were very concerned about water-quality issues and were willing to consider changes in management, particularly changes that would also be profitable (e.g., Padgitt, 1985, 1987). A consortium of Iowa agencies and institutions set out to implement a coordinated demonstration, education, and research program to address these problems.

Even though important research questions needed to be answered, the consortium also realized that many productive solutions were already known. Promoting implementation of improved, integrated farm management was recognized as the key. First steps included setting realistic yield goals by soil and field management units, accounting for all available nitrogen sources on the farm (e.g., credits from crop rotation and manure), and then following with appropriate use of fertilizer-N. The prime thrust of Iowa's program has been on these proven approaches where significant improvements could be made immediately, to improve both the profitability as well as the environmental performance of crop production.

The Iowa programs have addressed implementation of these technologies largely through variations of traditional voluntary approaches. The programs have utilized a large and varied network of on-farm demonstration and implementation projects, but these were coupled with an aggressive marketing and information delivery plan, that included socio-economic and program evaluations (Hallberg, 1991).

The consortium of institutions collaborating in these efforts principally included: state and federal agencies, the Iowa Department of Agriculture and Land Stewardship, Iowa Department of Natural Resources, USDA - Soil Conservation Service, the Agricultural Stabilization and Conservation Service, and the Agricultural Research Service, and the US Environmental Protection Agency; state institutions, Iowa State University - the Cooperative Extension Service (CES), the Departments of Agronomy, Agricultural Engineering, Economics, Sociology, and the Agricultural and Home Economics Experiment Station, and the University of Iowa - Hygienic Laboratory, the Institute for Agricultural Medicine and Occupational Health, the Graduate Program in Urban and Regional Planning, and the Public Policy Center; and grass roots support from Iowa Conservancy Districts and Soil Conservation Districts, as well as other private and farm interest groups.

Project Development

The consortium's efforts built on research and demonstration efforts initiated in 1981 in the Big Spring basin. By 1986 these had expanded into the Big Spring Basin Demonstration Project (BSBDP), a prototype for later statewide efforts. In 1986, legislation established Iowa's Agricultural-Energy Management Fund, which implemented statewide efforts in the Integrated Farm Management Demonstration Project (IFMDP). The IFMDP initiated or enhanced many innovative projects, including the Integrated Crop Management (ICM) program, the Practical Farmer's of Iowa operational demonstrations, various local networking groups, the Field Extension Education Laboratory (FEEL), and animal manure-brokering pilot projects.

In 1987, the Iowa Groundwater Protection Act (IGWPA) provided further support for these programs. The IGWPA also created the Leopold Center for Sustainable Agriculture at Iowa State University, which has provided additional initiatives and research leadership. The 1987 legislation set forth other mandates related to quality-assurance in soil testing and nutrient recommendations, and a more intensive pesticide applicator certification and training program, which includes training and testing in nutrient management.

Based on the success of the ICM program, the Governor and legislature provided support to establish the Model Farms Demonstration Project (MFDP), in 1989. MFDP field efforts began in 1990, expanding the scope of statewide programs.

Research and development projects were also initiated. Intensive work began in 1985 to find and calibrate plant tissue tests and a nitrogen soil test -- a badly needed new tool for N management. These efforts have been supported by the Iowa Fertilizer and Chemical Association, as well as the consortium of public agencies and institutions.

The success and approach of the projects carried over into other mainstream efforts of the Extension Service and ISU agricultural programs, and also into other agency projects, new and old; soil conservation programs, Iowa's Resource Enhancement and Protection Program's water quality projects, and Nonpoint Source Programs (Sec. 319, Clean Water Act). They also influenced new federal initiatives: the ASCS-ACP ICM pilot program (adapted after Iowa's model), USDA Water-Quality Initiative projects, and the Water-Quality Incentives Program in the 1990 Food, Agriculture, Conservation and Trade Act (FACTA). Various local programs also have been initiated by private colleges and institutions (e.g., Dordt College Agricultural Stewardship Center; Iowa Natural Heritage Foundation), local groups (tillage clubs, conservancy districts), and organizations (Practical Farmers of Iowa; the Land Stewardship Project).

Marketing Program

While founded in traditional approaches to promote voluntary adoption, the magnitude of the consortium's efforts and the aggressive marketing of new technologies provide a new dimension. The marketing scheme recognizes that altering agricultural management is as much a sociological process as a technical one. The inertia of 20-30 years of development and utilization of current production systems must be overcome. Proposals for altered or refined management technologies must compete with the mixed messages and innumerable sales pitches about production strategies and environmental issues that besiege the farm operator. Hence, projects typically begin with sociological surveys (e.g., Padgitt, 1985, 1988, 1991) that identify: producers' perceptions, knowledge, and concerns about soil and water quality problems; knowledge and skills of alternative practices; and willingness to adapt to alternative practices. The surveys are also used to inventory current practices (for later evaluation of change). In short, they help define: what do local producers perceive their problems are, their needs are? What are they *willing* to do, what are they *able* to do? What are they currently doing that can readily be improved? This information allows the utilization of local knowledge and willingness as a first stage in implementation (Padgitt, 1991; Hallberg, 1991).

The information marketing and project implementation strategy builds on this information. Implementation has three inter-related objectives: 1. to enhance awareness and recognition of problems; 2. to provide awareness and contact with alternative practices while providing confidence that the practices are viable; and 3. to collaborate with farmers in the transition to new practices. These three objectives aim at helping farmers overcome perceived risks and other impediments to change (Contant, 1990b; Hallberg, 1991).

Marketing Statistics

Basic statistics from the IFMDP illustrate the magnitude of the marketing effort. On average the IFMDP has annually established about 300 on-farm demonstration sites; some in every county of the state, with more than 5,000 plots in replicated trials. Over 90% of the sites are on private farms, some are plot scale, but many are full width trials or fully implemented operations on the farm. Locating sites in every part of the state greatly enhances local credibility and acceptance of the new approaches. The statewide scope and replicated trials supply needed data to provide confidence in their viability.

The results of the demonstration and implementation projects are aggressively distributed through various education and media efforts; field days, self-guided tours, special newsletters, traditional Extension meetings, other special farm-group meetings, targeted local and regional press releases, and radio and TV spots. Local media coverage provides further credibility and interest. Release of project results often generates follow-up stories by regional or national news media and agricultural magazines which provides further dissemination (e.g., Walter, 1988; Swoboda, 1989). In the typical year, over 100 field days have been held, with attendance of 5,000 or more; 150 to 200 group meetings, with documented attendance of 10,000 to 18,000; an estimated 1,200 to 1,600 taking self-guided tours; 120 news releases distributed to some 600 local and regional outlets; 90 radio and TV spots noted; over 6,000 newsletters distributed, plus brochures, pamphlets, and flyers. In addition, special demonstration sites, displays, or programs are targeted for major events, such as county and state fairs, the World Ag Expo, and Living History Farms.

RESULTS OF PROJECTS

The results of the N-management programs will be reviewed from two perspectives; the individual projects and from statewide surveys and nitrogen use data. Illustrations from individual projects, the BSBDP, the IFMDP, and soil test demonstrations, provide an overview of pertinent results that have been the cornerstone of the larger marketing program to improve N-management.

BIG SPRING BASIN DEMONSTRATION PROJECT RESULTS

Various educational efforts have been underway in the Big Spring basin area since 1982. These have included contacts with the approximately 200 farmers in the basin through farm census surveys, newsletters, and local press and media coverage. On-farm demonstration and implementation projects began in earnest in 1984, and were greatly expanded with the 1987 crop season under the BSBDP.

A key focus of N-management programs in the BSBDP has been providing appropriate N-credits to corn following alfalfa in a crop rotation. Results from 5 years of local on-farm demonstration projects (Table 1) show that farmers lost money using more N than contained in a starter fertilizer (0 to 24 lbs-N/acre rate) on corn following a good multi-year stand of alfalfa. Maximum yields are often obtained with no added nitrogen. Longer-term data from northeast Iowa Experiment Station farms also support this. When the project began in 1981, basin inventories showed that area farmers applied an average of 123 lbs of fertilizer-N per acre on corn after good alfalfa stands - at a loss averaging about $18/acre.

In 1987, several years into the education and marketing efforts, 52% of farmers surveyed noted reducing fertilizer nitrogen rates since 1982 (Table 2). While such responses are promising, annual inventories of farm practices (and area sales records) provide additional information (Table 3). From 1981 to 1989, basin farmers reduced fertilizer-N rates by 33% for first-year corn after alfalfa, by about 22% for second-year corn, and by 15% on continuous corn (3 or more years corn), giving an aggregate reduction of

Table 1. Summary of results from on-farm demonstration projects of N-management for first-year corn following alfalfa in the Big Spring Basin Demonstration Project. Five years data (1985-1989) from 26 farm sites, involving 6 to 8 fertilizer-N rates, replicated 4 times for yield data from 728 plots. (There is no significant difference in yields.)

Fertilizer-N applied	1985-89 average corn yield	Average **LOSS** at N-rate applied
lbs-N/acre	bu/acre	$/acre
0-24	169	
		-$6.50/ac
25-49	168	
		-$14.00/ac
75-99	164	
		-$17.75/ac
100-124	167	
		-$25.25/ac
150-174	170	
		-$29.00/ac
175-200	167	
		-$32.75/ac

Table 2. Results from 1987 farm management census of Big Spring basin farmers. (Responses summarized as % of 217 farmers responding.)

In response to the question: Since 1982, have you reduced, increased, or not changed your:

Nitrogen fertilizer applications?
52% = reduced; 4% = increased; 45% = no change.

P & K fertilizer?
39% = reduced; 4% = increased; 57% = no change.

Herbicide use?
23% = reduced; 3% = increased; 74% = no change.

