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AN IMPACT ASSESSMENT MODEL OF LIMITING CROP PESTICIDE USAGE IN AGRICULTURE

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By

John J. Kania and Bruce B. Johnson*

Introduction

The use of agricultural crop pesticides has increased more than five-fold since 1950.[1/] U.S. consumption of chemical pesticides currently exceeds one billion pounds of active ingredients annually; more than half of this volume is used for agriculturally-related enterprises. The explanation behind such growth is one of economics. The agricultural producer's rationale for using chemical pesticides on crops is to increase net revenues through 1) improved yields associated with more effective pest management, and/or 2) decreased cost of pest control.

Increased usage of chemical pesticides have not been free of societal concern. Application of toxic chemical substances to large land areas leads to the many-faceted issue of benefit-risk characteristics. In response to the potential danger to man and his environment in both site and off-site contexts, comprehensive monitoring and regulatory institutions have been established. Under the Federal Environmental Pesticide Control Act (FEPCA) of 1972, the Environmental Protection Agency (EPA) has been

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1/ The term "pesticide" refers to herbicides, insecticides, defoliants, and growth regulators. In this study, pesticide usage will be limited to chemical weed control (herbicides) and chemical control of crop insects (insecticides).

given the authority to regulate pesticide usage (including agricultural pesticides). As part of this effort, assessments are made of the potential risk from pesticides to either man or his environment. Pesticides that are suspected of causing potential risks are subjected to a benefit/risk analysis through a review process called Rebuttable Presumption Against Registration (RPAR). On the basis of this review, the decision is made to cancel, restrict, or reregister the pesticide in question.

As part of the RPAR review, the economic impact of possible removal or restriction is to be appraised. Thus, in the final analysis, environmental risks are to be weighed against the economic consequences. Historically, however, neither the necessary data base nor the economic modeling framework was sufficiently developed for effective economic assessment.

In response to this need, many states have recently carried out comprehensive studies of the current usage of agricultural pesticides on major crops.[2/] But models useful for economic assessment of potential policy decisions have generally remained in conceptual stages or have been designed to assess only the extreme case of banning all pesticides. Therefore, a study was undertaken to develop an assessment framework capable of measuring the economic impacts of specific bans of commonly

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[2/] For example, the 12-state North Central Region recently completed a study of crop pesticide usage during 1978. A few states, such as California, have maintained a comprehensive monitoring effort for several years.

used agricultural pesticides. The specific objectives were:

1. Develop a model of representative crop production regions in Nebraska with refinements including the actual 1978 pesticide-use pattern.

2. Analyze producer adjustment to various pesticide limitations using a linear programming routine.

3. Develop appropriate linkage of projected production changes in a national agricultural simulation model capable of projecting price effects and, ultimately, producer revenue changes.

4. Simulate a series of pesticide limitation scenarios and analyze the economic impacts within the context of change to producer and consumer surplus.

Review of Literature

One of the earliest conceptual models to evaluate the economic implications of pesticide-use policy was by Headley and Lewis (9). These authors developed an economic appraisal of pesticide usage and suggested pesticide policy changes to reduce the social costs associated with pesticides. Included in their economic framework were agriculture, human health, and environmental consequences, including both market and non-market valued effects. Further refinements in the Headley-Lewis work were made by Langham (16). Edwards (5) attempted to quantify the Headley and Lewis model using the welfare concept of changes in producer plus consumer surplus. Pesticide usage, according to Edwards, should be managed to equate its marginal social cost with its marginal social benefit. Horne (11), Lacewell and Masch (15), Taylor and Frohberg (34), Rovinsky and Reichelderfer (28) used linear programming techniques to estimate the impacts of various pesticide limitation scenarios on agricultural production.

Horne, Rovinsky, and Reichelderfer emphasize the spatial shifts in production as a response to a pesticide ban. Lacewell, and Masch present a tax disincentive model for limiting the use of a given pesticide.

With the exception of Taylor and Frohberg's model, all of these models assume, either implicitly or explicitly, that the crop selling prices remain constant after imposition of a pesticide ban. Such an assumption is reasonable for situations where the pesticide in question is used in only a few producing regions or is used in many regions but the crop acreage treated is small. Clearly, a pesticide ban, while causing a leftward shift in a local or regional supply curve, would not necessarily affect appreciably the total market supply-demand equilibrium for the given crop. But a national ban on a pesticide heavily used on a given crop would quite likely have an effect on the market price. For such a case, an assumption of a constant price could lead to misleading and erroneous results.

Taylor and Frohberg provide a more useful methodology that does account for a price change in response to supply curve shifts from pesticide limitation. However, this model is able to analyze the effect only under the extreme scenario of banning all herbicides or insecticides. Other conceptual approaches to the pesticide problem have also been suggested. Richardson and Badger (26) present an environmental impact matrix analysis as an approach capable of handling both qualitative and quantitative dimensions of the pesticide issue. The matrix depends, however, on an arbritrarily determined ranking scale and weighing scheme. Jenkins (13) advocates a systems approach to the pesticide issue but much of the needed data are simply not available.

None of the previous studies deal explicitly with the effects of the more probable scenario of limiting or banning a single pesticide which was being utilized on a major portion of the national acreage for a given crop. Such a model would provide a more definitive estimate of economic benefits and costs for the policy maker who is faced with determining whether the benefit from banning a particular pesticide does, in fact, outweigh the possible loss of farm income and increased prices for farm commodities.

The Theoretical Framework

Decisions concerning the reduction of toxins in the environment, by restriction of pesticide use, involves the usual weighing of welfare gains against the losses. Society gains from reduced hazards to the environment and human health and implicity from a sense of an improved quality of life. The losses can include higher production costs as a result of reduced yields per acre and/or the substitution of more costly inputs. Over time, these economic losses may be reduced or even eliminated by the use of a new technology such as biological control, innovative farming practices, or new pesticides less damaging to the environment. However, if new techniques are not forthcoming, these losses can be anticipated into the foreseeable future.

According to Pareto optimality criteria, the existence of economic losses due to a pesticide limitation precludes an unambiguous effect of a policy recommendation. In other words, if anyone can be shown to be worse off as a result of the adoption of limits on pesticide use, one cannot conclude that economic welfare would be enhanced by such a policy (10). Hicks, and Kaldor, however, propose a compensation test which is a potential Pareto optimum; if the gainers could compensate the losers and still retain a residual gain, then a policy change could enhance economic welfare. But Scitovsky argues that no improvement in welfare is possible in the Hicks-Kaldor logic unless it can be shown that the losers could not bribe the gainers, ex ante, to forgo the policy change.

All of these tests would not likely be met in applied economics. The best one can hope for according to Harberger (8) is simply to aggregate gains and losses associated with an event in an unweighted fashion and recognize that this information is only one input to the decision framework. With this objective in mind, the gains and losses from pesticide limitation will be estimated by examining the change in Marshallian consumer and producer surplus after imposition of various pesticide limitations.[3/]

The surplus model used in this study for the assessment of a pesticide ban on a particular crop is illustrated in Figure 1. The primary objective was to design a model for examining impacts in one locality (Nebraska in this study) subsequent to a nationwide pesticide ban.[4/] The most likely impact from a national pesticide ban on a specified crop is that

