Policy Implications on the Reduction of Nitrogen Fertilizer Use on Non-Irrigated Corn-Winter Wheat Production in North Alabama

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Agriculture has been identified for sometime as a major contributor of nonpoint-source (NPS) pollution of U.S. surface and groundwater (McIntosh and Williams, 1992). Nonpoint-sources, especially croplands, are the largest source of nutrients in U.S. waterways. One study revealed that nonpoint sources are responsible for 82 percent of total nitrogen (N) discharges and 84 percent of phosphorus discharges. Field crops alone are responsible for 39 percent of all nitrogen loads and 30 percent of all phosphorus loads (Carpenter et al., 1998).

Over the years, crop yields in the U.S. have increased significantly, due largely to an increase use in commercial fertilizer. Faeth (2000) reveals that between 1965 and the mid-1990s, N fertilizer use by farmers has increased significantly by about 160 percent from 4.6 million tons to 12 million tons. Alabama farmers every year purchase and apply 115,000 tons of nitrogen, 60,000 tons of phosphate and 73,000 tons of potash in the form of commercial fertilizer (LRPOW for all Alabama Extension Programs, 1997). Total inputs in nitrogen for crop production are not expected to decrease within the future.

Increase fertilizer use, especially nitrogen, has led to major environmental concerns and has come under close scrutiny by environmental stakeholders. Nitrogen management has become a required skill due to the complex behavior of nitrogen. Therefore, farmers have to understand nitrogen so they can manage it for maximum profit and minimum environmental impact.

Today, many U.S. waterways remain partially impaired and the quality of our drinking water continues to deteriorate. Government policies to regulate the use of nitrogen are designed to reduce or eliminate N contamination of surface and groundwater. Schaub (p.25) indicates that the reduction or elimination of chemical use in agriculture "is an issue that has been raised and is not likely to go away."

The U.S. government, over the years, has spent billions on water-quality legislation and programs. The Clean Water Act (CWA) of 1972 was enacted to protect water quality by controlling the discharge of pollution from industrial, municipal and other point sources.

However, the CWA was later amended in 1977 and again in 1987 to include nonpoint pollution. The CWA when it was first enacted in 1972 had the federal government agreeing to pay up to 75 percent (later reduced to 55 percent) of the construction and design cost for municipal treatment plants. In addition, between 1974 and 1994, approximately $96 billion was spent through the federal construction grants program for municipal construction and upgrades for point source control with another $117 billion added by local governments (AMSA/WEF, 1999).

Despite the successes of government regulations, the job of achieving clean water in the U.S. is far from over. According to Faeth (p.1), "roughly 40 percent of the nation's surface waters remain at least partially impaired and surveys suggest there has been little improvement recently." In the U.S. there are 3,456 waterways that are considered as "impaired" by nutrients and another 141 impaired by algal blooms caused by excess nutrients (USEPA, 1999).

In the state of Alabama there are approximately 650,000 acres in mainstream reservoirs, lakes, ponds and streams. Of all the fresh water in the 48 contiguous states in the U.S., 8 percent originates in or flows through Alabama (LRPOW for all Alabama Extension Programs, 1997). These water sources are threatened by nitrate contamination, which has become a major problem in many rural areas.

Although the state of Alabama has no nitrogen regulations in place, the need for such regulations will be required in the near future, if not sooner. One major reason is the Poultry production geographically concentrated in the Sand Mountain region in the north. Alabama ranks second in the U.S. in poultry production. Poultry litter is being applied as fertilizer to croplands in huge amounts. A 1991 study of poultry litter used as fertilizer within North Alabama revealed that nitrogen had been applied in excess of crop needs and had leached underground to a depth at or near the bedrock resulting in the potential for groundwater contamination (Kingen, et al., 1994).

Nonpoint-source pollution from Alabama agriculture poses a potential risk to the environment. Whether that risk is generated from poultry litter or manufactured nutrients' (fertilizers) application on croplands, their effects on surface and groundwater contamination should be examined. Therefore, any policy geared towards their reduced application, should consider the economic consequences in addition to the environmental.