Insecticide use?
19% = reduced; < 1% = increased; 81% = no change.

IF you have REDUCED your use, why did you do so?

98% = trying to reduce input costs.
83% = Learned I can reduce inputs without hurting yields.
84% = Concerned with water quality and safety from handling chemicals.

about 21% on all corn acres. Yields generally increased during this time (Table 3). While the yield differences are largely related to weather, the yield data has helped area farmers understand they can address both environmental concerns and profitability. The substantial shift in fertilizer N-rates is illustrated in Figure 1.

For farmers in the Big Spring basin the reductions from 1981 to 1989 translate to: a reduction of over 1.2 million lbs of N applied per year; a savings of about $200,000 per year (or an average of about $1,000 per farm); and an energy savings equivalent to over 250,000 gallons of diesel fuel per year. Even so, there are many producers who can still make substantial improvements (Fig. 1).

Other projects in the region provide an assessment of the effect of the Big Spring demonstrations and marketing efforts. In 1987, Blackmer and others (El-Hout and Blackmer, 1990) conducted on-farm surveys of N management in areas surrounding the Big Spring basin, including corn stalk and tissue tests and nitrogen soil tests. Farmers in these adjacent areas averaged 121 lbs fertilizer-N/acre on first-year corn after alfalfa, essentially the same rate used by Big Spring basin (BSB) farmers in 1981. But by 1987, BSB farmers had reduced rates to about 84 lbs-N/acre, illustrating the effects of the BSBDP educational programs.

Poor alfalfa stands may provide little available-N, necessitating fertilization. However, the plant and soil-test data from the adjacent areas indicated many of these fields had 2 to 3 times the N needed to maximize corn yields (El-Hout and Blackmer, 1990).

By 1989, after the expansion of the Big Spring programs and with implementation of statewide marketing programs, surveys (Hallberg et al., 1990; Kross et al., 1990) showed area farmers reducing to rates of about 105 lbs-N/acre on first year corn.

INTEGRATED FARM MANAGEMENT DEMONSTRATION PROJECT

Many components of the IFMDP deal with nitrogen management (e.g., Miller et al., 1991). The Nitrogen Management (NM) project element implemented by ISU-CES is a statewide initiative

Table 3. Fertilizer-nitrogen (FN) rates used for corn and continuous corn yields, from farm census inventories in the Big Spring basin; inventories consist of personal enumeration surveys, conducted with the farm families in the basin; response rate averages about 90% from the approximately 200 farm operators in the basin.

	Basin average fertilizer-N rates				Ave Yield
Rotation	All corn	1st-yr corn after alfalfa	2nd-yr corn after alfalfa	Continuous corn	Continuous corn yields
Year	------	*lbs-FN/acre*		------	*bu/acre*
1981	174	123	160	178	128
1982	174	123	---	178	138
1984	158	115	155	169	130
1986	147	96	---	153	149
1987	149	84	121	157	141
1988	141	84	124	151	79
1989	138	82	125	151	147

exemplary of the program (Killorn et al., 1987, 1988, 1989, 1991, in press). Over the first 4 years (1987-1990) the NM project set up 87 demonstration sites on different farms throughout Iowa. Each involved 13 or 14 N treatments, with 4 replications each; a total of over 4,700 plots, used to develop a refined N-crop yield response data base for Iowa farmers. At each site the farm cooperator's N rate was one of the treatments. Over the 4 years only 33% of the sites had a significant yield response from fertilizer, but this ranged widely dependent on weather conditions. In 1988 and '89, with significant N carry-over related to drought conditions, only about 18-20% of the sites had a response to added fertilizer-N. With better weather in 1987 and '90, 55-60% of sites showed significant responses.

In 1987, fertilizer rates for optimum corn-grain yield averaged 91 lbs-N/acre less than the rates normally used by the farm cooperators. In 1990, for the sites that had a significant yield response from N, optimum yields were produced at rates averaging 31 lbs-N/acre less than the cooperators. If the sites that showed no response to fertilizer are included, the rates for optimum yield averaged about 60 lbs-N/acre less than cooperators' normal rates. These figures show that to improve management and balance profitability and environmental concerns, producers must have more reliable methods to estimate N-fertilizer needs on a year-to-year basis. The soil, stem and stalk nitrogen tests being calibrated in these projects are part of the effort to develop such tools.

As an example of the IFMDP information marketing program, the NM project results were presented at well-advertised field days attended by over 5,100 people. In 1987 and 1988 sites were also established at the Farm Progress Show and the International Ag Expo which had a combined attendance of about 500,000. Results have also been presented in newsletters and CES meetings throughout the state.

Integrated Crop Management Program

The Integrated Crop Management (ICM) project was designed to demonstrate the economic viability of providing field scouting services and management assistance for improving row-crop production (Voss et al., 1989; Smidt et al., 1991). ICM emphasizes whole-farm resource planning and provides various services (e.g., pest scouting and nitrogen soil testing) for improved management decisions that reduce unneeded applications of fertilizers and pesticides. Results from the ICM pilot program in Butler County have been widely recapped in various media (e.g., Thompson, 1989; Seim, 1990).

The Butler County project involved 48 farms

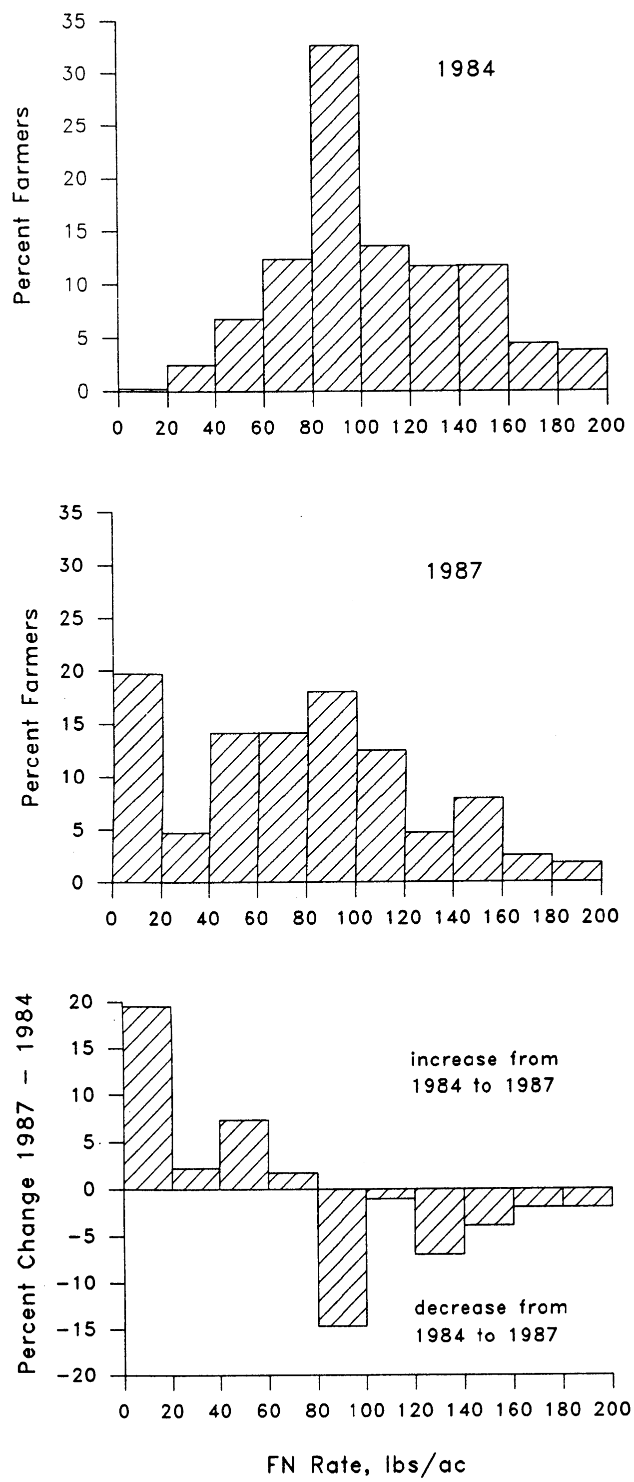


Figure 1. Frequency distributions from 1984 and 1987 showing changes in fertilizer nitrogen rates applied to first-year corn after alfalfa by farmers in the Big Spring basin.

operating about 25,000 acres. In each of the first two years the project increased the net return of these farms by about $500,000 per year. As an example, fertilizer-N use was reduced on these farms by 240,000 lbs in 1989 through setting realistic yield goals by soils, giving appropriate crop rotation and manure credits, and some use of the pre-sidedress soil nitrate test.

CALIBRATING A NITROGEN SOIL TEST

Efforts to calibrate and implement soil test methods for N-management have been part of all the projects (e.g., BSBDP, IFMDP). As noted, in 1985 research efforts set out to find a soil test to guide refined fertilizer-N application under Iowa conditions. Efforts have focused on methods for rapid measurement of soil-nitrate concentrations, either in the early spring, to calibrate pre-plant applications, or in late spring, as a pre-sidedress test. The best results have been from late spring, from pre-sidedress soil-nitrate testing (Magdoff et al., 1984; Magdoff, 1991; Blackmer et al., 1989). The test procedures and application have been tailored to Iowa conditions and afford a refined estimate of nitrogen needed that then can be sidedressed to the growing crop (Blackmer et al., 1991).

One project to implement and evaluate the nitrate soil test began in 1989 in cooperation with fertilizer dealers. The demonstration trials were designed as replicated, full-width tests in farmers' fields. Comparisons were made between crop yields with N applied according to the soil-nitrate test and with the dealer's normal rate. Equivalent yields were produced using the soil test but with reduced fertilizer-N rates, averaging 76 lbs-N/ac less in 1989 and 27 lbs-N/ac less in 1990 (Table 4). In 1989, there was significant N-carryover from dry weather and reduced yields in 1988. In 1990, following a wet winter and spring, carryover was much less, as were the rate reductions afforded. In 1990, 27% of sites required full rates of N; however, at 73% of sites N-rates were reduced. These sites were not selected to be representative of statewide conditions.

