Economic Impacts of Land Use Changes from a Restricted Nitrogen Fertilizer Strategy

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The impact of increased nitrogen fertilizer use on agricultural productivity and indirectly on land use has been most significant. The impact of nitrogen fertilizer use or non-use obviously is not isolated in the farming sector of our economy. Indirectly through farm yield changes, nitrogen fertilizer use impacts on rural areas by changes in income and employment levels. These rural communities have oriented their level of business around the nitrogen induced increases in agricultural productivity. It is quite possible that many of the services provided by these communities would be curtailed if nitrogen induced productivity is diminished through laws restricting nitrogen fertilizer use.

An uncertain aspect of nitrogen fertilizer use relates to the impacts of enforcement of PL 92-500, *The Federal Water Pollution Control Act Amendments of 1972.* Guidelines have been promulgated for both point and non-point sources of agricultural pollution. A key issue is what may happen to regional agricultural production patterns if restrictions are placed on the quantities of actual nitrogen which can be applied per acre of cropland. Some areas may be able to obtain a competitive advantage in the production of food and feed grains, and shifts in production of the crops may occur. However this issue is not analyzed in this paper.

This paper represents an effort to analyze the regional impact of restricting nitrogen use on the amount of agricultural land required to maintain current and projected regional shares of production for wheat, grain sorghum and corn in the Texas-Oklahoma Panhandle. The paper represents some of the results of an Oklahoma State University study completed in early 1975 [Rathwell].

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Procedure

The study region selected for the analysis includes a 12 county area in the Panhandle of Texas and a five county area in the Panhandle of Oklahoma. The region is a major wheat and grain sorghum producing area. Corn acreage is increasing rapidly with most of the production utilized locally as cattle feed.

Two nitrogen fertilizer strategies were developed for this analysis. The baseline strategy was based on the 1972 agricultural situation and nitrogen fertilizer use in the region. Its function was to serve as a base for comparison of the restricted nitrogen strategy. The 1972 crop year was selected since it precedes the 1974 fertilizer shortages and the relaxation of government acreage restrictions.

The restricted nitrogen strategy reduced the per acre application rate of nitrogen fertilizer to a point where rates lower than this level would take the acres out of crop production. This is especially evident on irrigated lands in the Oklahoma-Texas Panhandle area. Agronomic data suggests this cut off level is 30 pounds of actual nitrogen applied per acre on irrigated wheat and 80 pounds of nitrogen per acre on irrigated corn and grain sorghum in the TexasOklahoma Panhandle region.

Restricted nitrogen does not affect dryland wheat or grain sorghum in the Panhandle area. Insufficient rainfall limits dryland nitrogen fertilizer applications to only better quality lands, where yields warrant approximately 8 to 14 pounds of nitrogen per acre, depending on the soil class.

Market prices are the same as for the baseline strategy. Production expenses per acre were decreased by an amount equal to the per bushel yield reduction based on the actual nitrogen fertilizer application rates.

The Model

The analytical tool used to evaluate the impact of restricting nitrogen use and land use patterns is an aggregate linear programming model developed on the 1972 base year. The model projects land adjustment patterns for 1975 and 1990 assuming regional shares of production are met for each time period.

The model assumes the total regional land area as the unit of analysis with yield levels varying according to soil classes, fertilizer application rates, and land development costs attributable to an individual acre. Aggregation across all acres for the soil types and land use capability class determines the model's total impact.

The advantages of this macro approach lies largely in the data requrements and the time and costs of analysis. Another advantage, and a crucial part of this analysis, is the ability to incorporate soil information. Only rarely is there soil variation within a given farm large enough to induce large yield differences. A macro approach allows for significant differences in soils and the necessary production variations, which can give rise to considerable differences in the optimum organization of the region's farm enterprises.