The objectives of this study are to estimate the effects on nitrogen leaching of possible mandated reductions in nitrogen use and to evaluate the impact of nitrogen reduction on crop yield and profitability of corn-winter wheat small farms in North Alabama.

The analysis was applied to a representative North Alabama dry-land corn-winter wheat small farm located in Madison County. Corn and winter wheat production in Madison county rank second and first in the State respectively. Given the high dependence of corn and a lesser extent of winter wheat on nitrogen for good yields and the economic value of both crops to the Madison economy, the environmental and economic impacts of a nitrogen control policy to reduce nitrate leaching in field crop production, are important. The results of this analysis will make good discussions on the impact of nitrogen control policies and will be of interest to government, farmers, nitrogen producers and environmental stakeholders.

MODEL DESCRIPTION

The Great Plains Framework for Agricultural Resource Management (GPFARM) decision support system (DSS) is used to analyze the environmental and economic impacts of reductions in nitrogen use on small farms in North Alabama. GPFARM was developed by Great Plains System Research (GPSR), a division of the United States Department of Agriculture (USDA), Agricultural Research Service (ARS) and Northern Plains Area (NPA). The general purpose of the model is to provide an operational framework for a whole farm/ranch decision support system across the Great Plains including site-specific management, socio-economic analysis and environmental impacts. The flexibility of GPFARM allows users to input soil and climate information relative to their states.

GPFARM decision support system assesses production economics and environment impacts of policy changes before they are implemented. The economics module is based on Budget Planner, which was developed in 1985 by Dr. Dana Hoag of the Department of Agricultural and Resource Economics at Colorado State University. The program has been modified by Dr. Hoag, Dr. James Ascough and Bruce Vandenberg of the ARS GPFARM team. The economics module helps the farmer estimate his/her costs and returns per acre for each enterprise. This basic information is developed into several types of results that can help with common management decisions (GPFARM Help System).

The science modules of GPFARM simulate biological, chemical and physical processes on a management unit, a land unit that has one type of management or system management. There are eleven process level models which include crop growth, cropland water erosion, depth weight, forage and range livestock, nutrient and residue management, potential evapotranspiration, soil properties, rangeland water erosion, water balance and chemical transport and weeds and wind erosion (GPFARM Help System).

DATA AND DATA ANALYSIS

Annual data for the period 1991 -2000 is used in GPFARM simulation. Farm enterprise budgeting procedures are used to determine farm profitability in terms of net farm income. Enterprise budgets are from Alabama Cooperative Extension System. Management practices data are from County Extension agents, soil data from the Natural Resources Conservation Service (NRCS) and climate data from Alabama Office of State Climatology and Climate Generator (Cligen). Cligen is a stochastic weather generator that produces daily time series estimates of precipitation, temperature, dew point, wind, and solar radiation for a single geographic point, based on average monthly measurements for the period of climatic record, like means, standard deviations, and skewness. The estimates for each parameter are generated independently of the others (http://horizon.nserl.purdue.edu.Clign/).

The study considers an expected- profit- maximizing farmer who must decide to utilize his or her land efficiently given the resources and commodity prices available. Alternately, the total acreage available to the farmer is fixed, thus the farmer's decision must take into consideration the optimal allocation of the land and other inputs used to maximize expected profits. The analysis further examines a farmer who has

400 acres of crop land. Corn and winter-wheat are produced using a set of per acre inputs given certain uncontrollable elements such as weather. Therefore, if the farmer chooses a non-optimal level of inputs, crop yield will suffer negatively affecting profits.

The study analysis further investigates the impact of different reductions - 5, 10, 15 and 20 percents in nitrogen fertilizer use on a 400-acre corn-winter wheat farm under dry-land conditions. Nitrogen applications vary according to the crop specification. The small farmer applies the recommended N rate of 120 pound per acre to his corn, 80 pounds (incorporated dribbled) applied at planting and 40 pounds (surface/side dressed) when the corn is knee high. For winter wheat, a recommended rate of 80 pounds per acre, 20 pounds (incorporated dribbled) applied at planting and 60 pounds (surface/broadcast) in February. Ammonium nitrate, the most common type of nitrogen used, is priced at $.13/pounds.