(The project with the fertilizer dealers has been supported by the Leopold Center, the Iowa Fertilizer and Chemical Association (IFCA), IFMDP, BSBDP, and the USEPA. The IFCA has supported the project because marketing and

Table 4. Summary of results from soil-nitrate test, cooperative-calibration trials with fertilizer dealers (Blackmer and Morris, unpublished).

No. sites	N-fertilizer treatment	Mean FN rate	Mean corn yield
		lbs-N/acre	bu/acre
	1989:		
23	dealer's normal rate	123	130
	rates from soil test	47	131
	1990:		
41	dealer's normal rate	131	137
	rates from soil test	104	137

Table 5. Summary of soil-nitrate test results from the Iowa State University Soil-Test Laboratory (Killorn, unpublished).

NO_3-N in upper foot of soil	% of normal fertilizer-N recommended	1989	1990	1991
ppm	%	--- % of samples ---		
10 or less	100%	6	29	24
11-12	80%	5	11	10
13-15	60%	9	13	14
16-18	40%	11	9	9
19-20	20%	5	6	4
> 21	0%	64	32	39
No. samples		818	1,173	792
Range, ppm		2-138	1-94	2-116
Median, ppm		26	15	16

selling services such as soil nitrate testing can help to improve the profitability and financial stability of their clients, and offset lower income from decreased product sales.)

In 1989, the CES Soil-Test Lab at Iowa State University began offering soil-nitrate analysis. Results for 1989-1991 (Table 5) show trends (Fig. 2) following the weather patterns noted above. In 1989, over 60% of samples suggested no further N was needed for optimum yields, and only about 6% of sites required a full complement of N. In 1990 and 1991, the situation was different; 24-29% required a full increment of N for optimal production while 32-39% of samples indicated no further N required. These data are exemplary of the necessity of this new tool for N-management improvement. The soil-nitrate tests and other tests being calibrated are *not* panaceas, nor foolproof, and further work is underway to refine their application.

PROGRESS BEYOND THE PROJECTS?

The project data reviewed above, while encouraging, are only from a very small subset of Iowa farms. Even with as broad a scale as Iowa's programs have operated, they still have worked directly on only 2-3% of Iowa farms. Coupled with the outreach and marketing programs through field days and local activities, perhaps 20-25% of Iowa farmers have been reached through local sources, which tend to be the most effective. Information marketing efforts, on a larger scale, as well as independent media coverage of project results have distributed information to all parts of the state. And, from 1988 through 1990, pesticide applicator training and certification programs delivered educational materials to over 30,000 private applicators and farmers. These marketing efforts attempt to broaden the adoption of improved management beyond the farmers directly involved in the projects.

While changes on individual project farms have been significant, there will never be time nor money available for such programs to directly reach each and every farmer. Hence, there are significant questions about the effectiveness of the projects. Are the project results carrying over to neighbors and other observers? Are the larger scale marketing programs having an effect? Are there measurable improvements in farm management statewide that will result in environmental improvements?

Trying to assess effects on this scale are difficult; data are limited, and in these relatively early stages impacts will likely be small and grow slowly. Two sources of information are reviewed to assess indications of change. First, various surveys of farmers attitudes and farm management practices, and second, standard state and national data collected on nitrogen use. The latter provide an important historic data base for comparison.

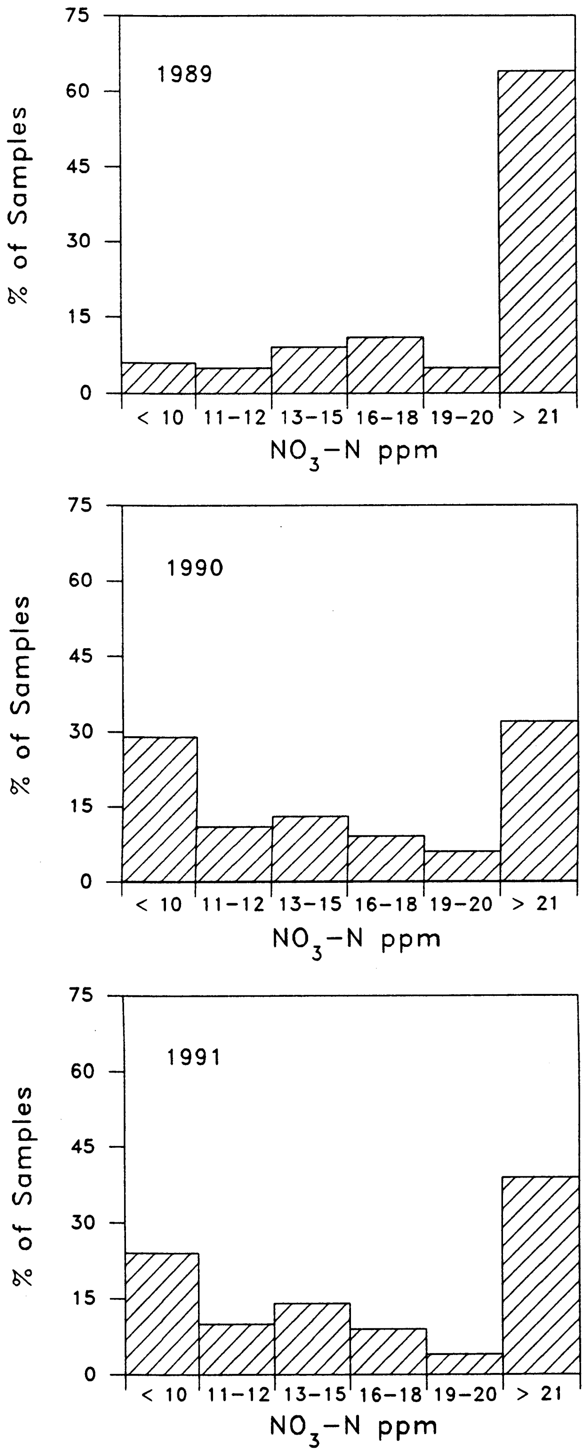


Figure 2. Frequency distribution of soil-nitrate tests results from the ISU Soil Testing Laboratory for 1989-1991; see Table 5 (Killorn, unpublished). The distributions illustrate the annual variability which complicates N-management for producers.

IOWA FARM SURVEYS

Various surveys indicate that the projects have affected the attitude of Iowa farmers. In the 1989 "Iowa Farm and Rural Life Poll" (Lasley et al., 1989), for example, 78% of Iowa farmers agreed that "modern farming relies too heavily upon insecticides and herbicides;" and 76% agreed "modern farming relies too heavily upon chemical fertilizer." In the 1991 Poll (Lasley et al., 1991), 53% al., 1991), 53% of Iowa farmers indicated that they felt farmers apply "about the right amount" of nitrogen, but 46% felt that they applied too much; 78% indicated that farmers could reduce production expenses with more careful nitrogen management.

Program surveys of farm management provide more direct indications of project effectiveness. A 1990 survey conducted as part of the evaluation of the IFMDP provides insight to the relative impact of the demonstration projects and statewide changes in N-management (Table 6). One part of the survey assessed management changes for three sets of farmers: 1. "cooperators" - farmers who participated in demonstrations on their farms; 2. "neighbors" - farmers adjacent to cooperator's farms, most of whom have had some contact with the demonstrations; and 3. a statewide survey of "other" farmers. Since 1985, 63% of cooperators have changed N management; of those who changed, 77% decreased fertilizer-N rates and only 7% increased rates. In comparison, 56% of neighbors and other farmers report changes since 1985. For neighbors, 70% of those reporting changes, decreased rates while only 45% of other farmers report decreases; 24% of neighbors and 21% of other farmers report increasing rates. As a percentage of all farmers in each group, 49% of cooperators decreased N rates, while 39% of neighbors, and 25% of other farmers decreased N-application rates; 4% of cooperators increased rates, while 14% of neighbors and 12% of other farmers increased. The gradient of these changes illustrate an expected diffusion outward from direct project contact.

The different reasons respondents provided for changing or not changing practices also indicates the effectiveness of program education and technology delivery efforts. Cooperators more commonly cited use of soil tests,

Table 6. Changes in farmers nitrogen management plans since 1985, reported by IFMDP cooperators, neighbors to IFMDP cooperating farmers, and statewide random sample of other farmers. From 1990 IFMDP evaluation surveys (Contant, in preparation).

In response to the question: "What overall changes have you made to your nitrogen plan since 1985?"

	COOPERATORS:		NEIGHBORS:		STATEWIDE sample:	
Changed plans:	**63%**		**56%**		**56%**	
	% of those who changed:		% of those who changed:		% of those who changed:	
Decreased application rate:	**77%**		**70%**		**45%**	
Reasons (multiple responses):						
Soil test results;		74%		44%		42%
Environmental concern;		70%		44%		53%
Following new recommendation;		53%		35%		46%
To reduce costs;		51%		65%		68%
Concern over health effects;		43%		22%		8%
Credit taken for manure/legumes;		38%		48%		47%
Lower yield goal;		13%		0%		8%
					other;	26%
Applied same amount more frequently:	**10%**		**6%**		**18%**	
Applied same amount less frequently:	**7%**		**0%**		**16%**	
Increased application rate:	**7%**		**24%**		**21%**	
Reasons (multiple responses):						
Weather conditions;		75%		0%		35%
Soil test results;		75%		50%		39%
Following new recommendation;		25%		13%		22%
Higher yield goal;		25%		100%		88%
Poor past results;		25%		13%		17%
					other;	13%
Did not change plans:	**37%**		**44%**		**44%**	
Of those that "Did not change," why not?						
Reasons (multiple responses):						
Practices work well;		78%		96%		91%
Concern over lower yields;		33%		31%		34%
Lack of information that profits won't decrease;		22%		27%		21%
Soil, crop, &/or equipment requirment;		22%		23%		21%
Already apply little;		17%		4%		13%
					other;	7%

Table 7. Results from selected statewide surveys in Iowa.