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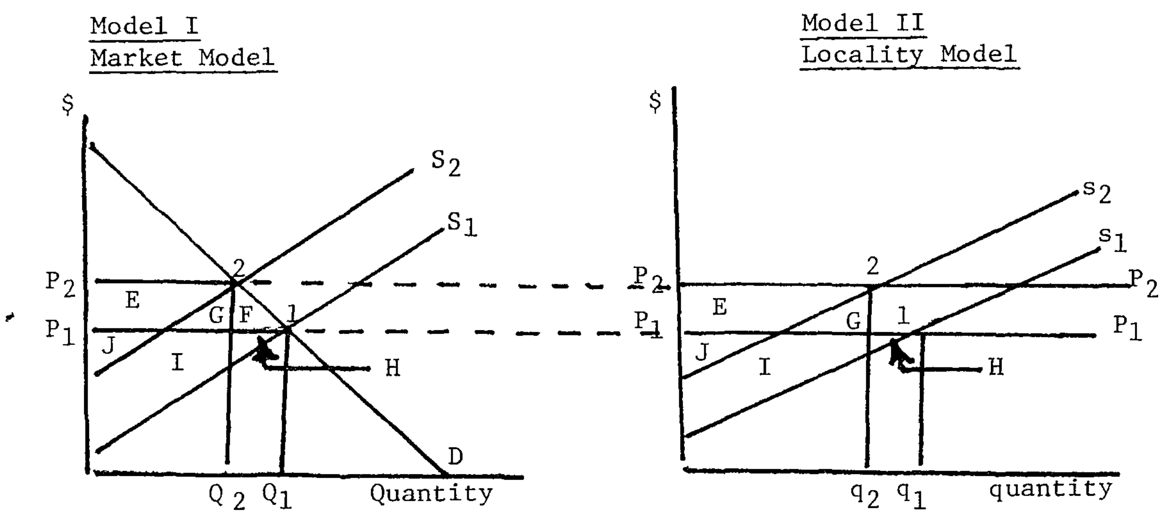
3/ Consumer surplus represents an aggregate revenue measure of the difference between consumers' total willingness to pay and what they have to pay. Producer surplus represents an aggregate revenue measure of the difference between revenues actually received by producers for a given production level and what would have been an acceptable payment for that output.

4/ A locality is defined as a geographical region or regions or a state accounting for only a small portion of the total market supply for a specified crop.

producers are forced to turn to more costly substitute pest control and/or adopt farming practices that result in production declines. This impact is illustrated in Figure 1 by a shift in the market supply curve from S_1 to S_2 (Model I) and the locality supply curve from s_1 to s_2 (Model II).[5/] Model II for the locality reflects a price taking market situation such that demand is perfectly elastic. Aggregate market equilibrium determines the price which local producers must accept (P_1 or P_2 in Figure 1), irregardless of any shift(s) in their local supply.

Figure 1
Pesticide Limitation Models (PLM)



[5/] If producers are not using the most efficient pesticides prior to a ban, then the market and locality supply curves in Figure 1 could shift to the right if a superior pest control technology is adopted, resulting in production cost declines and/or output increases.

The end result of a reduced aggregate supply is a higher price since market supply S_2 now intersects the demand curve D at a higher price level P_2 (point 2 in Model I). Next the alteration of the market supply-demand relation shifts the locality price line upward from P_1 to P_2 (Model II) resulting in producers in the locality receiving a higher price per unit for their reduced crop output. A gain or loss in producer revenue would occur depending upon the percentage increase in commodity price relative to the percentage decrease in quantity produced. If the former exceeds the latter, then there will be a net revenue increase and vice versa. Graphically this is illustrated by the gain of area E less areas I and H.

At the aggregate market level (Model I), a supply reduction results in consumers paying a higher price per unit. The change in consumer surplus or well-being will be equal to the sum of areas E, G and F and will be a loss. The change in producer surplus is represented by the sum of area E less the sum of areas H and I. The reduction in economic welfare from output curtailment is then the sum of (E-H-I) - (E+G+F). Consumers lose in having to pay a higher price for a smaller output, while the producers may gain or lose depending on the elasticity of demand and supply curves.

It should be noted, however, that in order to simplify the illustration, Model I was depicted with a non-shifting demand curve. The actual simulation of Model I (described in the next section) allows for such shifts as the various markets interact.

Finally, it should be noted that the welfare effects of the foregoing pesticide model are partial, in that only the economic gains and losses arising from the production of an agricultural crop are involved. Not accounted are possible social gains accruing from 1) reduced hazards to the environment and human health, 2) a greater feeling of well-being with the knowledge that pesticide residual loading of the environment is being reduced. Also, this model includes neither the public costs of cleaning up any environmental damage nor the associated governmental administration and enforcement efforts.[6/] As a consequence, the decision-maker is left with some normative judgement in deciding whether the accounted and unaccounted-for gains do in fact outweigh the accounted and unaccounted-for losses arising from a pesticide limitation policy.

The Methodology

Two models were used interdependently to assess the economic impacts associated with various pesticide bans. For the Nebraska locality, the pesticide ban analysis utilized a linear programming framework described in the following subsection. Impact simulation for the national market was performed by use of U.S. Department of Agriculture's NIRAP model described in the second subsection.

The Linear Programming Model

The basic linear programming formulation was applied to the 1978 pesticide-use situation found in Nebraska. It included the production of corn, grain sorghum, and corn in rotation with other crops (including

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[6/] Some attempts have been made to measure the costs of pollution from pesticide use in several counties of Oklahoma and one in Florida (25, p. 158).

soybeans, alfalfa, and oats). The objective function was to maximize net revenue (return to the fixed factors of production) for the production of the above-named crops.

The land base is comprised of five major crop-producing regions in Nebraska (illustrated in Appendix E). Crop producing activities were specified for representative cropping rotations in each region. Specifically, these included continuous grain sorghum, continuous corn, and corn in rotation with soybeans, alfalfa or alfalfa plus oats. The producing activities for each rotation was varied by the use or nonuse of pesticide treatments (treatment was the recommended application rate). In sum, producing activities differed by pesticide treatment, geographic location, and crop rotation. A total of 102 different production activities were specified for the state of Nebraska.

Yield data inputed into the LP model were based upon published averages for the various areas of the State. In those cases where yields were affected by pesticide restrictions, percentage adjustments were made to these averages. The percentage changes were estimates obtained from UNL weed scientists and entomologists.

Aggregate crop budgets for the 1978 production year were prepared for each of the specific regions with a cropping mix believed to be representative. Details of these budgets were based heavily upon published UNL crop budgets (6).

<u>The Market Model</u>

National market simulation involved the use of USDA's National-Inter-Regional Agricultural Projections system (NIRAP) (3). NIRAP is an annualized model of the United States food and agricultural complex developed and maintained by the Economics and Statistics Service (22). The principal use of NIRAP, for this study, was to simulate the impact of non-price scenario-determined supply shifts on one or more major agricultural commodities.[7] Scenario-determined supply shifters were specified for feed grains and soybeans, whereupon NIRAP determined the new equilibrium price and quantity from the benchmark (point 2 in Model I) using econometrically-derived own and cross price elasticities for the crop commodities. Output of the NIRAP system included the new equilibrium price and quantity for all commodities affected through the supply shifts.

With determination of point 2 in Model I, the change in surpluses was then calculated according to equations (1) and (2).

$$CCS = \sum_{i=1}^{5} [(P_{2i}-P_{1i})\ (Q_{1i}+Q_{2i})/2] \qquad (1)$$

$$CPS = \sum_{i=1}^{5}([(P_{2i}-P_{1i})Q_{2i}/2] - [(P_{1i}-A_{1i})Q_{1i}/2]) \qquad (2)$$

$$CSW = CCS + CPS \qquad (3)$$

Where:

i = 1(corn), 2(grain sorghum), 3(oats), 4(barley), 5(soybeans);

P_1 = benchmark price;

P_2 = scenario determined price (from NIRAP);

Q_1 = benchmark quantity;

Q_2 = scenario determined quantity (from NIRAP);

A_1 = benchmark supply schedule (S_1) intercept on price axis;

CCS = change in aggregate consumer surplus;

CPS = change in aggregate producer surplus;

CSW = change in social welfare.

7/ For an expanded discussion on the capabilities of the NIRAP System, the reader is referred to Quance (22).

The Analysis Procedure

Five procedural steps were performed on each of the pesticide ban scenarios to assess the economic impact at the state and national levels. First, a benchmark solution to the linear programming model for the Nebraska locality was obtained which simulated the actual 1978 production basis or point 1 in Model II. Secondly, the impact of a pesticide ban was estimated by excluding the purchase and use of the banned pesticide(s) and rerunning the linear programming model for a new optimal solution. With the assumption that point 1 in Model I represented the U.S. production basis and average crop price received in 1978, the third step was to impact the NIRAP market model by the projected national supply shift.[8/] The result from NIRAP provided the new market price and quantity supplied which is represented by point 2 in Model I. Fourth, the Nebraska linear programming model was then rerun with the new market price to find the quantity supplied (point 2 in Model II). Finally, the changes in revenues as a result of the specific ban were calculated.

