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**U.S. AGRICULTURE UNDER  
FERTILIZER AND CHEMICAL RESTRICTIONS  
*PART 1***

**by**

**Glenn A. Helmers,  
Azzeddine Azzam, and  
Matthew F. Spilker**

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## U.S. AGRICULTURE UNDER FERTILIZER AND CHEMICAL RESTRICTIONS - PART 1

### Preface

This paper and a more detailed companion paper are two of four papers reporting on a two-part study of fertilizer and chemical use in agriculture. Currently there is considerable discussion regarding the role of fertilizer and chemical use in agriculture. The discussion includes questions about the impact of fertilizer and chemical restrictions as well as how commodity programs affect resource use in agriculture. Resource use refers to the levels of land, labor, and other production inputs used in agricultural production. One resource, fertilizer and chemicals, will receive particular emphasis.

This analysis examines output and other resource adjustments in agriculture in response to limitations of fertilizer and chemicals. This analysis is useful to the understanding of how much resource adjustment potential exists in agriculture. The greater the resource substitution potential in response to a restriction on fertilizer and chemicals, the less output will fall and agricultural product prices increase.

A second analysis presented in two companion papers, examines federal commodity programs and their impact on resource use in agriculture, particularly fertilizer and chemical use. It provides a perspective to evaluate the effect of alternative programs and program features on output quantity and prices as well as the quantity of resources and their prices in agriculture.

The fertilizer and chemical restriction analysis is presented in two parts. This part is an overview and summary of the study of the effects of fertilizer and chemical restrictions on U.S. agriculture. The companion

document is a more technical description of the study for those interested in the methodology, data, and results in greater detail.

### Introduction and Objectives

The objective of this analysis centers on estimating the impacts of restrictions on fertilizer and inorganic chemicals on cropping agriculture. Currently there is significant concern over the role of fertilizers and chemicals used in agriculture and their impact on the environment, particularly groundwater quality. Also, there is concern that the current dependence on finite energy supplies should be reduced. Further, concern over the effect of chemical products on food safety is increasing. Some farm operators have explored production methods using less chemicals because of concerns over health risks. Also to reduce production risk, alternative production methods using fewer purchased inputs are receiving more attention by farm operators. Interest in crop rotations has grown primarily as an alternative method to provide fertility needs and pest control. Some observers view crop rotations and greater use of tillage as an alternative production system which not only reduces dependence on fertilizer and chemicals but can reduce soil erosion. However, others dispute this by pointing out that less herbicide use and greater machinery tillage increases susceptibility to soil erosion. Some also contend that chemicals enhance food quality rather than reduce it.

It has been proposed that fertilizer and chemical use in agriculture be reduced by both indirect and direct policy. Direct policy involves restrictions on use and taxing fertilizer and chemicals. Indirect policy involves changing federal commodity programs to reduce incentives to use purchased forms of these chemical inputs. Here, direct restrictions are examined. Important questions surround the effect of reductions in fertilizer

and chemical use, regardless of policy method.

The major question is what impact would reductions in fertilizer and chemicals have on agricultural output? This is important because if agricultural production is significantly reduced, concerns over food scarcity and food price rises must be addressed. Linked to that issue is how other resources adjust to reductions in fertilizer and chemicals. The greater the resource adjustment capability, the less output is reduced. If output is not greatly reduced following fertilizer and chemical restrictions and other resource adjustments, output prices would not greatly increase and food prices would not significantly increase.

Evaluations of the impact of restrictions on fertilizer and chemicals in agriculture can be examined from either a farm perspective or from an aggregate view. A farm perspective is useful but does not adequately describe how much resource adjustment can and does occur in the total sector. Current production methods are often perceived as technically efficient from a farm perspective with little potential to substitute resources. Aggregate changes in input uses in agriculture in response to changes in inputs, input prices, and output prices are considerably larger than is generally perceived. The aggregate analysis used here is based on resource substitution relationships previously estimated and published. Restrictions on fertilizer and chemicals can be expected to increase the use of some inputs but reduce the use of others. When fertilizer and chemicals are reduced, some inputs are not effective substitutes and their use will also decrease. When effective resource substitution does not occur, agricultural output decreases. When more potential exists to substitute other resources for fertilizer and chemicals, agriculture production will not decline as much.