Survey:		IFMDP* (Padgitt, 1989)	SWRL* (Kross et al., 1990)	Energy* (Duffy and Thompson, 1990)
Information year:		**1988**	**1988**	**1989**
Fertilizer-N usage --				
Application rates, lbs-N/acre,	on:			
continuous corn;		136	132	na
corn after soybeans;		109	122	na
corn after alfalfa;		na	95	na
% giving N-credits for --				
crop rotation-soybeans:		80%	76%	- -
average credit;	lbs-N/acre	34	na	36
crop rotation-alfalfa:		na	92%	- -
average credit;	lbs-N/acre	na	na	59
manure application:		<50%	50%	51%
average credit;	lbs-N/acre	na	na	39
% reporting reducing fertilizer-N rates:				
since 1985;		12%	na	na
since 1980;		na	23%	na

* IFMDP: a 1988 survey to designed to gather statewide data on management practices and farmer's attitudes; part of evaluation of the IFMDP.

* SWRL: a 1988 survey of sites selected for sampling in the Iowa Statewide Rural Well-Water Survey.

* Energy: a 1989 survey designed to gather detailed information about on-farm energy use and equipment inventories.

na: - not asked

environmental concerns, and new recommendations (Table 6). All local surveys indicate farmers are very concerned with components of their profitability and production costs and they need information and further confidence before attempting alternatives (e.g., Contant, 1990a; Table 6, also).

Three independent statewide surveys of Iowa farmers and farm-management practices were conducted in 1988 and 1989 using population sampling techniques to provide representative insight to changes by Iowa farmers (Padgitt, 1989; Hallberg et al., 1989, Kross et al., 1990; and Duffy and Thompson, 1990). A fourth survey was conducted in 1991, as a random sampling of certified private pesticide applicators who had attended CES certification testing programs (Padgitt and Wintersteen, 1991).

One survey (Table 7) indicates that 23% of farmers reported reducing fertilizer-N rates since 1980, and another reports 12% reduced rates since 1985. In the 1991 applicator survey, 39% of respondents noted using lower N rates in 1991 than in 1988, with an average reduction of 38 lbs-N/acre. Reasons for these reductions included: taking appropriate credits for manure (45%), or a preceding legume crop (21%), and calculating N need based on soil type and yield goal (23%).

In the statewide surveys, 75-80% of farmers growing corn after soybeans report giving an average of about 35 lbs-N/acre credit to the following corn crop (Table 7). About 90% of farmers planting corn after alfalfa report giving N-credits, but fewer farmers grow alfalfa. Only 50% of farmers using manure on corn acreage are giving N-credits.

Two of the surveys gathered information on fertilizer-N rates as well (Table 7); these rates are not significantly different from one another or from the Iowa Agricultural Statistics. Figure 3 summarizes N application rates from the SWRL survey. As in Figure 1 from the Big Spring basin, Iowa farmers give some credits for legume rotation benefits, shifting the averages toward lower application rates. However, the frequency distributions illustrate there is considerable progress yet to made in reducing application rates in these instances, as well.

The N-rate distributions (Fig. 3) suggest there are more opportunities for reducing N-rates; they also suggest that some producers could benefit from additional N on corn. The 4% of IFMDP cooperators who increased fertilizer rates are also indicative of program technology transfer efforts. The primary reasons cited by these cooperators for increasing rates reflect appropriate considerations (Table 6).

The various surveys also show that farmers report some reductions in P and K fertilizer and herbicide and pesticide use. The 1991 applicator survey reported 22% used less herbicides and 28% used less insecticide; while 7% reporting using more herbicides and 3% more insecticides. The amount of pesticide reductions was small, but other positive steps were reported. For example, 50% of certified applicators report scouting fields and calibrating their equipment more often.

NITROGEN USE IN IOWA

Farm survey information is valuable for gauging change and for altering program directions to further "target" the market. However, more direct measures of project effectiveness are also needed. Data on fertilizer management and total fertilizer use are collected by the USDA National Agricultural Statistics Service, Economic Research Service, the Iowa Department of Agriculture and Land Stewardship (e.g., Skow and Holden, 1990; Vroomen, 1989) and the Tennessee Valley Authority (TVA) and can be used to assess historic and current nitrogen use in Iowa and the cornbelt.

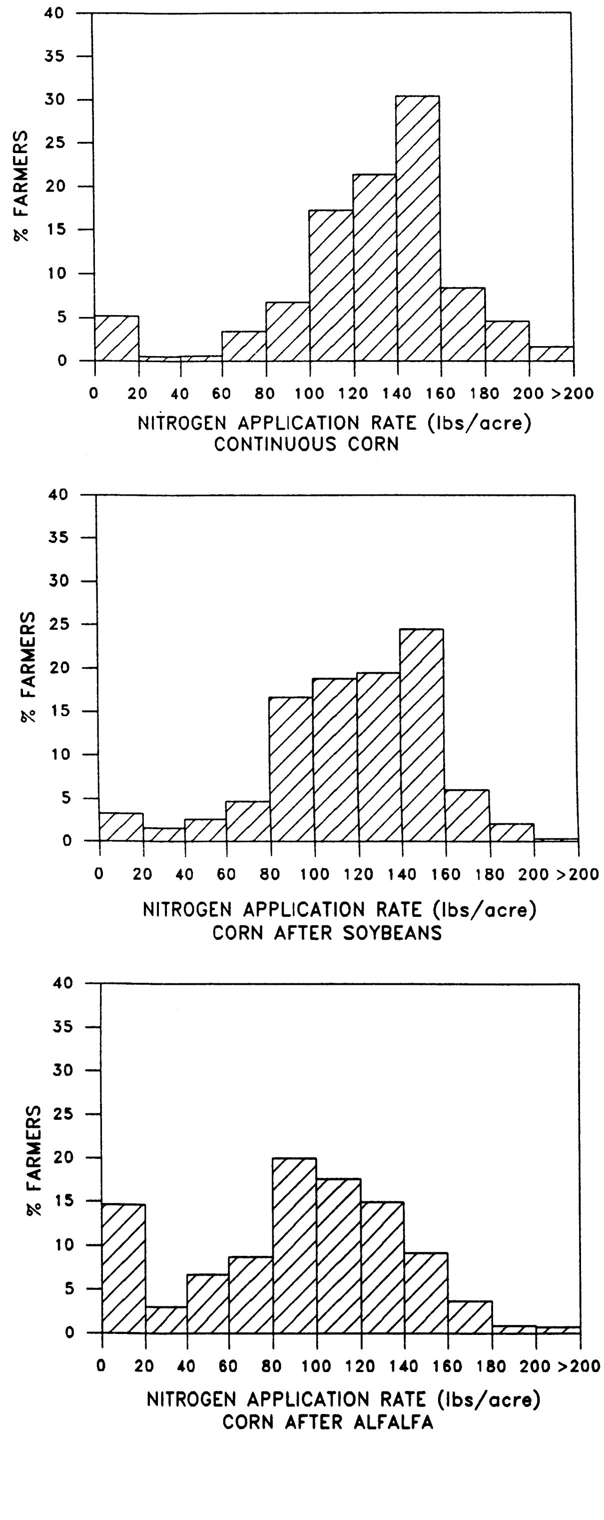


Figure 3. Frequency distributions of fertilizer nitrogen rates reported by Iowa farmers for various corn rotations (from the SWRL survey, Kross et al., 1990).