The Findings

The economic effects from three categories of pesticide bans were investigated in this study. Bans were imposed on individual pesticides: Treflan, Furadan and Counter, and atrazine for the purpose of observing the effects of eliminating pesticides that see wide use in Nebraska as

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[8/] For the first 3 scenarios, it was assumed that the pesticide selection and the impact, if any, on yield were reflective of the broader feed grain producing region and not just of Nebraska. For the other scenarios, aggregate supply shifts were based upon previously published estimates (34).

well as other major producing regions.[9] Then bans were imposed on all herbicides or insecticides for specified crops to reveal the effects on farmers and consumers when alternative chemical controls are not available to agricultural producers. Last, a total pesticide ban on all crops modeled was simulated in an attempt to reveal some of the effects of a return to organic farming methods.

Representation of the actual 1978 Nebraska pesticide-use pattern (benchmark solution) is found in Table 1. Gross revenues from the primary crops totaled $2.1 billion with returns to fixed factors of production being $1.2 billion. The cost of herbicides and insecticides was over $95 million, representing nearly 11 percent of the variable production costs.

Data in Table 2 are changes from the benchmark solution which occurred as a consequence of various pesticide bans.[10][11]

9/ Reference to commercial products or trade names is made with the understanding that no discrimination is intended and no endorsement by the Institute of Agriculture and Natural Resources, UNL, is implied.

10/ For bans on (1) Treflan, (2) Counter and Furadan, and (3) atrazine (scenarios 1 - 3), aggregate supply shifts were estimated on the basis of the Nebraska simulation since no studies at the national level were found. It was determined from a review of 1978 Pesticide Use Surveys for Iowa, Illinois, Indiana, Kansas, Michigan, Minnesota, Missouri, Ohio, and Wisconsin that the Nebraska use of these particular pesticides was somewhat less than the average for the Cornbelt region. Thus the impact of these pesticide bans are, in all probability, conservatively low.

11/ For scenarios 4 through 8 aggregate supply shifts were determined from the Taylor and Frohberg results (34). Although Taylor and Frohberg did not model all producing areas, their regions (Cornbelt states) are sufficiently important (Cornbelt states account for approximately 70 and 60 percent of the nation's output of corn and soybeans respectively) that the obtained results are good proxies for the aggregate level.

Table 1. Nebraska Farm Revenues, Costs, Production and Prices, 1978.

Item	Benchmark Solution
Revenues: ($1,000)	
Corn	1,551,505
Soybeans	283,028
Alfalfa	64,608
Grain Sorghum	222,363
Oats	10,466
Total	2,131,970
Costs: ($1,000)	
Cultivations	26,278
Diesel Fuel	226,920
Nitrogen Fertilizer	156,220
Scouting Program	4,799
Herbicides	66,285
Insecticides	29,162
Other Variable Costs	394,764
Total	904,428
Returns to fixed factors of production for Nebraska producers ($1,000)	1,227,542
Production:	
Corn (1,000 bu.)	738,812
Soybeans (1,000 bu.)	41,930
Alfalfa (1,000 ton)	2,019
Grain Sorghum (1,000 bu.)	115,814
Oats (1,000 bu.)	8,051
Crop Prices: (annual average)	
Corn ($/bu.)	2.10
Soybeans ($/bu.)	6.75
Alfalfa ($/ton)	32.00
Grain Sorghum ($/bu.)	1.92
Oats ($/bu.)	1.30

Table 2. Economic Changes Resulting From Selected Pesticide Bans.

Item	Scenario								
	1 Ban Treflan	2 Ban Counter and Furadan	3 Ban Atrazine	4 Ban All Herbicides	5 Ban Soybean Herbicides	6 Ban Corn Herbicides	7 Ban Corn Insecticides	8A Ban All Pesticides (Pessimistic)	8B Ban All Pesticides (Probable)
<u>Nebraska</u>									
Change in:									
Revenues: ($1,000)									
Corn	0	+ 2,275	+ 14,776	+ 104,585	+ 28,689	- 225,623	- 264,863	- 333.339	- 315,526
Soybeans	0	+ 231	+ 419	+ 52,605	-103,597	+ 50,442	+ 214,018	+ 903,464	+ 704,773
Alfalfa	0	0	0	+ 26,176	+ 14,176	+ 29,760	+ 29,760	+ 70,976	+ 100,448
Grain Sorghum	0	+ 2,316	- 2,644	- 1,743	- 13,898	+ 41,693	+ 11,581	- 222,363	- 222,363
Oats	0	- 47	+ 81	+ 3,620	+ 2,962	+ 4,090	+ 2,399	+ 3,059	+ 10,530
Total	0	+ 4,775	+ 12,632	+ 185,244	- 71,667	- 99,638	- 7,104	+ 421,798	+ 277,863
Costs: ($1,000)									
Cultivations	0	- 859	0	+ 25,125	+ 2,452	+ 13,229	- 1,837	+ 39,305	+ 37,532
Diesel Fuel	0	- 128	0	+ 2,697	+ 5,066	- 13,380	- 15,820	+ 194	- 3,786
Nitrogen Fertilizer	0	0	0	- 7,038	+ 9,423	- 29,658	- 22,916	- 149,999	- 154,829
Scouting Program	0	0	0	- 4,372	0	- 4,561	+ 3,650	- 4,799	- 4,799
Herbicides	+ 2,301	+ 795	- 17,721	- 66,285	- 11,170	- 40,445	- 1,603	- 66,285	- 66,285
Insecticides	0	- 9,240	0	+ 12,134	+ 6,306	+ 5,848	- 28,225	- 29,162	- 29,162
Other Variable Costs	+ 1	0	0	+ 5,836	+ 21,182	- 30,166	- 34,019	+ 14,453	+ 22,010
Total	+ 2,302	- 9,432	- 17,721	- 31,903	+ 33,259	- 99,133	- 100,770	- 196,293	- 199,319
Net revenues or returns to fixed factors of production for Nebraska producers ($1,000)	- 2,302	+ 14,207	+ 30,353	+217,147	-104,926	- 505	+ 93,666	+ 618,091	+ 477,182
Production:									
Corn (1,000 bu.)	0	- 5,897	0	-109,120	+ 63,317	- 208,459	- 156,621	- 289,304	- 221,666
Soybeans (1,000 bu.)	0	+ 575	0	- 11,053	- 24,776	+ 32,839	+ 32,478	+ 68,647	+ 75,108
Alfalfa (1,000 ton)	0	0	0	+ 818	+ 443	+ 930	+ 930	+ 2,218	+ 3,139
Grain Sorghum (1,000 bu.)	0	0	- 2,557	- 23,889	0	0	0	- 115,814	- 115,814
Oats (1,000 bu.)	0	- 36	0	+ 591	+ 2,956	+ 1,340	+ 1,340	0	+ 6,136
Corn Prices: (annual average)									
Corn ($/bu.)	0.00	+ 0.02	+ 0.02	+ 0.53	- 0.13	+ 0.40	+ 0.11	+ 0.61	+ 0.29
Soybeans ($/bu.)	0.00	- 0.07	+ 0.01	+ 4.12	+ 3.71	- 2.29	- 0.07	+ 3.98	+ 1.69
Alfalfa ($/ton)	0.00	+ 0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Grain Sorghum ($/bu.)	0.00	0.02	+ 0.02	+ 0.48	- 0.12	+ 0.36	+ 0.10	+ 0.56	+ 0.27
Oats ($/bu.)	0.00	0.0	+ 0.01	+ 0.33	- 0.08	+ 0.25	+ 0.07	+ 0.38	+ 0.18
<u>National</u>									
Change in:									
Nat'l. Aggregate Consumer Surplus ($ million)	0	- 106.63	- 180.75	- 10,211.34	- 4,137.45	+ 958.67	- 876.33	- 10,704.57	- 5,063.58
Nat'l. Aggregate Producer Surplus ($ million)	---a/	+ 26.24	44.71	+ 2,187.51	+ 925.84	- 157.29	+ 190.99	+ 2,281.36	+ 1,072.83
Nat'l. Aggregate Welfare ($ million)	---a/	- 80.38	- 136.04	- 8,023.83	- 3,211.51	+ 801.39	- 685.34	- 8,423.21	- 3,990.75

a/ A ban on Treflan resulted in Nebraska soybean producers turning to higher cost alternative herbicides, but the 3.5 percent increase in production costs was <u>not sufficient</u> to reduce output. Thus, there was no basis upon which to project the impact at the national level under this methodology. However, it is expected that most producers who had used Treflan would incur an increase in production costs and a narrowing of their profit margins, comparable to or greater than that for Nebraska.