The effects on crop production resulting from a reduction in fertilizer and chemicals would not be expected to affect all agricultural sectors and

farms in identical ways. Some commodities and farms would be expected to more strongly influenced than others.

The analysis is an intermediate-term analysis (four to six years) in which resource adjustments to fertilizer and chemical restrictions occur and food consumer behavior also adjusts to declining output. Were a shorter term horizon examined and fertilizer and chemical restrictions imposed immediately, the output reductions and output price increases would be much more dramatic than those results estimated here. However, if it is assumed that policies which would result in reduced fertilizer and chemical use in agriculture are phased in gradually, the study results would approximate the likely adjustments not only in the intermediate run but in the short run as well.

Two separate models were examined in this study. The first was a three output-five input model. The outputs were feedgrains, wheat, and soybeans. Inputs were land, labor, machinery, fertilizer and chemicals (as one input), and another category ("other") aggregating the rest of the inputs. The second model was a one output-seven input model. For this model output is aggregate farm output. The input categories were land, labor, capital, energy, fertilizer, pesticides, and "other."

An economic model was developed in which output demand, input supply, and resource substitution elasticities were obtained from existing literature. This type of model allows for "rebounding" between various resource and output markets in achieving new supply-demand equilibria following a fertilizer and chemical restriction or "shock." It parallels economic reality because shifts in supply and demand in output and input markets are a characteristic of the U.S. economy. In a nonexperimental setting, the effects of "shocks" are difficult to analyze because such shocks cannot be controlled. Economic modeling allows the shocks to be controlled and analyzed.

The impact of restricting one resource on the use of other resources is determined by a complex set of forces among resource markets, among product markets, and between resource and product markets. The three basic technical relationships incorporated in the model include 1) product demand functions, 2) input supply functions, and 3) product supply and resource demand functions. The latter set of relationships emanate from the existing production technology or process. The responses (shifts in supply and resource demand functions) are triggered by a) how well resources substitute for one another (elasticities of substitution), b) how sensitive is output demand (elasticity of demand), and c) how responsive is the supply of resources (input supply elasticity). Cross elasticities of demand among the three commodities were included. Cross elasticities of demand enable the linkage between crop demands to be implemented so that when the price of one crop rises, the demand for other crops also rise.

### Results

The results for the three crops are presented in Table 1. A 10 percent reduction in fertilizer and chemicals decreased wheat production by 1.26 percent and soybeans by 2.20 percent. Feedgrain production actually increased. Except for fertilizer and chemicals, all resource use increased in feedgrain production. For both soybeans and wheat, land and machinery use declined (in addition to fertilizer and chemicals) but labor and "other" inputs increased.

To investigate how sensitive the results are to further disaggregation of the inputs, elasticities of resource substitution were directly estimated and used to estimate the impact of a fertilizer and pesticide reduction on aggregate farm output (Model 2). The reasoning is that if the results are robust, the output effect of fertilizers and pesticides reductions, when not

lumped in one input should not depart dramatically from the results in Model 1. The results of this exercise are also shown in Table 1 for two categories of outputs which, are called program and nonprogram outputs. It is evident from the results, that even with the disaggregation process, the effect on output in aggregate is not dramatic.

An income analysis of producers was not attempted here. In the short run it would be expected that due to reduced output, product prices could significantly increase. In the intermediate and long run, product prices are less responsive to reduced output and resources adjust to limit output effects of reduced fertilizer and chemicals.