Corn and winter-wheat prices for 1991- 2000 are averaged to approximate expected price. Crop prices are the averaged marketing prices received by farmers, 1991 – 2000 provided by Alabama Agricultural Statistic Service's *Prices Review 2000*. Marketing year prices are weighted prices for commodities sold during the marketing year and represent prices received by farmers at the point of first sale. The average prices for corn and winter-wheat are $2.64 and $3.08 per bushels respectively.

Given these conditions, the study analysis focuses on the policy that restricts the amount of N fertilizer per acre applied. The small farmer is faced with the uncertainty of the effects such reductions or restrictions on nitrogen use will have on crop yield and profitability. In terms of the environment, it is expected that any reduction in nitrogen use will have a positive effect; the end result is reduced nitrogen leaching.

Data analysis is evaluated on the premise that management practices and input variables are held constant, except for N fertilizer application which varies according to policy scenarios. Bearing this in mind, the level of nitrogen leaching post and pre policy is analyzed to determine the effectiveness of the policy. In addition, a comparison analysis of yields/profits of the crops post and pre nitrogen control policy is evaluated. This allows for a dollar value to be placed on the nitrogen policy; therefore, facilitating an economic feasibility assessment of adopting the policy by farmers.

RESULTS AND DISCUSSION

Historical and generated weather data for Huntsville from 1991 – 2000 were used to simulate yields and nitrate leaching. Huntsville is the only Local Climatologically Data (LCD) for North Alabama. Soil type, cropland slope and management operations for the hypothetical farm were entered into GPFARM to obtain simulated yields as well as the expected nitrate leaching.

GPFARM model settings were calibrated based on 1991 -2000 corn data from National Agriculture Statistics Service (NASS) for Madison County. GPFARM model was run under similar weather, soil and management conditions used in North Alabama. Where necessary, further adjustments in GPFARM parameters were made until the average simulated corn and winter wheat yields were close to the average actual yield. Due to a lack of data, it was not possible to evaluate GPFARM estimates for N leaching.

Effects of N Control Policy on N Leaching

The baseline scenario is based on Alabama Cooperative Extension nitrogen application recommendations of 120 pounds of nitrogen per acre and 80 pounds per acre for corn and winter wheat production respectively. In the second, third and fourth scenarios, N applications for corn are reduced 5, 10, 15 and 20 percents respectively. Ammonium nitrate is the most common type of nitrogen fertilizer used and makes up about 33 percent nitrogen. One hundred and twenty pounds of nitrogen applied to corn is equivalent to 363 pounds of ammonium nitrate, while for winter wheat, 80 pounds of nitrogen is equivalent to 241 pounds of ammonium nitrate. A total of 10 years are considered in this study. The effects of the scenarios on nitrate leaching are evaluated to determine the level of leaching expected under each scenario. They will provide valuable information regarding the impact a possible mandated policy to reduce nitrogen use in field crop production in order to minimize nitrate leaching from agriculture.

Some factors affecting nitrogen leaching are the application rate and type of nitrogen, land cover, soil type and weather conditions. The soils in Madison County fall within the soil area of Limestone Valleys and Uplands. Soils in this area are mainly red clayey with silt loam surface textures. Decatur and Dewey soils are extensive throughout the soil area (Mitchell and Meetze, 1990). Given the types of soils located in this area, leaching is excessive during periods of heavy rainfall. During extended dry seasons the soil dries out and becomes very hard with deep cracks. Nitrate leaching particularly becomes a problem when there are periods of heavy rains followed by periods of dryness.