At the national level, the general result found from the banning of pesticides in scenarios 2 through 7 was that the agricultural sector usually gained in revenue at the expense of consumers. Farmers received higher prices for a lower crop output resulting in net revenue gains, while consumers lost through higher commodity prices. Consumers, however, lost substantially more from the price increases than producers gained, thus this analysis suggests a net loss for society. The most extreme case occurred in scenario 4 when all herbicides were banned on corn, grain sorghum, and soybeans. This resulted in a welfare loss to society of $8 billion. When herbicides were banned entirely for particular crops (e.g. soybeans, scenario 5 or corn, scenario 6) acreage was shifted from the affected to the unaffected crops. This resulted in some benefit to consumers in the form of unaffected crops being supplied in greater output at lower prices. These gains were, however, less than the losses from higher prices on the affected crops in scenario 5. For scenario 6 the opposite result occurred with consumer gains from a 40 percent lower soybean price and greater output more than compensating for a 19 percent higher corn price.

In general, Nebraska producers experienced a revenue gain (returns to the fixed factors of production) through higher prices on a reduced output for the crops affected by the pesticide ban. For the uneffected crops that had an increase in production, Nebraska producers lost some revenue on those due to lower market prices. But in most scenarios these losses did not outweigh the gains.

Individual Pesticide Bans

Scenarios 1 through 3 presented in Table 2 reveal the impacts of banning important individual pesticides. Bans are placed on the use of Treflan on soybeans, Counter and Furadan on corn and grain sorghum, and atrazine on corn and grain sorghum.

Treflan ban. Due to suspected health hazards for humans and the environment, Treflan was placed on the Pre-RPAR list in 1979 for review and possible restriction. If the review (scheduled for completion in 1981 by the Environmental Protection Agency) substantiates the hazards, restrictions on Treflan use could be forthcoming. The severity of the restrictions will depend on the perceived health risk and the negative economic impact. Results of this study suggest that the negative economic impact would, most likely, be limited to agricultural producers. The banning of Treflan (scenario 1) simply results in a substitution of a higher cost alternative. But the incurred production cost increase is not sufficient to reduce the output of soybeans. The pesticide substituted in Nebraska is Lasso, the next most cost-effective herbicide (after Treflan), from the remaining major alternatives of Tolban, Amiben, and Lasso plus Lorox or Sencor. In this analysis, cost of herbicides rose by 3.5 percent and producer net revenues fell by $2.3 million.

In terms of the Nebraska farming sector, the net revenue effect of a Treflan ban is relatively minor. Producers' net revenues are reduced less than two-tenths of one percent.

Counter and Furadan ban. Counter and Furadan are the leading corn insecticides used on Nebraska farms (14) and also heavily used in Illinois, Iowa, Indiana, and Missouri.[12/] A ban on the use of these insecticides (scenario 2) results in a substitution of Sevin and Thimet. As a consequence, corn production falls nearly one percent due to somewhat less effective pest control. However, a two cent per bushel increase in the market prices of corn and grain sorghum and a saving in the cost of the substitute insecticides, combine to increase producer new revenues by $14.2 million for Nebraska farmers. In terms of total net revenues, this represented 1.2 percent increase for Nebraska's farming sector.

Atrazine ban. Atrazine alone and in combination with other herbicides is used on over 60 percent of Nebraska's corn acreage (14). A ban on this pesticide would cause a substitution of 2,4-D Esters and 2,4-D Amines in the northeast and eastern regions, Bladex in the north central region, and Banvel in the southwest region of Nebraska. Prowl which is commonly used in combination with atrazine is also eliminated in this scenario. For similar reasons, Eradicane and Sutan see substantially less usage. No yield reduction on corn would be anticipated with an atrazine ban, according to UNL weed scientists, if proper management exists.

Atrazine is also the predominant herbicide used on Nebraska grain sorghum, and at present, there are no perfect substitutes. Here Ramrod was selected in the combination with the forms of 2,4-D as the next best alternative. This resulted in a 2.2 percent production loss on sorghum from less effective weed control.

12/ Based on preliminary findings of 1978 state benchmark surveys of agricultural crop pesticide usage.

The impact on the national feed grain supply from diminished grain sorghum production forced the price of corn, oats, and grain sorghum up a few cents, and indirectly raised the price of soybeans one cent. In addition, the herbicides substituted for atrazine were generally cheaper resulting in a total cost for herbicide treatment falling by $17.7 million in Nebraska. Lower production costs coupled with increased revenues, from slightly higher market prices, combined to increase Nebraska producer revenues by $30.3 million, a 2.5 percent increase.

Obviously, the results of this scenario are heavily contingent upon the validity of the above assumption that no corn yield reductions would result from the substitution of alternative treatments to atrazine. The fact that many producers currently prefer atrazine over less costly inputs would suggest the latter may be somewhat less effective. However, according to weed scientists, there would be little or no yield effect of this substitution so long as there is effective management.

Impacts of Pesticides Banned by Groups on Specific Crops

The banning of all herbicides on corn, grain sorghum, and soybeans (scenario 4) would have a substantial effect on Nebraska producers. Production declines, assuming comparable declines elsewhere, would result in sharp increases in commodity prices, particularly corn and soybeans. Net revenues for Nebraska producers increase nearly 18 percent.

Banning all soybean herbicides (scenario 5) would result in a shift of acreage into continuous corn and corn in rotation with alfalfa and oats. Overall, the corn acreage would increase approximately 9 percent, while soybean acreage would be halved. The acreage in corn is treated with the following herbicides: atrazine, 2,4-D Esters-Amines, Bladex, Banvel, and Lasso. Furadan is selected as the corn insecticide.

Such a shift in production, assuming this impact would characterize national production, would cause feed grain prices to fall by about 6 percent while the price of soybeans would rise by 55 percent. For Nebraska producers this translated into a total revenue loss of $71.7 million. When the effect of higher corn production costs are added, producer revenues fell by $104.9 million, nearly a 9 percent decline from the benchmark return. This contrasts with a small surplus gain for producers nationally. The reasoning behind this is that a greater decline in Nebraska soybean production occurred as compared to that for the nation.

Banning all corn herbicides (scenario 6) or corn insecticides (scenario 7) results in a dramatic acreage shift to soybeans in rotation with corn or corn in rotation with alfalfa. In this instance, the soybean acreage is treated with the herbicide, Treflan.

For scenario 6, feed grain prices rose by an average of 19 percent while the price of soybeans fell by 34 percent. For Nebraska farmers, this translated into a total revenue decline of $99.6 million; but the savings in production costs limited the net revenue loss to only $.5 million.

For scenario 7, the impact of banning all corn insecticides is in the same direction as that for the herbicide ban of scenario 6, in that, Nebraska producers experienced declines in revenue, costs, and corn production. The main difference, however, between the scenarios was the 25 percent greater loss in corn production from banning herbicides vis-a-vis insecticides. The smaller loss in corn production when insecticides were banned had the effect of a smaller revenue decline which resulted in an increase of $93.7 million in Nebraska producer net revenues.

Impacts From a Total Pesticide Ban

An attempt was made in scenario 8 to simulate the impact from banning all pesticides for all crops in the model and requiring producers to use nonchemical farming methods. For this scenario, impacts on crop yields and aggregate crop production are not known with any certainty. Case studies on individual organic farm operations exist from which the Nebraska crop yields could be inferred. However, the crop yields obtained are quite variable from case to case. More importantly, it would be difficult to ascertain whether these yields are, in fact, representative when all producers adopt organic farming methods. For impacts on the aggregate crop output, judgments of persons knowledgeable about agriculture, must be used. The most optimistic view is that the decrease in crop production would be negligible after turning to organic farming. The most pessimistic view claims a crop production decline equal to that under conventional farming without pesticides. The production decline that would probably occur is somewhwere between these views.