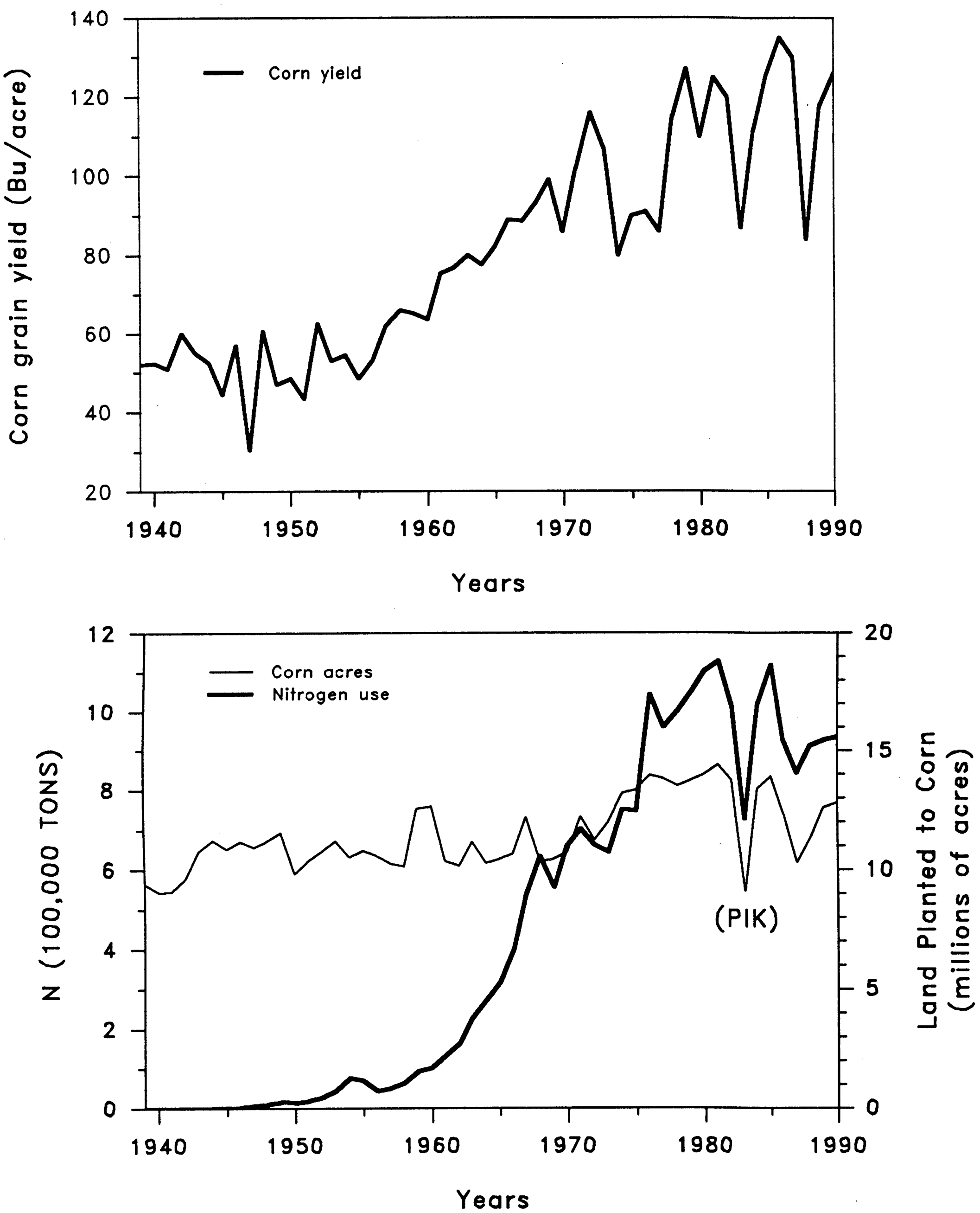


Figure 4. Total fertilizer-nitrogen use in Iowa (as N), land planted to corn, and state average corn-grain yields (upper graph), 1939 to 1990. Data from Iowa Agricultural Statistics and TVA (e.g., Berry and Hargett, 1991).

Historical Trends; Total N Use

The Iowa Department of Agriculture and Land Stewardship (IDALS) and the Tennessee Valley Authority (TVA), in coordination with IDALS, track and report total annual fertilizer sales. These figures provide an independent view of nitrogen use in Iowa.

Use of fertilizer nitrogen in Iowa has changed dramatically over time, increasing 10-fold between about 1960 and the late-1970's (Fig. 4). Since 1985, however, total fertilizer-N use has declined. For this analysis, total fertilizer-N (FN) use is a rather crude indicator, because it is a function of FN used on all crops, the rate of FN applied per crop acre, and the number of acres in production. In Iowa the majority of FN is used on corn. While corn comprises about 50% of total harvested crop acres, corn production uses about 85% of the total FN. Changes in total FN use largely parallel changes in crop acreage, particularly total corn acreage. For example, in 1983, the PIK program reduced corn acreage by about 30%; and, in 1987, with a large annual set-aside program and the first stages of CRP signups, corn acreage declined in Iowa by about one million acres. Both periods show a parallel decline in the amount of total FN used (Fig. 4).

Figure 4 also shows the state average corn-grain yields and illustrates several points. First, the benefits of fertilizer-N use in Iowa's corn-soybean farming systems are clear: over time, increases in crop yield were concurrent with increases in N use, with relatively small increases in total corn acreage. Perhaps the greatest portion of the increased yields are related to improved crop hybrids (Duvick, 1987), but there is little question that the production benefits of fertilizer-N played a role.

The increase in total-N use with proportionately small increases in acreage (Fig. 4) means that there was a substantial increase in the rate of FN applied per acre after about 1950. This presents an interesting model because the various collaborating agencies and institutions, in this period, were promoting the use of fertilizer-N and trying to persuade Iowa producers of its production benefits. Producers had to be convinced that it was economical and more productive to spend money on these amendments.

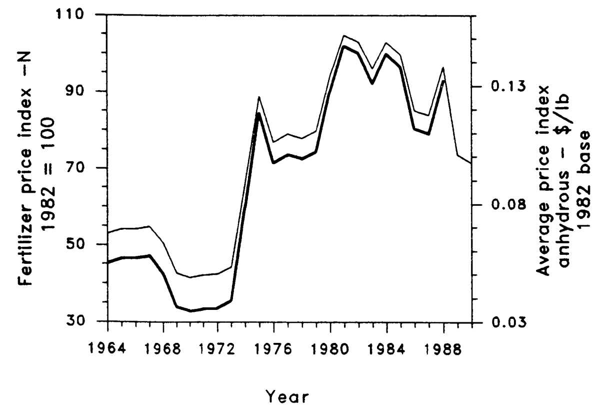


Figure 5. Fertilizer price index and average price paid for anhydrous ammonia fertilizer, 1964 - 1990; standardized to 1982 base. (Data from Vroomen, 1989, and various issues "Agricultural Prices," USDA, Nat'l. Agric. Stats. Serv.).

Other Influences on Fertilizer Use

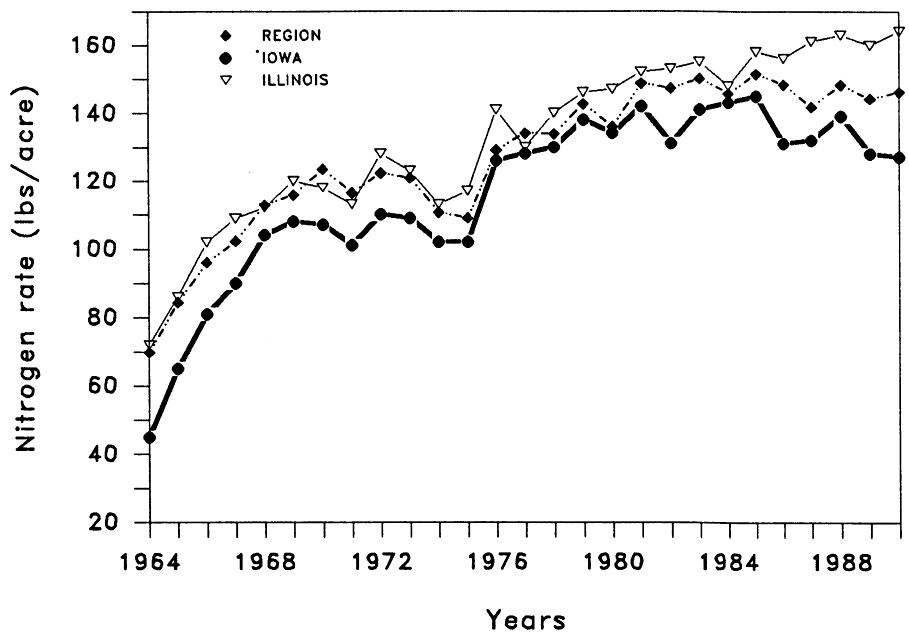
Many diverse factors influence crop acreage and overall fertilizer-use trends: government land and commodities programs; the fertilizer price structure, foreign demand for fertilizer; energy costs; and the general status of the agricultural economy. Even nationally, corn production has a great affect on FN use trends, accounting for 40-45% of total usage (e.g., Vroomen, 1989). The slowdown in the increase of fertilizer use in the late 1960's and early 1970's accompanied a time of grain surpluses and consequent land diversion programs (see Crosswhite and Sandretto, 1991). As the export market rapidly expanded in the early 1970's, stocks declined, grain prices rose, more land went into production, and fertilizer use increased sharply in 1975. The steep rise in use wasn't maintained; fertilizer use dropped, then rose slightly and generally stabilized, as the price of fertilizer more than doubled because of price deregulation and the "energy crisis" of the 1970's (compare Fig. 4 and Fig. 5). There was no discernable impact on N use during the agricultural economic crisis of the 1980's. Since 1985, the price of fertilizer has generally been declining (Fig. 5) in response to a national reduction in crop acreage. With falling prices some increase in the per-acre application rate might be expected, however.

Table 8. Total fertilizer used in Iowa, 1985-1990; averaged rate of fertilizer-N (FN) per crop acre; the reduction, or difference from 1985 use, and the dollar and energy value of the reduction.

Year	Total crop acres harvested	Total corn acres	Total fertilizer material used (raw material)	Total N fertilizer used	Reduction from 1985 FN use	Reduction from 1985 FN use	Value of reduction from 1985 FN use
	1,000s acres		tons	as tons-N	tons-N	1,000s lbs-N	dollars
1985	25,030	13,900	3,728,956	1,128,497			
1986	23,796	12,300	3,122,069	933,510	194,987	389,974	$58,496,100
1987	20,956	10,300	2,899,277	852,534	275,963	551,926	$82,788,900
1988	23,092	11,300	3,145,918	920,833	207,664	415,328	$62,299,200
1989	24,097	12,600	3,023,707	933,631	194,866	389,732	$58,459,800
1990	23,276	12,800	3,187,906	947,416	181,081	362,162	$54,324,300
				Total:	1,054,561	2,109,122	$316,368,300

Year	Total crop acres harvested	Average FN used per crop acre	Reduction in FN used relative to 1985 rate	Value of reduction from 1985 FN rate	Energy value of FN reduction in equivalent gallons of diesel fuel
	1,000s acres	lbs-N/acre	1,000s lbs-N	dollars	1,000s gal-dsl-eq
1985	25,030	90			
1986	23,796	78	285,552	$42,832,800	71,388
1987	20,956	81	188,604	$28,290,600	47,151
1988	23,092	80	230,920	$34,638,000	57,730
1989	24,097	77	313,261	$46,989,150	78,315
1990	23,276	81	209,484	$31,422,600	52,371
		Total:	1,227,821	$184,173,150	306,955

Land areas from Iowa Agricultural Statistics and National Agricultural Statistics Service.
Total fertilizer-N tonnage from Berry and Hargett, 1991, TVA; Fertilizer Summary Data, 1990; and Iowa Dept. Agric. and Land Stewardship, Distribution of Fertilizer reports.
Value of fertilizer calculated at $0.15/pound-N.
Average FN used per crop acrea, calculated from: total FN used in lbs / total crop (harvested) acres.
Reduction in FN used relative to 1985 FN rate, calculated from: (total crop acres* 1985 FN rate [90 lbs-N/ac]) - (total crop acres* actual FN rate for year).
Energy value estimated at 4lbs-N = 1 gal diesel fuel (as equivalent btus).