Nitrogen application at the recommended level, 120 pounds per acre for corn and 80 pounds per acre for winter wheat, caused the greatest N leaching of 61.3 pounds per acre compared to 5, 10, 15 and 20 percent reductions in nitrogen (Table 1). Given a corn winter wheat rotation under dry land conditions, a 5 percent reduction in the amount of nitrogen applied per acre translated into an average of 5.43 percent per acre less nitrate leaching. This lower nitrogen application was expected to lower nitrate leaching, but the simulation results show that the nitrate leaching rate was higher for the 5 percent nitrogen reduction scenario than for the baseline scenario. This situation was observed for 1997 (highest leaching observed) and 1999. However, as expected nitrate leaching was less overall for the 5 percent reduction than for the baseline scenario. This unexpected inverse relationship between levels of nitrogen application and level of nitrate leaching was observed in other scenarios for other years. A detailed examination of the data confirms that weather was the primary cause for this inverse relationship. Weather conditions contributed to this high level of leaching for these years. Rain at planting and first fertilizer application was favorable, however, there was a period of dry weather followed by a period of heavy rainfall when the second application of fertilizer was applied.

Table 1. Leaching Pre and Post Policy for Dry-land Corn-winter wheat Production

CWW[1] Rotation Leaching (lbs/ac)	**Year**										
	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Avg.
Baseline	1.3	3	6.3	5.5	0.5	5	18.7	14	5	2	6.13
5% N Reduction	1.3	2.6	5.5	5	0.4	3.8	19.9	8.4	5.5	1.9	5.43
10% N Reduction	1.3	2	5.1	4	0.3	2.8	17	13.5	5.5	1.5	5.3
15% N Reduction	1.3	1.7	4.8	3.7	0.4	4	12.8	9.4	5.6	1.4	4.51
20% N Reduction	1.3	1.4	3.4	3.3	0.4	2.8	10.5	6.3	4.1	1.2	3.47

[1] Corn Winter Wheat

Overall, the study confirms the existence of a positive relationship between nitrogen use and nitrate leaching. Moreover, the simulation results show that as nitrogen use declines, the level of nitrate leaching declines at an increasing rate. For example, at the 5 percent and 10 percent reduction in nitrogen use, nitrate leaching decreased 11.4 percent and 13.54 percent respectively. Furthermore, at 15 percent and 20 percent reduction in nitrogen use, nitrate leaching decreased 26.43 percent and 43.39 percent respectively over the ten-year study period.

GPFARM 2.0 Corn-winter wheat Yield Simulation and Statistical Analysis

Version 2.0 was used to simulate annual corn and winter wheat yields for the study area (Table 2). Simulated yields are important in the calculation of gross receipts and net returns.

Table 2. Annual Whole Farm Yields for Madison County, Alabama

	CWW Rotation Yield (bu/ac)	
Year	Observed	Generated
1991	82.00	83.70
1992	51.90	53.77
1993	50.00	77.17
1994	57.10	47.23
1995	104.00	96.67
1996	40.00	41.49
1997	83.00	89.93
1998	46.00	44.49
1999	121.00	95.94
2000	63.00	50.84

In order to evaluate the capability of the model for reproducing corn and winter wheat yields, statistical analysis were performed using the Statistical Package for Social Sciences (SPSS) analysis of variance to test the difference between the simulated and observed corn and winter wheat yields. Annual mean simulated for corn/winter wheat rotation yield was 69.80 bushels per acre while annual mean observed corn/winter wheat rotation yield was 68.55 bushels per acre. The mean from the observed data did not differ significantly from the values obtained from the simulated data. Correlations were also made between simulated and observed corn yield using SPSS linear regression. Results indicate an R^2 of .751 suggesting that approximately 75 percent of the variation in the predicted yield (GPFARM) is explained by the observed yield. Furthermore, a correlation of .867 between the observed corn/winter wheat yields and simulated corn/winter wheat yields was observed. These results suggest a significant correlation between observed and simulated corn/winter wheat yields and support the model's good predictive ability.