Scenario 8A was designed to model the most pessimistic impact from a total pesticide ban by assuming Nebraska crop yields to be no better than that for conventional farming without pesticides. In addition, chemical fertilizers were reduced considerably and assumed to be replaced with alternative practices. Estimates of aggregate production declines were found by summing Taylor and Frohberg's (34) production impacts from a total herbicide and an insecticide ban. This resulted in national production declines estimated to be 15 and 22 percent, respectively, for corn and soybeans.

Scenario 8B was designed to simulate the impact from banning all pesticides by assuming more moderate and more probable aggregate declines of 8 and 11 percent respectively, for corn and soybeans. Nebraska corn and soybean yield declines were set in similar fashion, i.e., yield losses were set midway between no loss and that assumed for scenario 8A.

The results of the total pesticide ban simulation are present in Table 2.[13/] Net revenue of Nebraska farmers reaches the highest level of change in scenario 8A when compared to any scenario under conventional farming methods (scenario 1 through 7). Returns to Nebraska producers' fixed factors of production under this scenario increased 50 percent above the 1978 benchmark level. This is due to higher crop prices for a smaller output, and lower costs of production from avoidance of pesticides and nitrogen fertilizer. The results of scenario 8B are similar to that of 8A, but the magnitude of change in total revenue production and producer surplus is more moderate. Producer returns increase 39 percent above the benchmark level.

13/ Production of grain sorghum in both scenarios 8A and 8B falls to zero because only a corn-soybean production activity was specified for the eastern and southcentral regions of Nebraska. If a soybean-grain sorghum rotation had been included, the impact to scenarios 8A and B would be to lower the production of corn and increase that for grain sorghum. Change in total revenues and producer revenues then decrease, modestly, since the price of grain sorghum is somewhat lower than that for corn, and may not change much since grain sorghum and corn prices are closely correlated.

At the aggregate level, the largest net loss in social welfare would occur in scenario 8A ($8.4 billion) with a total pesticide ban. With the more moderate crop production and yield declines assumed for scenario 8B, society welfare losses decrease to only $3.9 billion. It is important to note, however, the distributional aspects of such a ban. The consumer faces considerable increases in ag commodity prices. This may imply that a total pesticide ban would be politically unacceptable, primarily from the standpoint of the consumer rather than the producer.

THE CONCLUSIONS

An analysis was made to assess the economic impacts of several pesticide restriction scenarios on crop production in Nebraska. A restriction could specify that one, several, or all herbicides or insecticides be banned from agricultural use. Since pesticide bans are national in extent, the impacts on a given locality should not be analyzed under the assumption that market prices remain constant for all crops. Rather than maintaining the constant price assumption, or varying prices in some arbitrary manner, a conceptualization and procedure were presented and then applied to estimate the market price effects on particular crops subsequent to a national pesticide ban.

The overall impact from a pesticide restriction generally resulted in a positive gain for agricultural producers at the expense of consumers. Such a result is quite consistent with previous research (34), where specific comparisons were impossible.[14/] Given the nationally dictated

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[14/] Comparisons were made on the total herbicide (scenario 4) and insecticide ban (scenario 7) of this study and that for Taylor, Frohberg (34, P. 31).

bans discussed in this analysis, consumers lost an amount less than 1 percent of U.S. Personal Disposable Income for 1978 in all scenarios examined. At the national level, producers gained surplus in an amount up to 9 percent of 1978 U.S. Farm Income in the situations studied.[15/]

If Harberger's (8) welfare aggregation postulate is accepted, however, the sum of the gains and losses net to an overall loss for society in all but one of the scenarios. But, this estimated social gain or loss is not complete in that neither the costs of government enforcement were deducted, nor were the social gains from reduced health hazards included.

This study has also attempted to address the issue concerning the banning of all pesticides and requiring producers to turn to nonchemical farm practices. While total economic losses to consumers were found to be substantial, these need to be weighed against such non-pecuniary gains as improved human health and an increased aesthetic sense of environmental well-being. Further research is needed to address the questions concerning the health and environmental costs from the continued use of chemical pesticides. Also research on the economic implications of biological controls as a substitute for insecticides might reveal interesting results.

The Implications

For a given national ban on a pesticide or pesticides, the economic implications for locality producers will depend heavily on the following parameters:

1. Availability of cost-competitive substitutes.
2. Extent of pesticide use within the locality and across all localities.
3. The number of commodities affected by the pesticide ban.

15/ For 1978, U.S. Personal Disposable Income was $1,458.4 billion, and Net Farm Income was $25.2 billion (37).

If an effective and cost-competitive substitute is available, then there will be no surplus gain or loss for locality producers. If the pesticide in question has no good substitutes (units of effectiveness per dollar) and use is confined to only a few producing localities, then the producers in the impacted locality will bear a revenue loss. If the pesticide has no good substitutes, and use is extensive within and across most localities, the gain or loss will depend upon the relative market impacts and interactions on all affected commodities. Locality producers will realize a revenue gain if the increased net revenue (revenue minus production costs) from those commodities with market supply declines resulting in higher prices, is greater than the decreased net revenue from those commodities with market supply increases resulting in lower prices. Otherwise local producers will incur revenue losses. Any appraisal of the impacts of national pesticide restrictions will require 1) the need to model the complexities of commodity market interactions and 2) the summation of revenue gains and losses for locality producers in order to determine their resultant economic surplus position.

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Appendices

Appendix A

Table A1. Estimated 1978 Production and Acreage Harvested in Nebraska for the Pesticide Limitation Model.

Region/Crop	Acreage Harvested	Production (1,000 bu.)
Northeast		
Corn	1,561,000	149,487
Soybeans	453,000	15,378
Alfalfa	335,000	1,225
Eastern		
Corn	2,982,700	273,126
Grain Sorghum 2/	1,327,500	102,789
Soybeans	755,700	25,806
Southcentral		
Corn 1/	1,511,000	187,314
Grain Sorghum 2/	226,200	13,166
Soybeans	19,000	732
Northcentral		
Corn 1/	508,500	59,225
Alfalfa	155,000	613
Southwest		
Corn 1/	521,500	61,710
Alfalfa	46,000	197

1/ Irrigated corn acreage only.

2/ Dryland sorghum acreage only.

Source: Nebraska Agricultural Statistics, 1978 Preliminary, Nebraska Crop and Livestock Report Service.

Appendix B

Table B1. Estimated Crop Yield For Each Pesticide Use Strategy.*

Northeast Nebraska

Rotation	Herbicide	Insecticide[2]	Corn Yield[13] bu/acre
Corn after corn	Any[6]	1 or 2	109
	Any	3,4,5, or 6	106
	Any	None	93
	None	1 or 2	89
	None	3,4,5, or 6	86
	None	None	73

Rotation	Herbicide	Insecticide	Corn Yield bu/½ acre	Soybean Yield bu/½ acre
Corn followed by Soybeans	Any[6]	1 or 2	54	15 w/herbicide[7] 12 no Herbicide
	Any	3,4,5, or 6	53	
	Any	None	51	
	None	1 or 2	45	
	None	3,4,5, or 6	43	
	None	None	41	

Rotation	Herbicide	Insecticide	Corn Yield bu/½ acre	Yield bu/1/8 acre Oats[8]	Yield tn/3/8 acre alfalfa[9]
Corn (4 yrs) followed by Oats (1 yr) & Alfalfa (3 yrs)	Any[6]	1 or 2	54	10	1.50
	Any	3,4,5, or 6	53		
	Any	None	51		
	None	1 or 2	45		
	None	3,4,5, or 6	43		
	None	None	41		

* See footnotes at end of table.