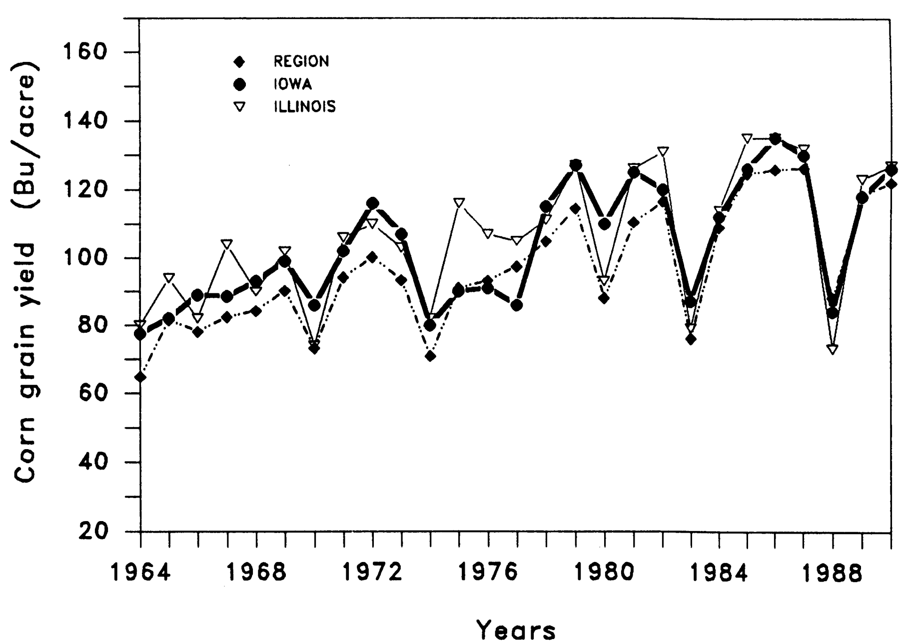


Figure 6. Average fertilizer-nitrogen rates applied to corn and average corn-grain yields, 1964-1990, for Iowa, Illinois, and the major cornbelt region (excluding Iowa; includes Illinois, Indiana, Missouri, Ohio, and Nebraska). From USDA, Economic Research Service and National Agricultural Statistics Service reports (Vroomen, 1989; various issues "Agricultural Resources; Inputs, Situation and Outlook Report").

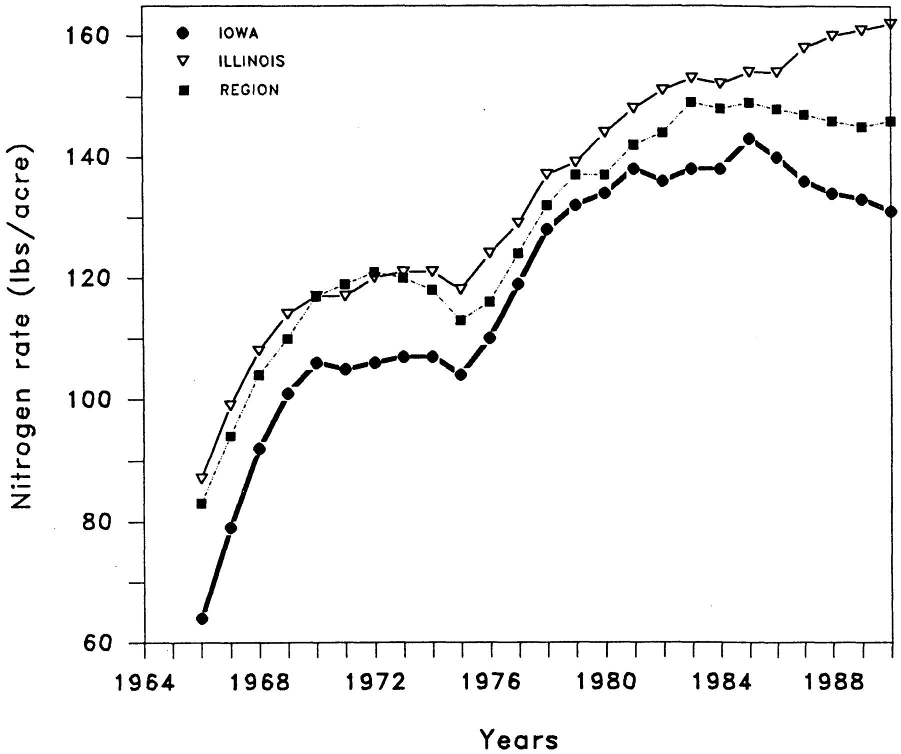


Figure 7. Three-year running mean (moving average) of annual average fertilizer-nitrogen rates applied to corn; from data in Fig. 6.

Total FN use has declined in Iowa, decreasing by over 180,000 tons in 1989 and in 1990, compared to 1985 (Fig. 4). Using a moderate price estimate, Iowa farmers spent about $60 million dollars less per year on fertilizer-N in 1986-1990 than in 1985 (Table 8). In 1985 there were over one million more acres of corn than in 1990, however. Comparing 1985 and 1990: total corn acreage declined about 8%; but the decline in total fertilizer-N was double, about 16%.

Per Acre Fertilizer Nitrogen Rate

It is difficult to evaluate the significance of changes in total FN use. To account for the differences in total acres, the changes in the annual per acre rate of FN used can be evaluated. Some rate changes are implicit in the total FN data. For example, in 1986 and 1989 total Iowa crop acreage was similar, with about 300,000 more acres corn in 1989 (Table 8), yet total FN use was nearly 28 million pounds lower in 1989.

Table 8 shows the calculated average FN, in lbs-N/acre, for 1985-1990. The fertilizer sales records only provide data on total usage, and hence, these rates project total FN used, divided by the total acreage of all crops. The projections show that 1989-1990 FN use in Iowa was reduced by 200 to 300 million pounds, relative to 1985 rates, with a cost reduction of $31-47 million.

While these projections are real savings, their meaning is still difficult to assess, particularly in relation to Iowa's programs. These average FN rates have little basis in reality, because they include the entire spectrum of crops harvested in Iowa. Some of the yearly differences may simply be related to differences in the mix of crops included. From 1989 to 1990, total crop acreage declined, but corn acreage increased, for example. The emphasis of Iowa's demonstration and education programs has been on nitrogen management related to corn, and data particular to corn production should provide the most direct evaluation.