A 10 percent reduction in fertilizer and chemicals was to this point, used for discussion purposes. For smaller and larger reductions in fertilizer and chemicals, the resulting effects are multiplicative (a 20 percent reduction is estimated to result in twice the effect of Table 1). However, more confidence should be placed in the impacts resulting from small restrictions in fertilizer and chemicals than from larger changes. While it is impossible to be precise about the limits of fertilizer and chemical restrictions which can be examined with confidence, extending the multiplicative effects beyond a 25 percent reduction in fertilizer and chemical use should be avoided.

The reason that the accuracy of these models can weaken for wider "shocks" is because the resource substitution relationships used in the models have been derived from evolutionary changes in the agricultural economy observed across time. Imposing major shocks (such as a 50 percent reduction in fertilizer and chemicals) would be expected to invoke widely different production methods for which the resource substitution relationships for that setting are unknown. Further, such a different thrust would likely change the direction of technology. How technological change induced by a major

fertilizer and chemical restriction would impact resource substitution is difficult to project.

On the one hand it can be suggested that as large reductions in fertilizer and chemicals are made, less resource substitution potential exists than found here. This would occur if as fertilizer and chemicals are reduced, initial reductions have little impact on output but subsequent reductions involve successively greater output sacrifices. This effect (greater output sacrifices to successively larger reductions in fertilizer and chemicals) depends upon how much the productivity of fertilizer and chemicals changes as wider reductions are considered. However, it can also be argued that under large reductions in fertilizer and chemicals, a different input oriented agriculture would emerge such that it becomes increasingly easy to substitute other inputs for fertilizer and chemicals through, for example, innovative management and crop rotations. Also, it can be argued that if future technological changes in agriculture are directed toward minimizing the use of fertilizer and chemicals, reductions in fertilizer and chemicals would involve lower output sacrifices than used in this analysis.

The technical limitations to this analysis beyond those already stressed are: 1) elasticities of resource substitution may not be the same for all crops, thus regional impacts could be different from those inferred from the model, 2) the elasticities used in the study have not been tested for statistical significance, 3) the product demand and cross elasticities of demand as well as the input supply elasticities are taken from those published in agricultural economic literature in which there are some differences, and 4) the paths of adjustment identified here resulting from fertilizer and chemical restrictions have not been traced across time and if combined with stochastic events (such as drought), could lead to wide changes from year to

year in reaching the intermediate-run conclusions.

This research shows that in the intermediate and long run, U.S. agriculture demonstrates a strong capability for resource substitution within the range of the assumed percentage fertilizer and chemical restrictions. Overall, agricultural output is estimated to be only slightly affected by a reduction in fertilizer and chemicals.

Compared to average product price variability which historically has occurred, the increased product price estimated here resulting from reduced product supply are of relatively minor magnitude. The impact of higher agricultural product prices on food prices is beyond this analysis. Such impacts hinge on the share of the products analyzed here in the food price index together with their price changes. Also, cross elasticities of demand for food price items would need to be considered to be confident of full food price impacts. Yet given the low product price impacts found here, food price impacts would similarly be expected to be minor.

Table 1. Estimated Output, Output Price, and Resource Use Impacts Resulting From a Ten Percent Reduction in Fertilizer and Chemical Use in Agriculture (In Percent).

	Model 1			Model 2	
	Feedgrains	Wheat	Soybeans	Program	Nonprogram
Output	.19	-1.26	-2.20	.20	-.86
Market Price	.78	1.56	2.75	-.20	.86
Land	1.74	-2.32	-3.65		
Labor	14.67	15.50	12.90		
Machinery	.10	-2.85	-2.97		
Other	5.95	5.69	4.43		
Fertilizer and Chemicals <sup>1/</sup>	-8.62	-11.31	-13.73		

<sup>1/</sup> In aggregate a 10 percent decline was observed. The differences from 10 percent for the different sectors occur because transfers among sectors are permitted and some sectors more effectively use fertilizer and chemicals.