Regression plot for the observed corn/winter wheat yields and simulated corn/winter wheat yields (Figure 1; $p < 0.001$) were conducted using SPSS regression analysis. Most of the differences between the observed and the simulated data are due to possible correlations with planting dates, expected price of corn and the use of specific pesticides. However, statistical analysis shows that the model is capable of representing many characteristics that existed in the observed data.

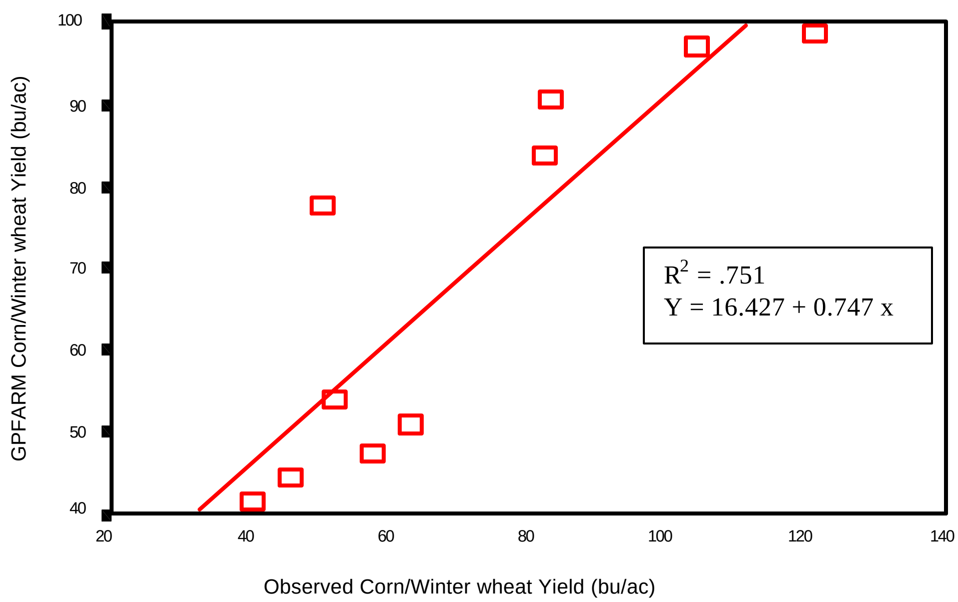

Figure 1. Regression plot for Madison County corn/winter wheat yield values

Effects on Crop Yield and Profitability

The effects of a possible mandated policy to reduce N leaching from field crop production on crop yield and profitability are of interest to corn/winter wheat producers. As mentioned previously, farmers operate to make profits. Consequently, it is vital to evaluate the effects of such mandated policies on corn/winter wheat yields and farm profitability.

As mentioned before, a set of policy scenarios is developed to examine the impacts of nitrogen control policy on corn/winter wheat yields and the profitability of corn/winter wheat production. Expected crop net returns per acre equal the expected crop price times the crop yield simulated by GPFARM for 1991 -2000 minus crop expenses. Corn/winter wheat's simulated annual yields (Table 3) over the ten years were multiplied by corn price to produce annual gross receipts. Direct costs were subtracted from gross receipts to produce the farm's annual profit or loss.

Table 3. Estimated Whole Farm Yields Simulated by GPFARM

Corn/winter wheat Rotation Yields (Bu/Ac)											
	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Average
Baseline	83.70	53.77	77.17	47.23	96.67	41.49	89.93	44.49	95.94	50.84	68.12
5 % N Reduction	82.03	51.55	77.15	46.03	93.17	40.75	88.10	43.37	93.39	49.40	66.49
10% N Reduction	80.52	49.57	74.89	44.16	88.62	41.26	85.81	40.63	91.74	47.63	64.48
15% N Reduction	78.31	47.60	72.70	43.28	84.21	39.57	85.02	40.61	87.01	46.31	62.46
20% N Reduction	77.20	45.04	71.70	41.18	81.22	39.10	86.07	39.56	83.89	44.49	60.95