Nitrogen Rates For Corn Production

FN use rates on corn are compiled by state

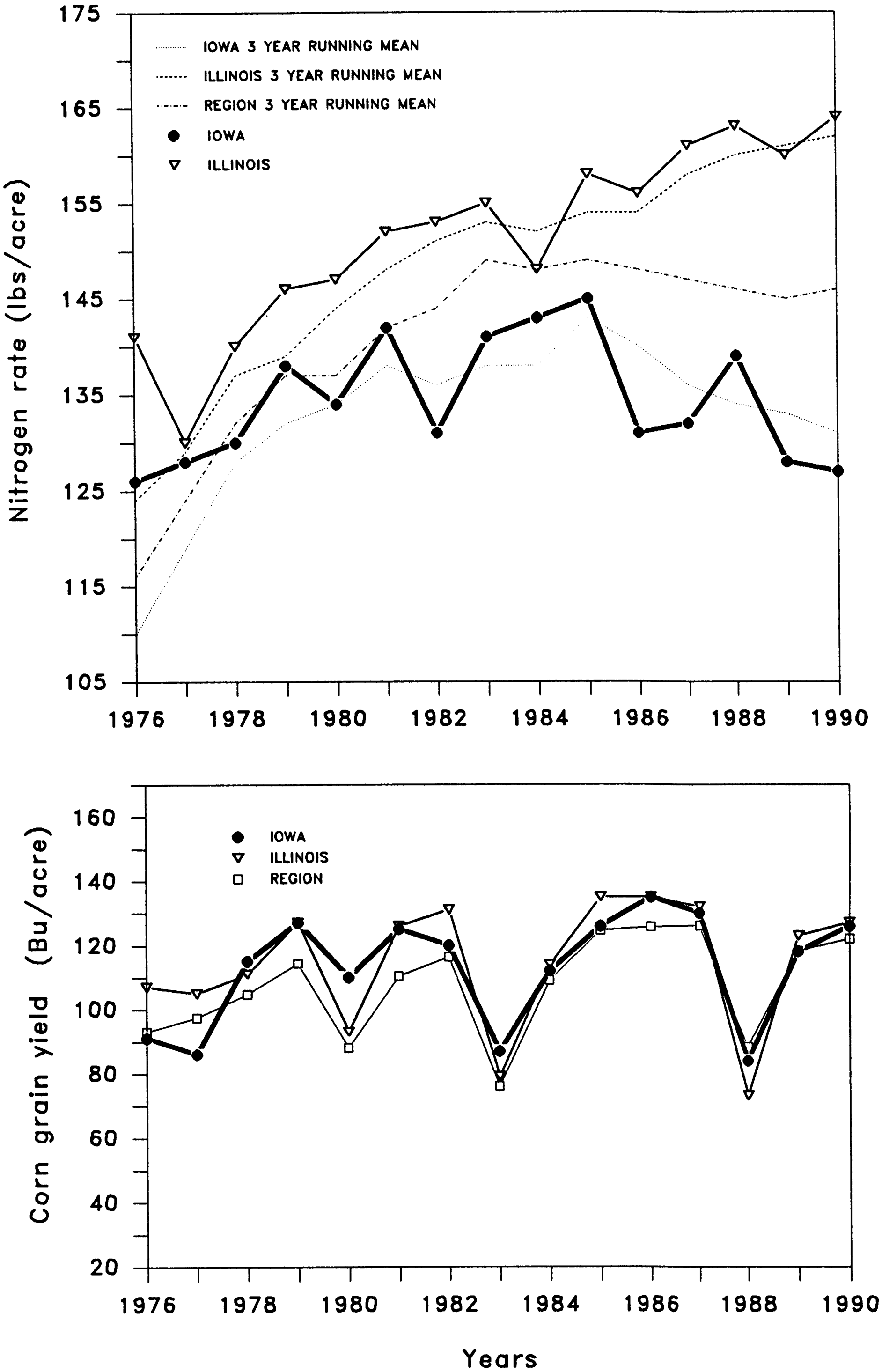


Figure 8. Average fertilizer-nitrogen rates applied to corn and average corn-grain yields, 1976-1990, for Iowa, Illinois, and the cornbelt region (as in Fig. 6). Plot shows annual values for Iowa and Illinois and 3-year running mean for Iowa, Illinois, and the region.

by the USDA National Agricultural Statistics Service, Economic Research Service (e.g., Skow and Holden, 1990; Vroomen, 1989). Figure 6, summarizes the annual-average fertilizer-N rates applied to corn and corn yields for Iowa, Illinois, and the general corn-belt region, from 1964 to 1990. The historic trend in FN rates on corn in Iowa is the major factor defining the record of total-N use (Fig. 4). The use trends noted in Figure 4, from the mid-1960's to the early 1980's, are also apparent in the changing rates shown in Figure 6.

To understand what is happening in Iowa, the regional data are needed as a benchmark for comparison. As noted, there are many external factors that influence fertilizer use and these factors affect changes throughout the cornbelt and the agricultural sector. Iowa and Illinois rank one and two in national corn acreage and production, and the comparison with the cornbelt region and Illinois provide perspective for evaluating changes that are common to major corn producing states versus those that may be unique to Iowa. Unique changes in Iowa can be used as a measure of effectiveness of Iowa's statewide educational programs.

The historic pattern of increasing FN use in Iowa is a simple parallel record of the trends in Illinois and the cornbelt. While Iowa average FN rates are generally lower than elsewhere in the region, some rate differences would be expected among states because of differences in soils, climate, and farm system composition. Throughout this time Iowa has ranked at the top of average yields, except in drought years that affected Iowa more than states to the east (Fig. 6). In a particular year, Iowa and regional trends may be divergent. A simple 3-year running average filters out the annual statistical variations and makes the parallel, regional evolution in FN use quite clear (Fig. 7). At this scale Iowa's divergence in the late 1980's becomes more apparent. After 1975, the per acre rate of increase in fertilizer use slowed considerably. Figures 8 and 9 provide two views of the 1976 to 1990 period. After 1985 the average FN rates exhibit divergent trends. From 1985 to 1990, rates in the corn-belt remained steady, or increased slightly, about 4%, possibly in response to declining fertilizer prices. At this point Iowa departs from the parallel regional trends of the prior 20 years. Iowa rates declined

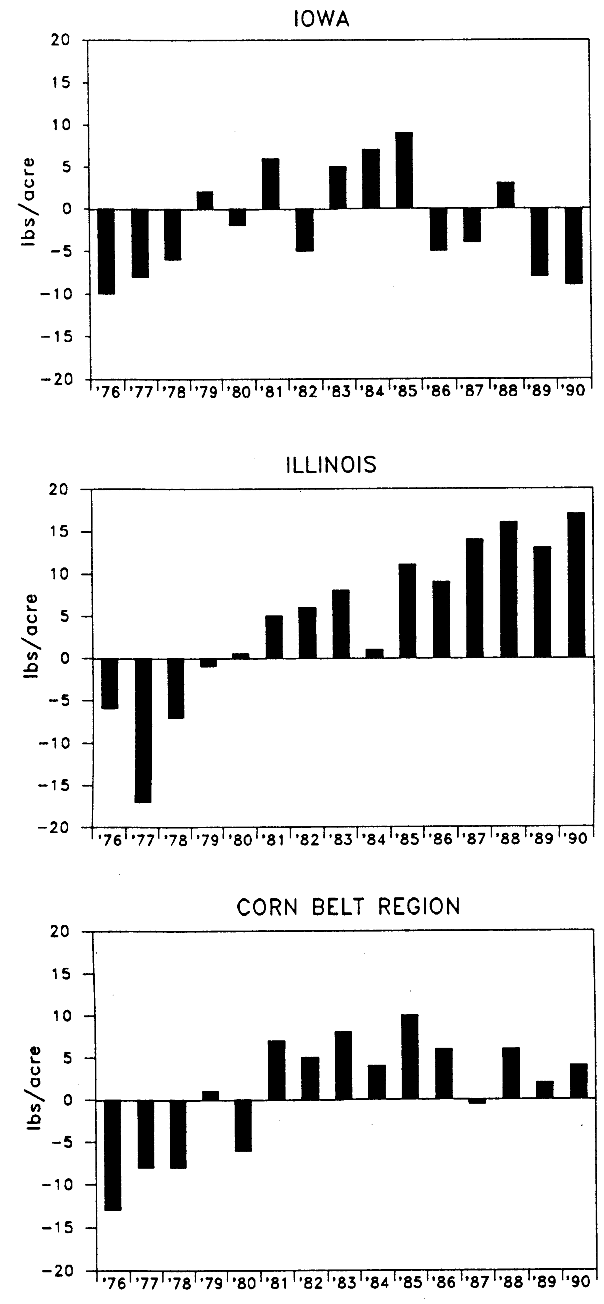


Figure 9. Departure (+ or -) of annual average fertilizer-nitrogen rates applied to corn from the 10-year, 1976 to 1985 average rate for Iowa, Illinois, and the major cornbelt region (as in Figs. 6 and 8). 1976-1985 average rate equals the zero line; the 10-year averages are: Iowa, 136 lbs-N/acre; Illinois, 147 lbs-N/acre; and Corn-Belt region, 142 lbs-N/acre.

Table 9. Reduction in fertilizer N applied to corn in Iowa, related cost savings for Iowa farmers, and related energy savings: 1986 - 1990.

Year	Total corn acres	Average Iowa fertilizer-N rate for corn	Total FN used on corn	Reduction in FN used relative to 1985 FN RATE	Value of reduction from 1985 FN rate	Energy value of FN reduction in equivalent gallons of diesel fuel
	1,000s acres	lbs-N/ac	1,000s lbs-N	1,000s lbs-N	dollars	1,000s gal-dsl-eq
1985	13,900	145	1,995,345			
1986	12,300	131	1,579,074	168,756	$25,313,400	42,189
1987	10,300	132	1,332,408	131,222	$19,683,300	32,806
1988	11,300	139	1,554,993	67,122	$10,068,300	16,781
1989	12,600	128	1,596,672	212,058	$31,808,700	53,015
1990	12,800	127	1,560,576	221,184	$33,177,600	55,296
		Total:	9,619,068	800,342	$120,051,300	200,086

Land in corn from Iowa Agricultural Statistics and national Agricultural Statistics Service.
Iowa fertilizer-N rate on corn from National Agricultural Statistics Service, Economic Research Service (e.g., Vroomen, 1989; various issues Agricultural Resources, USDA-ERS).
Total fertilizer-N used on corn calculated from: land in corn * fertilizer-N rate* percentage of corn acres fertilized.
Reduction in fertilizer-N applied calculated from: land in corn* 1985 FN rate (145 lbs-N/ac) - land in corn* actual FN rate for year.
Value of fertilizer calculated at $0.15/pound-N.

approximately 12%, from 145 lbs-N/acre in 1985 to an average of 127 lbs-N/acre in 1990; yet there are no relative reductions in crop yields (Fig. 8).

This trend appears unique to Iowa, and does not appear related to external factors affecting the corn producing region as a whole. These independent data, like those from various Iowa projects, indicate that Iowa producers are moving toward more prudent N management in response to Iowa program efforts.

Cost Savings to Iowa Farmers

While the changes in the state average FN rate may appear small, the reductions and savings are substantial when prorated to Iowa's annual 11-13 million acres of corn. Table 9 summarizes the changes in Iowa, the economic and energy value of these savings to Iowa farmers relative to 1985 usage. Iowa farmers have reduced total N loading into the environment by over 800 million pounds between 1986 and 1990, and reduced their costs by an estimated $120 million. Further, this is an energy savings equivalent to over 200 million gallons of diesel fuel.

Another standard method to estimate such savings is by extension of these time-series trends. Projections of the pre-1986 trends indicate that if Iowa rates had continued to parallel regional trends, 1990 rates would have been greater than 1985 (Figs. 7 and 8). Compared to this projection rates in 1989 and 1990 declined about 15%; a reduction of approximately 270 million pounds of nitrogen per year. This indicates a savings to Iowa farmers of over $40,000,000 per year (the estimates provide a range of $80 to $89 million for these two years).