Eastern Nebraska

Rotation	Herbicide	Insecticide[2]	Corn Yield[13] bu/acre
Corn after corn	Any[1]	1 or 2	126
	Any	3,4,5, or 6	122
	Any	None	107
	None	1 or 2	103
	None	3,4,5, or 6	100
	None	None	84

Rotation	Herbicide	Insecticide	Corn Yield bu/½ acre	Soybean Yield bu/½ acre
Corn followed by Soybeans	Any[1]	1 or 2	63	19 w/herbicide[3]
	Any	3,4,5, or 6	61	15 no herbicide
	Any	None	59	
	None	1 or 2	52	
	None	3,4,5, or 6	50	
	None	None	47	

Rotation	Herbicide	Insecticide	Sorghum Yield bu/acre
Sorghum after sorghum	Atrazine and Ramrod + Atrazine	2,4,7,8, or 9	82
		None[12]	80
	Ramrod + 2,4-D Amines	2,4,7,8, or 9	78
		None[12]	78
	None	2,4,7,8, or 9	62
		None[12]	62

Southcentral Nebraska	Herbicide	Insecticide	Corn Yield[13] bu/acre
Corn after corn	Any[9]	1 or 2	134
	Any	3,4,5, or 6	130
	Any	None	114
	None	1 or 2	110
	None	3,4,5, or 6	106
	None	None	90

			Corn Yield bu/½ acre
Corn followed by Soybeans	Any[9]	1 or 2	67
	Any	3,4,5, or 6	65
	Any	None	62
	None	1 or 2	55
	None	3,4,5, or 6	53
	None	None	50
			Soybean Yield bu/½ acre
			20 with herbicide[11]
			15 no herbicide

			Sorghum Yield bu/acre
Sorghum after sorghum	Atrazine and Ramrod + Atrazine	2,4,7,8, or 9	61
		None[12]	61
	Ramrod + 2,4-D Amines	2,4,7,8. or 9	58
		None[12]	58
	None	2,4,7,8, or 9	46
		None[12]	46

Northcentral Nebraska			Corn Yield bu/acre
Corn after corn	Any[4]	1 or 2	125
	Any	3,4,5, or 6	121
	Any	None	106
	None	1 or 2	102
	None	3,4,5, or 6	99
	None	None	84

Rotation	Herbicide	Insecticide	Corn Yield[13] bu/½ acre
Corn (3 yrs.), alfalfa (3 yrs.)	Any[4]	1 or 2	62
	Any	3,4,5, or 6	61
	Any	None	58
	None	1 or 2	51
	None	3,4,5, or 6	49
	None	None	47

Alfalfa[5] Yield tn/½ acre
2.0

Southwest Nebraska	Herbicide	Insecticide	Corn Yield bu/acre
Corn after corn	Any[11]	1 or 2	125
	Any	3,4,5, or 6	121
	Any	None	106
	None	1 or 2	102
	None	3,4,5, or 6	99
	None	None	8[illegible]

	Herbicide	Insecticide	Corn Yield bu/½ acre
Corn (3 yrs.), alfalfa (3 yrs.)	Any[11]	1 or 2	62
	Any	3,4,5, or 6	61
	Any	None	58
	None	1 or 2	51
	None	3,4,5, or 6	49
	None	None	47

Alfalfa[5] Yield tn/½ acre
3

Footnotes to Table B1.

1. "Any" herbicide in the Eastern region is one or a combination of the following: Lasso, Atrazine, Sutan, Ramrod, Bladex, Banvel, and 2,4-D.

2. Insecticides are 1=Counter, 2=Furadan, 3=Dyfonate, 4=Thimet, 5=Sevin, 6=Mocap, 7=Parathion, 8=Di-Syston, and 9=Cygon.

3. Soybean herbicides used in the Eastern region are Lasso, Amiben, Sencor, and Treflan.

4. "Any" herbicide in the Northcentral region is one or a combination of the following: Lasso, Atrazine, Sutan, Ramrod, and Bladex.

5. No significant quantities of pesticides were used on alfalfa in the Northcentral, Northeast, of Southwest regions.

6. "Any" herbicide in the Northeast region is one or a combination of the following: Lasso, Banvel, 2,4-D, Atrazine, Bladex, Ramrod, and Sutan.

7. Soybean herbicides used in the Northeast region are: Lasso, Treflan, Sencor, Lorox, and Amiben.

8. No significant quantities of pesticides were used on oats in the Northeast region.

9. "Any" herbicide in the Southcentral region is one or a combination of the following: Lasso, Banvel, Atrazine, Eradicane, Ramrod, Sutan and Prowl.

10. Soybean herbicides used in the Southcentral region are: Lasso, Treflan, and Sencor.

11. "Any" herbicide in the Southwest region is one or a combination of the following: Lasso, Banvel, Atrazine, and Sutan.

12. Only 25 percent of Nebraska sorghum was treated with insecticides. Where no insecticice was used, it was assumed that there was no insect problem.

13. <u>Data sources and yield reduction criteria</u>

    Pesticide types were determined from the 1978 Agricultural Pesticide Usage in Nebraska Survey conducted by the Department of Agricultural Economics, University of Nebraska, Lincoln, in cooperation with the North Central Regional Pesticide Assessment Program.

    Rules for reducing yields were formulated after reviewing Slife (33), Taylor and Frohberg (36), and interviewing weed scientists and entomologists at the University of Nebraska.

Footnotes to Table B1 (cont.).

Corn

1. Banning all herbicides results in an 18% yield reduction and requires one additional cultivation per acre.
2. Banning all insecticides results in a 15% yield reduction for corn grown in rotation with corn. A 7% yield reduction is assumed if corn is grown in rotation with soybeans, oats, or alfalfa.
3. Substituting Dyfonate (3), Thimet (4), Sevin (5), or Mocap (6) for Counter (1) or Furadan (2) was assumed to result in a 4% yield reduction from less insect control.

Soybeans

1. Banning all herbicides results in a 20% yield reduction on soybeans and requires two additional cultivations.

Sorghum

1. Banning all herbicides results in a 25% yield reduction on continuous sorghum and requires one additional cultivation per acre.
2. Substituting Ramrod + 2,4-D Ester Amines for Atrazine or Ramrod + Atrazine results in a 5% yield reduction from less weed control.
3. If no insecticide was used, it was assumed that there was no insect problem.

Appendix C

Table C1. INSECTICIDES: Purchase Price, Application Rate Per Acre, and Treatment Cost Per Acre.[1/]

INSECTICIDE	PRICE PER UNIT	RATE/AC	TREATMENT COST PER ACRE
CORN			
Counter	$1.03/lb.	7.5 lb.	$7.70
Furadan	.74/lb.	10.0 lb.	7.40
Dyfonate	1.20/lb.	5.0 lb.	6.00
Thimet	.75/lb.	6.5 lb.	4.75
Sevin	3.50/qt.	1.0 qt.	3.50
Mo-Cap	.59/lb.	10.0 lb.	5.90
SORGHUM			
Furadan	$ .74/lb.	10.0 lb.	$7.40
Thimet	.75/lb.	6.5 lb.	4.75
Parathion	1.20/lb.	0.5 lb.	.60
Di-Syston	2.50/lb.	0.625 lb.	1.56
Cygon	5.00/lb.	0.5 lb.	2.50

[1/] Prices and application rates provided by Dr. Robert Roselle, Extension Entomologist, Institute of Agriculture and Natural Resources, University of Nebraska, Lincoln.