The model solved the combination and level of enterprises which maximized net returns to the region, given the fertilizer levels. These land adjustments were obtained as follows:

$$\text{Max } Z = -C_1 - C_2 - \cdots - C_n + P_w \cdot W + P_{gs} GS + P_c \cdot C - P_n \cdot N$$

Subject to the following restrictions:

$$\begin{array}{lllllll}
A_{11}X_1 & + & A_{12}X_2 & + \cdots + & A_{1n}X_n & = & Y_1 \\
A_{21}X_1 & + & A_{22}X_2 & + \cdots + & A_{2n}X_n & = & Y_2 \\
A_{31}X_1 & + & A_{32}X_2 & + \cdots + & A_{3n}X_n & = & Y_3 \\
D_{11}X_1 & + & D_{12}X_2 & + \cdots + & D_{1n}X_n & \leqslant & R_1 \\
D_{21}X_1 & + & D_{22}X_2 & + \cdots + & D_{2n}X_n & \leqslant & R_2 \\
\cdot & & & & \cdot & & \\
D_{m1}X_1 & + & D_{m2}X_2 & + \cdots + & D_{mn}X_n & \leqslant & R_n \\
N_{11}X_1 & + & N_{12}X_2 & + \cdots + & N_{1n}X_n & \leqslant & B
\end{array}$$

Where Z = Total area net returns to management from wheat, corn, and grain sorghum less a nitrogen cost per pound applied. Operating labor, operating and capital costs, including land costs, were included in $C_1 \cdots C_n$.

$C_1 \cdots C_n$ = cost of producing a given crop on a given capability class and soil type.

P_n = nitrogen fertilizer cost per pound applied

P_w, P_{gs}, P_c = price received for wheat, grain sorghum and corn,

W, GS, C = bushels of wheat, grain sorghum and corn produced,

$X_1 \cdots X_n$ = acres of various land use activities,

$A_{11} \cdots A_{3n}$ = yield per acre per crop activity,

$D_{11} \cdots D_{mn}$ = acres of land by soil capability classes,

$N_{11} \cdots N_{1n}$ = amount of nitrogen applied per acre,

$Y_1 \cdots Y_3$ = total production per crop per time period,

$R_1 \cdots R_n$ = land restraints by capability class for dryland and irrigation acres.

Y_1, Y_2, Y_3 = wheat, grain sorghum, and corn production, respectively.

B = regional allocation of nitrogen fertilizer; zero for restricted nitrogen fertilizer strategy.

The basic sets of model restraints were: 1) production requirements, i.e., nitrogen fertilizer ($N_{11} \ldots N_{1n}$) and yield per acre ($A_{11} \ldots A_{3n}$); and 2) land resources, the amount of land available to produce the products ($R_1 \ldots R_n$). These restraints were exogeneously determined.

This objective function was of the standard maximization linear-programming type. The basic cost components were operating, ownership, and capital expenses; these costs and prices received are explained in Rathwell. The objective function was specified for each soil type, for currently producing lands and potentially producing lands. For example, enterprise budgets designate the cost per acre associated with Panhandle area wheat being produced on Class II clay loam soil. Using the Oklahoma State University Budget Generator as a reference budget, the deviations due to soil and land capability were considered, e.g., irrigated wheat yields on Richfield clay loam soils in the Oklahoma Panhandle area are estimated to be 46 bushels per acre, Utilizing 63 pounds of N per acre [Rathwell, p. 155]. Richfield clay loam is designated as a Class III soil in the *Oklahoma Conservation Needs Inventory*, published by the Soil Conservation Service. Other soils lower in productivity were assigned lower yields per acre [Rathwell; Gray].

The production level requirements for the model (Y_i) were developed by using the regional supply history. County data for wheat, grain sorghum and corn production from the Oklahoma and Texas Statistical Reporting Services were aggregated by study region. The percent that the area's production was of the 1972 United States production of wheat, grain sorghum and corn was considered the area's regional share of United States supply. This percent was then applied to the OBERS estimates for United States production for the years 1975 through 1990.

Land Use Changes and Related Economic Adjustments for the Restricted Nitrogen Strategy

The comparison of the two strategies indicates the possible changes required in land utilization due to a nitrogen restriction per acre. In 1975, 335,291 additional acres of wheat are required to produce the region's share of production (2,487,404 - 2,152,113) than if nitrogen had not been restricted on irrigated wheat (table 1). In 1990, an additional 90,832 acres of land are needed to meet the regional share of wheat for the restricted nitrogen strategy, when compared to the baseline strategy of no restrictions on nitrogen (i.e., nitrogen application rates based on 1972 levels).