Summary: Nitrogen Reductions and Cost Savings

Total fertilizer sales' records and standard national agricultural statistics afford an independent assessment of Iowa's programs to improve nitrogen management. These data indicate that average fertilizer nitrogen use in Iowa has departed from a 20-year history of parallel regional use trends. Iowa farmers reduced FN rates on corn by 12-15% since 1985, despite falling fertilizer prices, which might be expected to increase rates. There is no indication of any decline in corn yields. These

Table 10. Summary of average yearly nitrogen use reductions, cost savings to Iowa farmers, and related energy savings for 1989 and 1990.

	Reduction in fertilizer-N used by Iowa farmers		Savings to Iowa farmers from reductions in FN use	Energy value of nitrogen reductions
	Relative to 1985 rates	Relative to regional trends	Value range at $0.15/lb-N	In equivalent gallons of diesel fuel
Projected from:	*pounds-N/yr*		*dollars/yr*	*gals-diesel/yr*
Total FN use all crops;	**260,000,000**	**310,000,000**	**$39 - $47 Million**	**65 - 78 Million**
FN use on corn;	**217,000,000**	**270,000,000**	**$33 - $40 Million**	**54 - 68 Million**

With conservative projections for P & K reductions, pesticide use reductions, and tillage improvements overall savings equal:

$50 million / year

independent data reinforce surveys indicating that Iowa's agricultural-environmental initiatives are affecting farm management changes statewide, not just at the project scale.

These improvements in nitrogen management result in substantial economic and environmental benefits. For 1989 and 1990 the total savings from reduced nitrogen use alone equates to an $80,000,000 savings to Iowa farmers (Table 10). Surveys also indicate that farmers are making efficient reductions in other areas as well, including, reductions in P and K fertilizers, and pesticide use. Preliminary assessments of these reductions project a total savings of $100,000,000 for these two years.

The nitrogen use data can provide an important record for tracking continuing progress, as well. However, there will be year-to-year variability, and undoubtedly some years will show increases. As indicated in Figure 7, 3-year moving averages appear to provide an appropriate framework for reviewing these trends.

COST-BENEFITS OF IOWA'S AG-ENERGY-ENVIRONMENTAL INITIATIVES

The state of Iowa and its cooperating federal agencies have put considerable resources into these programs. The most significant funding has been appropriated by the state from oil-overcharge funds; this has totalled about $9.6 million between 1987 and 1990. From 1981 to 1990, state and federal special funding to these projects was about $11 million, including the oil-overcharge funding. At their peak, in 1988-89, between $2.5 to $3.6 million/year was allocated to these projects. These programs, conservatively, are now returning over 10-fold on these investments; with savings in 1989 and 1990 of over $40 to $50 million per year! However, significant oil-overcharge funding has ended with fiscal-year 1992, although some activities will carry over into 1993.

WATER QUALITY IMPLICATIONS

These documented reductions in nitrogen use should, with time, result in reductions in nitrate loading to Iowa's water resources. Various research has shown that the nitrate losses into shallow groundwater are proportional to nitrogen loading of the soil, in typical row-crop production (e.g., Baker and Johnson, 1981; Hallberg, 1987, 1989; Kanwar et al., 1983; Olsen et al., 1970). As summarized by Baker and Laflen (1983), NO_3-N losses with subsurface drainage, from controlled plot studies, related in nearly linear fashion to N application rates exceeding about 50 lbs-N/acre. Hence, the reductions underway in Iowa should provide water-quality benefits. However, the nitrogen cycle is very complex and there are many buffers and time-lags in the hydrologic system. It must be made clear that while the Iowa N-management results indicate that systematic improvements are underway, such incremental changes are NOT likely to be apparent in water-quality data in the short term.

WHAT'S THE BAD NEWS?

The data reviewed here are not all good news! While the various project and statewide results are very encouraging these same data also reveal much more needs to be done.

For example, distributions of N-rates from the statewide surveys show considerable room for improvement simply by crediting crop rotations appropriately. As discussed with Table 1, there is little economic benefit to applying more than a starter fertilizer to first-year corn following a good multi-year stand of alfalfa. Yet, as shown on Figure 1 for the Big Spring basin, a considerable number of producers still apply high rates of nitrogen. Statewide (Fig. 3), about 45% of farmers (with alfalfa) still apply over 100 lbs-N/acre to first-year corn after alfalfa; and the IFMDP and SWRL surveys indicate 15-30% apply more than 140 lbs-N/acre to corn following soybeans. While this is warranted in some cases there are clearly opportunities here for economically reducing these rates.

From IFMDP survey data, using the standard estimate of 1.2 lbs-N needed per bushel of corn harvested, Padgitt (1989) summarizes that about 25% of farmers are using fertilizer rates at least 25 lbs-N/acre above this guide for the yields they actually report. These rates are in addition to whatever N-credits might be available. The soil nitrate test data also suggest significant room for improvement (Table 5). During 1990-91, after relatively wet winter and spring weather, data from 32% to 39% of samples tested suggested *no* additional N was needed for optimal yields, and about 60-70% of samples indicated some reduction in nitrogen applications was feasible.

The three statewide surveys also point out that only 50% of farmers take any N credit for the manure they apply to row crops. Better manure management is a must for improving nitrogen efficiency and reducing overall N loading. The IFMDP survey indicated no association of fertilizer-N rates for corn with the nutrients available from manure on the farms (Padgitt, 1989). Estimates derived from the survey livestock inventories indicate that 20% of farmers potentially could supply about 50% of their N for corn from their livestock enterprises, and 5-10% might supply all their N with improved management.

The voluntary nature of the Iowa demonstration, implementation, and marketing programs will not influence every producer to change. However, significant accomplishments have occurred and considerable positive momentum has been established. For continuing progress some continuation of these cost-effective efforts must be extended and further refined for targeted marketing.

This points out another segment of the "bad news." These programs primarily have been funded primarily through special appropriations of oil overcharge funds because of the energy significance in reducing fertilizer and chemical use (e.g., Tables 9 and 10). Significant oil overcharge funding has ended with fiscal-year 1992. Most of this funding was allocated through the Iowa Groundwater Protection Act of 1987. For other environmental efforts, such as solid waste or underground storage tank management programs, the IGWPA established continued sources of funding. However, the large agricultural demonstration programs were not provided with any sustained source of funding. Hence, Iowa may lose this important momentum. The lessons learned from these projects will allow targeted marketing to further progress, at lesser funding levels than in the past, but currently there is no source of revenue for continuation. As demonstrated, these programs have provided more than a ten-fold return, reducing the input costs of Iowa farmers by over $100 million, as well as reducing environmental loading of nitrogen.

The "good news" of these significant cost-savings to Iowa farmers also have a down-side. Reductions in fertilizer purchases reduce income to local agri-businesses. In reducing costs for Iowa farmers, more of this revenue is likely to remain in Iowa, however. Also, projects such as the ICM initiative, the Field Extension Education Laboratory, and the soil-nitrate test cooperative project with dealers are approaches to encourage agri-business to develop services that can replace product sales while implementing greater overall efficiency in Iowa crop production.

PROGNOSIS AND SUMMARY

Change in agriculture is a sociological as well as a technological process, and as such voluntary change proceeds slowly. Even with the most aggressive of education and research programs, even when changes are economically beneficial, some producers are very slow to change -- there will be a "tail" of high rate N users on the distributions shown in Figures 1 and 3 for some time to come.

As earlier noted, Figure 4 presents an interesting model, depicting the rate of adoption of the use of fertilizer-N. It took 10-15 years for farmers to adopt the use of fertilizer-N, even with the very clear and consistent message that this would significantly increase production and profitability. In Iowa today there remain some farm operators who do not use fertilizer-N (e.g., Fig. 3). Hence, as we attempt to refine nitrogen management, reducing overall N-loading for environmental and economic efficiency, it will be difficult to expect a more rapid rate of change. Similarly, it took these many years of incremental increases in nitrogen loading, and many years of observation and monitoring, before the impacts of nitrate on Iowa's water resources were wholly apparent. It will take continued positive changes in N management and equally many years for water-quality improvements to be apparent beyond the local scale, as well.

Iowa's large-scale agricultural demonstration and education programs, coupled with their targeted marketing approach, are showing significant results. Independent statewide fertilizer-nitrogen use data indicate that Iowa producers have reduced nitrogen use on corn since 1985, diverging from regional trends, and in spite of declining fertilizer prices. Since 1986, these reductions total over 800 million pounds of N with no decline in yields. Cost reductions for Iowa producers of over $100 million, and an equivalent energy savings of over 200 million gallons of diesel fuel can be claimed.

As a conservative estimate of the benefits of these programs, the savings for 1989 and 1990 can be used (Table 10). For these years, nitrogen use was reduced relative to 1985 rates and regional trends by some 440 to 540 million pounds, with a cost savings of $65 to $80 million. Conservative estimates for other input reductions and efficiencies promoted by Iowa's programs indicate a savings of more than $100 million for these two years. The programs have provided a ten-fold "payback" on the $9.6 million oil-overcharge funds, and other state and federal funds, allocated to the programs, based on the 1989-1990 savings alone. However, the special funding provided by the state of Iowa for these programs is now ending. Hence, Iowa's efforts will likely lose momentum without further support.

Past estimates suggesting that nitrogen use in Iowa could be reduced by $100 million per year clearly seem feasible. Based on state surveys, considerable refinements are feasible through use of realistic yield goals and appropriate crediting for rotation and manure benefits. Further development of soil test methods are also needed. For major reductions to take place, however, continued program support will be required, as will be major efforts by Iowa agri-business to provide services to farmers that promote efficient nitrogen use.

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While the collaboration of agencies and institutions is requisite to the success of these projects the most important collaborators are the Iowa farmers and families that have participated in the demonstration programs. They are, all at once, the focus of these projects, the key workers in many of the demonstrations, and hopefully the principal benefactors. They have the gratitude of all the agencies and institutions involved. The level of cooperation and enthusiasm provided by local citizens is the best continuing tribute that these projects can receive.

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