Table C2. HERBICIDES. Purchase Price, Application Rate Per Acre & Treatment Cost Per Acre by Region[a]

Crop and Herbicide	Price Per Unit	Northeast (silty-clay-loam)	Eastern (silt loam)	Southcentral (silt loam)	Northcentral (sandy loam)	Southwest (sandy loam)
CORN						
Atrazine	$2.10/lb	3.75 lb $7.90/ac	3.00 lb $6.30/ac	3.00 lb $6.30/ac	2.50 lb $5.25/ac	2.50 lb $5.25/ac
Lasso + Atrazine	$3.60/qt $2.10/lb	2.00 qt + 1.50 lb $10.35/ac	1.25 lb $9.85/ac	2.00 qt + 1.25 lb $9.85/ac	2.00 qt + 1.25 lb $9.85/ac	2.00 qt + 1.25 lb $9.85/ac
Lasso	$3.60/qt	3.00 qt $10.80/ac	2.50 qt $9.00/ac	2.50 qt $9.00/ac	3.00 qt $10.80/ac	3.00 qt $10.80/ac
Sutan[2] + Atrazine	$1.60/pt $2.10/lb	3.75 pt + 1.50 lb $9.15/ac	3.75 pt + 1.25 lb $8.65/ac	3.75 pt + 1.25 lb $8.65/ac	3.75 pt + 1.25 lb $8.65/ac	3.75 pt + 1.25 lb $8.65/ac
Lasso + Bladex	$3.60/qt $2.50/lb	2.00 qt + 2.00 lb $12.20/ac	2.00 qt + 1.50 lb $10.95/ac	2.00 qt + 1.50 lb $10.95/ac	2.00 qt + 1.50 lb $10.95/ac	Not Used
Ramrod + Atrazine	$1.75/lb $2.10/lb	5.00 lb + 1.50 lb $11.90/ac	5.00 lb + 1.50 lb $11.90/ac	5.00 lb + 1.50 lb $11.90/ac	5.00 lb + 1.50 lb $11.90/ac	Not Used
Eradicane + Atrazine	$2.60/pt $2.10/lb	4.75 pt + 1.50 lb $15.57/ac	4.75 pt + 1.25 lb $15.05/ac	4.75 pt + 1.25 lb $15.05/ac	4.75 pt + 1.25 lb $15.05/ac	4.75 pt + 1.25 lb $15.05/ac
2,4-D's	(Ester & Amine) $1.00/pt	1.25 pt $1.25/ac	1.25 pt $1.25/ac	1.25 pt $1.25/ac	1.25 pt $2.25/ac	1.25 pt $1.25/ac
Bladex	$2.50/lb	4.00 lb $10.00/ac	3.00 lb $7.50/ac	3.00 lb $7.50/ac	3.00 lb $7.50/ac	Not Used
Prowl + Atrazine	$7.15/qt $2.10/lb	1.50 qt + 2.00 lb	1.50 qt + 1.50 lb	1.50 qt + 1.50 lb	Not Used	Not Used
Sutan[2]	$1.60/pt	5.00 pt $8.00/ac	5.00 pt $8.00/ac	5.00 pt $8.00/ac	5.00 pt $8.00/ac	5.00 pt $8.00/ac
			(Grass Control Only)			
Banvel	$4.50/pt	.50 pt $2.25/ac	.50 pt $2.25/ac	.50 pt $2.25/ac	.50 pt $2.25/ac	.50 pt $2.25/ac
Eradicance	$2.20/pt	5.00 pt $11.00/ac	5.00 pt $11.00/ac	5.00 pt $11.00/ac	5.00 pt $11.00/ac	5.00 pt $11.00/ac
SOYBEANS						
Lasso	$3.60/qt	2.50 qt $9.00/ac	2.50 qt $9.00/ac	2.50 qt $9.00/ac	2.50 qt $9.00/ac	2.50 qt $9.00/ac
Treflan	$3.33/pt	1.50 pt $5.00/ac	1.50 pt $5.00/ac	1.50 pt $5.00/ac	1.00 pt $3.33/ac	1.00 pt $3.33/ac
Prowl	$7.15/qt	1.00 qt $6.40/ac	1.00 qt $6.40/ac	1.00 qt $6.40/ac	.75 qt $4.80/ac	.75 qt $4.80/ac
Treflan + Sencor	$3.33/pt $5.83/lb	1.25 pt + .75 lb $8.45/ac	1.00 pt + .75 lb $7.70/ac	1.00 pt + .75 lb $7.70/ac	Not Used	Not Used
Tolban	$3.33/pt	1.50 pt $5.00/ac	1.50 pt $5.00/ac	1.50 pt $5.00/ac	1.00 pt $3.33/ac	1.00 pt $3.33/ac
Lasso + Sencor	$3.60/at $6.25/lb	2 qt + .75 lb $11.90/ac	2 qt + .75 lb $11.90/ac	2 qt + .75 lb $11.90/ac	Not Used	Not Used
Amiben	$2.62	6 qt $15.72/ac	6 qt $15.72/ac	Not Used	Not Used	Not Used
Lasso +	$3.60/qt	2 qt +2.0 lb $13.80/ac	2 qt + 1.5 lb $12.14/ac	Not Used	Not Used	Not Used
SORGHUM						
Atrazine	$2.10/lb	Not Used	2.5 lb $5.25/ac	3.0 lb $6.30/ac	Not Used	Not Used
Atrazine + Ramrod	$2.10/lb $1.75/lb	Not Used	1.0 lb + 5.0 lb $10.85/ac	1.0 lb + 5.0 lb $10.85/ac	Not Used	Not Used
Ramrod + 2,4-D (Ester & Amines)	$1.75/lb $1.00/pt	Not Used	5.0 lb .75 pt $9.50/ac	5.0 lb .75 pt $9.50/ac	Not Used	Not Used
Ramrod + Bladex	$1.75/lb $2.50/lb		4.0 lb $10.75 ac	4.0 lb $11.25/ac		

Source: 1978 Guide for Herbicide use in Nebraska, Extension Circular 78-130, Institute of Agriculture and Natural Resources, University of Nebraska, Lincoln.

Table C3. Diesel Fuel, Nitrogen Fertilizer, and Cultivation; Purchase Price and Application Rate Per Acre by Region.

	Cost	Application
Northeast Nebraska		
Diesel Fuel (cultivation)	$ .47/gal.	1 gal/acre
Diesel Fuel (all other use)		
Corn After Corn	.47/gal.	59.9 gal/acre
Corn, Soybeans	.47/gal.	45.4 gal/acre
Corn, Oats, Alfalfa	.47/gal.	32.6 gal/acre
Nitrogen Fertilizer[1/]		
Corn After Corn	2.80/ton	160 lb/acre
Corn, Soybeans	2.80/ton	80 lb/acre
Corn, Oats, Alfalfa	2.80/ton	100 lb/acre
Cultivation	2.89/acre	1
Eastern Nebraska		
Diesel Fuel (cultivation)	$ .47/gal.	1 gal/acre
Diesel Fuel (all other use)		
Corn After Corn	.47/gal.	59.9 gal/acre
Corn, Soybeans	.47/gal.	45.4 gal/acre
Sorghum After Sorghum	.47/gal.	8.0 gal/acre
Nitrogen Fertilizer[1/]		
Corn After Corn	2.80/ton	160 lb/acre
Corn, Soybeans	2.80/ton	80 lb/acre
Sorghum After Sorghum	2.80/ton	80 lb/acre
Cultivation	3.51/acre	1
Cultivation (Sorghum Only)	1.58/acre	1
Southcentral Nebraska		
Diesel Fuel (cultivation)	$ .47/gal.	1 gal/acre
Diesel Fuel (all other use)		
Corn After Corn	.47/gal.	52.4 gal/acre
Corn, Soybeans	.47/gal.	37.9 gal/acre
Sorghum After Sorghum	.47/gal.	7.0 gal/acre
Nitrogen Fertilizer[1/]		
Corn After Corn	2.80/ton	160 lb/acre
Corn, Soybeans	2.80/ton	80 lb/acre
Sorghum After Sorghum	2.80/ton	60 lb/acre
Cultivation	2.02/acre	1
Cultivation (Sorghum Only)	.87/acre	2

(Continued on next page)

Table C3 continued.

	Cost	Application
Northcentral Nebraska		
Diesel Fuel (cultivation)	$ .47/gal.	1 gal/acre
Diesel Fuel (all other use)		
Corn After Corn	.47/gal.	96.9 gal/acre
Corn, Alfalfa	.47/gal.	80.1 gal/acre
Nitrogen Fertilizer 1/		
Corn After Corn	2.80/ton	175 lb/acre
Corn, Alfalfa	2.80/ton	125 lb/acre
Cultivation	1.42/acre	0
Southwest Nebraska		
Diesel Fuel (cultivation)	$ .47/gal.	1 gal/acre
Diesel Fuel (all other use)		
Corn After Corn	.47/gal.	96.9 gal/acre
Corn, Alfalfa	.47/gal.	80.1 gal/acre
Nitrogen Fertilizer 1/		
Corn After Corn	2.80/ton	175 lb/acre
Corn, Alfalfa	2.80/ton	125 lb/acre
Cultivation	1.42/acre	0

1/ No nitrogen fertilizer applied to soybeans, alfalfa, or oats.