In evaluating the effects of the nitrogen control policy on whole farm yield, an evaluation of the four different policy scenarios was conducted. The first scenario examined a 5 percent nitrogen reduction (114 pounds of nitrogen per acre for corn and 76 pounds per acre for winter wheat) below the recommended rate. Simulated corn/winter wheat yields averaged 66.49 bushels per acre, an averaged reduction of 2.39 bushels per acre from the baseline. As nitrogen fertilizer was reduced further by 10, 15 and 20 percents, whole farm yields were affected negatively. Crop yields decreased by an averaged of 5.34, 8.30 and 10.54 bushels per acre as nitrogen fertilizer was reduced by 10, 15 and 20 percent respectively.

GPFARM was used to simulate the profit and loss budgets for the baseline and different policy scenarios (Tables 4). Baseline simulation results showed that when nitrogen was applied at the recommended rate, expected net returns averaged $67.70 per acre. At the same recommended nitrogen rate, corn/winter wheat yield averaged 68.12 bushels per acre. Corn was priced at $2.64 per bushel and winter wheat at $3.08 per bushel. Consequently, the farm's gross receipts averaged $190.31 per acre. Cost of production over the simulation period was also calculated to produced an averaged of $122.61per acre. Cost of production per acre under a 5 percent nitrogen reduction averaged $120.54 per acre, an averaged reduction of $1.69 per acre when compared to the baseline. The effects on net returns were also negative with an averaged reduction of $65.72 percent per acre, an averaged per acre reduction of $2.81 as compared to the baseline.

As nitrogen fertilizer was reduced further by 10, 15 and 20 percents, crop yields and crop profitability were affected negatively. These results were expected. Simulation results displayed an inverse relationship between nitrogen reduction and crop yield and profitability. As fertilizer cost was reduced, crop yield and profitability were negatively affected. For example, when nitrogen was reduced by 10 percent, crop yields dropped to 64.06 bushels per acre and net returns fell $64.06 per acre, a reduction of 5.34 bushels per acre and $2.95 per acre respectively as compared to the baseline. In addition, when nitrogen was reduced by 15 percent, crop yield was simulated at 62.46 bushels per acre, an 8.31decrease from the baseline. Also net returns under the same scenario were $60.55 per acre, an $11.47 per acre