Grain sorghum acreage was substituted for corn acreage in 1990 due to the nitrogen restriction. The 1975 estimate shows an increase of 315,900 acres of grain sorghum and 45,601 acres of corn. The 1990 figures indicate grain sorghum acreage still increasing by 116,045 acres but corn declining by 29,041 acres. The reason for this substitution of dryland grain sorghum for irrigated corn lies in the reduced profitability of corn relative to the lower yielding but lightly fertilized dryland grain sorghum.

The impact of nitrogen restrictions on agricultural production patterns in these 17 Texas and Oklahoma counties is an increase of 177,836 acres needed to meet regional shares of production for these three crops in 1990. These additional acres are more marginal lands. However, due to the nitrogen restriction, these lands used in dryland grain sorghum and dryland wheat are more profitable than irrigated corn or wheat.

Nitrogen fertilizer use by crop for the two strategies indicate a similar pattern. The baseline strategy utilized about 175 million pounds of actual nitrogen in 1975 and about 222 million pounds in 1990 (table 2). This is almost 29 million pounds more than the restricted nitrogen strategy in 1975 and about 83 million pounds more in 1990. The significant decrease in nitrogen fertilizer use can be traced to the increased acreage of dryland grain sorghum brought into production to meet feed grain regional shares of production. The

Table 1. Panhandle region's total land adjustments by crop for two nitrogen strategies: 1972, 1975, 1990

	Baseline Strategy			Restricted Nitrogen Stragegy		
Crop Year	1972	1975	1990	1972	1975	1990
	acres					
Wheat	2,138,425	2,152,113	2,285,417	2,138,425	2,487,404	2,376,249
Grain Sorghum	1,090,310	1,191,277	1,488,075	1,090,310	1,507,177	1,604,120
Corn	280,301	217,659	312,764	180,301	263,260	283,723
Total	3,409,036	3,561,049	4,086,256	3,409,036	4,257,841	4,264,092

Table 2. Panhandle region's fertilizer consumption by crop for two fertilizer strategies: 1972, 1975, 1990

	Baseline Strategy			Restricted Nitrogen Strategy		
Crop Year	1972	1975	1990	1972	1975	1990
	pounds					
Wheat	35,044,547	37,148,608	42,320,822	35,044,547	28,822,860	28,596,799
Grain Sorghum	93,970,486	98,784,764	122,064,828	93,970,486	93,238,261	87,830,640
Corn	29,804,853	39,227,193	57,586,200	29,804,853	24,379,289	22,866,640
Total	158,819,886	175,160,565	221,971,850	158,819,886	146,440,410	139,293,709

upper limits on nitrogen fertilizer use reduce the profitability of irrigated wheat, corn and grain sorghum. Consequently, farmers shift to dryland grain sorghum and dryland wheat. Many of the dryland grain sorghum acreages are not fertilized at all; relatively small rates of nitrogen are applied to the remaining acres.

Implications of Study

The Panhandle area of Texas-Oklahoma is a unique area. It typically utilizes large amounts of nitrogen fertilizer on highly productive irrigated crops. Farmers apply very little nitrogen fertilizer on dryland crops. Restriction of nitrogen fertilization makes irrigated lands much less profitable and reversion back to dryland farming more likely.

The impact of this forced land change could have other influences, both agricultural and environmental. Increased acreages, especially of land previously taken out of production, or new land brought into production initially require greater cash outlays. This is especially true on marginal agricultural land brought back into production. Lower on-farm income levels result from this forced changed land use pattern, if nitrogen fertilizer application rates are restricted.

Environmentally, the restriction of nitrogen fertilizer appears at first to suggest an improved natural environment. This is especially apparent for aquatic environments as there is less nitrogen runoff into streams. However, increased acreages brought into production also suggest that acreages previously used as habitat for terrestrial wildlife will be reduced, adversely affecting quail, deer and turkey populations in the Panhandle region. The environmental impact analysis is explained in detail in Rathwell.

In summary, substituting land for nitrogen fertilizer in the production of out food and feed crops does not improve our agricultural outlook. Farm incomes are decreased. The environmental quality issue becomes a tradeoff–slightly improved water quality and aquatic habitat, but a significant loss of terrestrial wildlife habitat.

References

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