Source: Based upon representative farm budgets presented in Estimated Crop and Livestock Production Costs, Nebraska 1978, Department of Agricultural Economics Report No. 80, Nov. 1977.

Appendix D

Table D1. Total Variable Costs

	Cost/Acre[1]
Northeast region	
Corn After Corn	\$53.54[3]
Corn - Soybeans	32.45
Corn - Oats - Alfalfa	36.33[4]
Eastern region	
Corn After Corn	\$53.54[3]
Corn - Soybeans	32.22
Sorghum After Sorghum	25.31[5]
Southcentral region	
Corn After Corn	\$44.54
Corn - Soybeans	33.35
Sorghum After Sorghum	25.67[5]
Northcentral region	
Corn After Corn	\$42.90
Corn - Alfalfa	37.45[2]
Southwest region	
Corn After Corn	\$64.46
Corn - Alfalfa	53.80[2]

1/ Variable costs per acre less herbicides, insecticides, fuel, fertilizer and cultivation.

2/ Cost per acre is a composite based on corn in rotation with alfalfa.

3/ Cost per acre is a composite based on irrigated and dryland corn production.

4/ Cost per acre is a composite based on corn in rotation with oats and alfalfa.

5/ Cost per acre is for dryland sorghum production only.

Source: Representative farm budgets presented in Estimated Crop and Livestock Production Costs, Nebraska 1978, Department of Agricultural Economics Report No. 80, 1977.

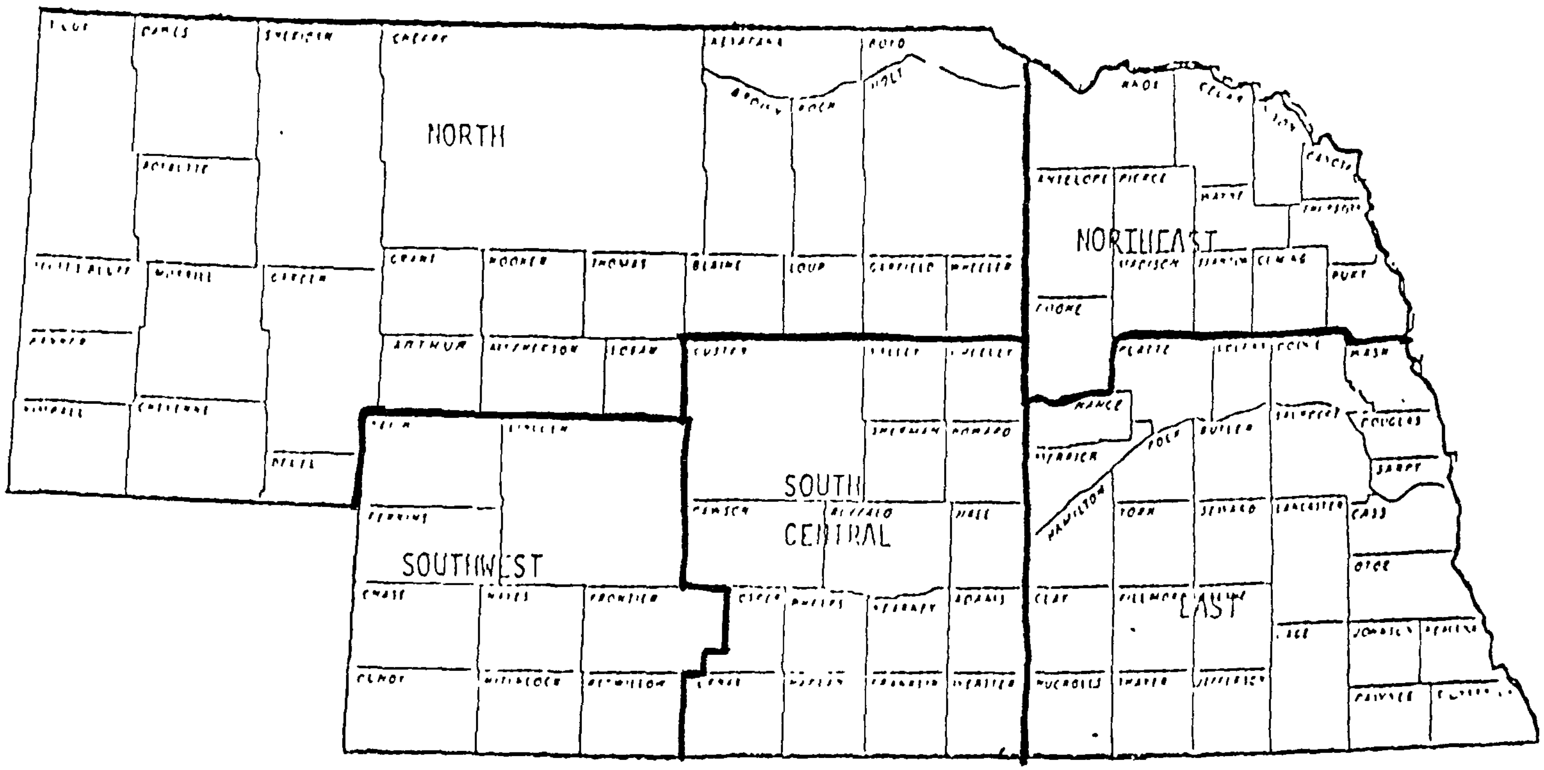

Figure E1. Sub-State Regions in Pesticide Impact Assessment Model.

Table 1. Linear Programming Model, Matrix Representation.

Rows	Purchase Activities: Herbicide Treatment	Purchase Activities: Insecticide Treatment	Purchase Activities: Fuel	Purchase Activities: N. Fertilizer	Purchase Activities: Cultivation	Production Activities: Pesticide Use Strategies Corn Rotation	Corn	Sorghum	Soybeans	Alfalfa	Oats	RHS
1 Obj. Function (Maximum Net Revenue)	$-P_{ht}$	$-P_{it}$	$-P_f$	$-P_n$	$-P_{cu}$	$-C_r$	S_c	S_{sr}	S_s	S_a	S_o	LTE 0
2 Corn (bu)						$-Y_{rc}$	+1					LTE 0
3 Sorghum (bu)						$-Y_{rsr}$		+1				LTE 0
4 Soybeans (bu)						$-Y_{rs}$			+1			LTE 0
5 Alfalfa (ton)						$-Y_{ra}$				+1		LTE 0
6 Oats (bu)						$-Y_{ro}$					+1	LTE 0
7 Land (acres)						+1						LTE L
8 Rotation (acres)						+1						GTE R
9 Herbicide Treatment	-1					+1						EQ 0
10 Insecticide Treatment		-1				+1						EQ 0
11 Fuel (gal)			-1		+1	$+D_r$						LTE 0
12 N. Fertilizer (lb)				-2000		$+N_r$						LTE 0
13 Cultivations (acres)					-1	$+CU_r$						LTE 0

Definitions

C Total variable costs for pesticide production strategy (exclusive of fuel, fertilizer, cultivations, and pesticides). Subscript r indicates the rotation.

P Purchase prices for pesticide per treated acre, fuel, fertilizer and cultivations with ht, it, f, n and cu subscripts delineated the input.

S Selling prices for corn, grain sorghum, soybeans, alfalfa and oats with c, r, s, a and o subscripts delineating the commodity.

Y Yield per acre for the rotations with r delineating the rotations and e, sr, s, a and o delineating the commodity.

D,N Quantity of fuel and nitrogen fertilizer applied to a specified rotation r.

CU Number of cultivations applied to a specified rotation r.

Bounds

Lower bounds are specified for purchase of pesticides and production activities to meet the pesticide use distribution and cropping patterns found in Nebraska for the benchmark scenario.