Table 4. Estimated Changes Arising from N Control Policy on Whole Farm

	Year										
Variables	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Avg.
Crop Yield (Bu/ac)											
Baseline	83.70	53.77	77.17	47.23	96.67	41.49	89.93	44.49	95.94	50.84	68.12
Changes from the Baseline (%)											
5% N Reduction	-1.99	-4.13	-0.03	-2.54	-3.62	-1.78	-2.03	-2.52	-2.66	-2.64	-2.09
10% N Reduction	-3.79	-7.81	-2.95	-6.50	-8.33	-0.55	-4.58	-8.67	-4.38	-6.31	-5.34
15% N Reduction	-6.44	-11.47	-5.79	-8.36	-12.88	-4.63	-5.46	-8.72	-9.31	-8.91	-8.31
20% N Reduction	-7.77	-16.23	-7.09	-12.81	-15.98	-5.76	-4.29	-11.08	-12.56	-12.49	-10.53
Gross Receipts ($/Ac)											
Baseline	220.97	165.61	203.73	145.47	255.21	127.78	237.43	137.02	253.27	156.58	190.31
Changes from the Baseline (%)											
5% N Reduction	-2.00	-4.13	-0.03	-2.54	-3.62	-1.78	-2.04	-2.51	-0.57	-2.82	-2.14
10% N Reduction	-3.80	-7.80	-2.95	-6.49	-8.32	-0.54	-4.59	-8.67	-4.37	-6.31	-5.38
15% N Reduction	-6.44	-11.47	-5.80	-8.36	-12.90	-4.62	-5.47	-8.71	-9.30	-8.91	-8.33
20% N Reduction	-7.77	-16.23	-7.09	-12.81	-15.98	-5.76	-4.30	-11.08	-12.55	-12.49	-10.62
Cost of Production ($/Ac)											
Baseline	148.33	96.89	148.33	96.89	148.33	96.89	148.33	96.89	148.33	96.89	122.61
Changes from the Baseline (%)											
5% N Reduction	-1.56	-1.89	-1.56	-1.89	-1.56	-1.89	-1.56	-1.89	-1.56	-1.89	-1.69
10% N Reduction	-3.14	-8.82	-3.14	-8.82	-3.14	-8.82	-3.14	-8.82	-3.14	-8.82	-5.39
15% N Reduction	-4.89	-10.43	-4.89	-10.43	-4.89	-10.43	-4.89	-10.43	-4.89	-10.43	-7.08
20% N Reduction	-6.30	-12.18	-6.30	-12.18	-6.30	-12.18	-6.30	-12.18	-6.30	-12.18	-8.62
Net Returns ($/Ac)											
Baseline	72.64	68.72	55.40	48.58	106.88	30.90	89.09	40.14	104.95	59.70	67.70
Changes from the Baseline (%)											
5% Reduction	-2.85	-7.29	-4.13	-3.84	-6.46	-1.45	-2.80	-4.03	0.85	-4.36	-2.81
10% N Reduction	-5.11	-6.38	-2.42	-1.86	-15.51	25.38	-6.69	-8.32	-6.11	-2.24	-2.95
15% N Reduction	-9.57	-12.94	-8.16	-4.23	-23.97	13.58	-6.38	-4.59	-15.53	-6.44	-7.82
20% N Reduction	-10.74	-21.96	-9.17	-14.07	-29.41	14.37	-0.93	-8.43	-21.39	-13.00	-11.47

reduction from the baseline. A 20 percent nitrogen fertilizer reduction showed an even greater crop yield reduction of 60.95 bushels per acre, a 10.53 dropped from the baseline. Net returns also suffered negatively, $58.08 per acre, $11.47 per acre reduction from the baseline.

In 1996, for a 10, 15 and 20 percent reduction in nitrogen fertilizer, expected net returns were slightly higher than the baseline. For example, $25.38, $13.58 and $14.37 percent increase in net returns over the baseline were recorded for these scenarios respectively. The increase in net returns over the baseline can be contributed to nearly similar yields combined with lower direct cost relative to the baseline.

SUMMARY AND CONCLUSIONS

The issue of surface and groundwater contamination by commercial fertilizer in addition to increased public concerns has caused government over the years to implement various safe water regulations. The formulation of agricultural policies by U.S. policy makers is mainly designed to minimize the adverse effects on the environment. Although these regulations have been successful, the waterways of the U.S. continue to be threatened by commercial fertilizer contamination. Commercial fertilizer (nitrogen and phosphorus) use has increased over the years and that trend is expected to continue.

The possible impacts of nitrogen control policies will have both environment and economic effects for the small farm. This study presented a model (GPFARM) which evaluated possible environmental and economic impacts for the representative small farm in North Alabama. Various policy scenarios were compared against the baseline recommended nitrogen use for corn and winter wheat production.

The impact of a possible mandated policy to reduce nitrate leaching from field crop production was a positive one for the environment. Nitrate leaching was reduced as the level of nitrogen was reduced. However, the effects of such a policy on crop yield and farm profitability were negative. As nitrogen was reduced, both yield and profitability were negatively affected.

Further studies need to be conducted to delve deeper into this important issue. Surface and groundwater contamination is a major problem and nonpoint sources are contributing significantly to the problem. The need for nitrogen control policies is critical; however, as the study findings showed, these policies are beneficial to the environment but not so economically. These studies should consider examining the effects on nitrogen control policies of government incentives looking at both the environmental as well as the whole farm economic impacts. A policy choice to achieve one environmental problem may result in an economic problem. The choice of policies affects agricultural production and farm profitability. Consequently, one policy may not satisfy all stakeholders and finding the balance between the two would be very challenging.

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