ANALYZING PEST CONTROL STRATEGIES FOR COTTON WITH AN ENVIRONMENTAL IMPACT MATRIX*

James W. Richardson and Daniel D. Badger

Agricultural pesticide use has come under an intensive attack from an environmentally aware society. The Environmental Protection Agency has placed restrictions on use of selected pesticides, including DDT. The use of pesticide is a paradox in itself. Without feasible alternative insecticide strategies, such as biological control, restrictions on the use of pesticides will decrease agricultural output and food costs will increase. However, with pesticide use, social costs in the form of environmental damages may occur. To make an equitable decision as to the future of pesticides, researchers and policy-makers have tried to determine the optimal level of use, optimal timing of application, extent of economic benefits, extent of social costs, and the effects on the economy of pesticide restrictions.

Agricultural economists have suggested and used several methods to analyze the effects of pesticide use and non-use. Headley and Lewis [2] presented a conceptual decision framework based on consumers' surplus, and Edwards [1] attempted a quantitative application of Headley and Lewis' methodology. Lacewell and Masch [4] and Horne [3] used linear programming to estimate the effects of various levels of pesticide use on agriculture and to some extent on the economy. The major problem encountered by these and other researchers has been that impacts, both beneficial and adverse, associated with pesticide use are qualitative as well as quantitative. Qualitative data has been the stumbling block for our conventional methodology.

In an effort to measure both qualitative and quantitative effects of pesticide use, an extensive survey was made of the four major cotton producing counties in Oklahoma. Interviewed were extension specialists, farmers, licensed pesticide applicators, health officials, and other technical advisors. The results of the survey and secondary data made up the bench mark for comparing the alternative methods of pest control. In the study area, the present method of insect control on cotton involves using toxaphene and methyl-parathion every seven days, after mid-July [5]. Another aspect of this project was to determine economic benefits and costs of the present and alternative pest control strategies.

The alternative methods of pest control analyzed for cotton were those considered to be feasible in Oklahoma at this time or in the near future (until the end of the 1970's). Alternative strategies analyzed were: (1) use non-persistent insecticides, primarily methyl-parathion; (2) utilize a scouting program to monitor insect levels and recommend pesticide control as insects reach an economic threshold; (3) plant strips of grain sorghum among rows of cotton as a biological trap crop control; (4) use no insect controls.

DEVELOPMENT OF THE ENVIRONMENTAL IMPACT MATRIX

A methodology has been developed for the analysis of quantitative and qualitative data relating to the use of agricultural inputs such as pesticides. This procedure has been synthesized into an environmental impact matrix. The Water Resources Council, in its proposed water resource development guidelines to replace Senate Document No. 97, and in the final adopted guidelines, has been a strong proponent of environmental impact matrices [6]. In our study the environmental impact matrix provides a means to rank alternative pest control strategies.

James W. Richardson is a research associate and Daniel D. Badger is professor of agricultural economics at Oklahoma State University.

*Oklahoma Agricultural Experiment Station Journal Article J-2769.

The environmental impact matrix presented here was developed specifically to analyze alternative pest control strategies for cotton and included three major parameters: economic, environmental and social well-being [5]. The net overall impact of different alternative pest control strategies was determined by weighting selected factors of variables under each of these major parameters and then determining the net beneficial and/or adverse impacts of each weighted factor.

The parameters in the matrix (Table 1) were selected from several environmental impact statements dealing with resource development projects, specifically the system of accounts suggested by the Water Resources Council [6]. Matrix parameters for the effects on the environmental and social well-being unique to pesticide use were developed by the authors.

The parameters in the matrix were worded as "change in," meaning a change in the parameter from the condition existing under the present system of control. For example, the parameter for the quantity of output was worded as "Change in quantity of output." Thus, in the evaluation of this parameter, the output from each alternative was compared to the output from the present system of control.

The three major parameters of the environmental impact matrix were assigned equal weights of 10.0 points each because the Water Resources Council Guidelines and other federal government regulations generally require that each of these parameters be given equal weight in making decisions concerning resource use [6]. The weights for individual parameters as well as the raw scores for qualitative variables were based on consensus values arrived at by a panel of Oklahoma State University researchers. This panel included agricultural economists, agronomists, entomologists, wildlife biologists and ecologists. (This method may have biased the weights to be those considered correct by informed professionals and not the average citizen.)

Parameter weights were assigned according to the importance of the parameter in the policy decision-making framework (Table 1). The parameter weights thus represent the value society as a whole might place on the parameter and do not necessarily represent the value one segment of society may assign to the parameter.

For example, the parameter weights given to "Change in cost of goods for consumers" and "Change in farm income" are equal. However, these two parameter weights are five times larger than the weights for "Change in quality of output" and "Change in employment in the region." It was the consensus of the research panel that in the four study counties, employment effects of the different strategies were minimal. Also, the effects of the different strategies on quality of final product harvested was not a critical factor, i.e., insect damage effects quantity but has little effect on quality and resulting price received.

A fairly high weight was assigned by the panel for the "Effect on rare and endangered species" (2.00), one of the Environmental Quality parameter variables. This was done because of the large number of migratory birds over wintering in the study area. "Change in aquatic environment" and "Change in vegetation" were weighted at 1.25 because the panel wanted these variables to enter the decision-making process with more weight than such variables as: soil erosion (1.00), number of acres available for wildlife (1.00), and food and cover (1.00). The weight for "Change in acute effect on fish and wildlife" was 1.00, larger than "Change in type of fish and wildlife in ecosystem" and "Change in chronic effects on fish and wildlife," because cotton farmers in the study area have been substituting methyl-parathion and toxaphene for DDT over the past five years [5, p. 35].

The Social Well-Being parameter included variables for "Recreational opportunities," "Anxiety factor," and "Other human life considerations." The panel agreed 70 percent of the weight should be assigned the latter two variables since they represent greater direct and indirect effects of pesticides on humans. Under the Social Well-Being parameter, one of the largest subvariable weights was assigned to "Change in number of deaths from pesticides." This weight may appear low to other researchers, since this is such a drastic effect. However, our study failed to find any confirmed deaths in the study area of farm workers, pesticide applicators, or any non-farm persons from pesticides used on cotton. Other variable weights under this parameter were assigned by the panel by considering the variable's relative importance to the "Change in number of deaths from pesticides" subvariable.

To assign numerical raw scores to the alternative strategies, for each parameter, a scale from -5.00 to +5.00 was used. The value of each parameter for the present insect control strategy was assigned a value of zero, for purposes of comparison. Alternatives that improved upon the existing situation (from the present method of control) received a positive value, while those that produced effects worse than the present situation were given a negative value. Where quantitative values for a parameter of a particular strategy were available, raw score extreme values were assigned to the maximum value, and lesser values of other strategies were interpolated with respect to this extreme and the present system's zero value.

Qualitative changes in parameters were ranked with respect to the present method of control along the scale (-5.00 to +5.00) and assigned values according to the magnitude of the expected change from the present method of control. If the effects on a particular parameter of using alternative B were twice as beneficial (or detrimental) as the effects from alternative A, then the raw score of B was twice that of A. The raw score of B was then based upon its relative relationship to the effects of the present method of control.

USE OF THE MATRIX FOR ANALYZING PEST CONTROL STRATEGIES

The estimated net returns (to land, labor, capital, and management) under the present insect strategy in Oklahoma are $101.50 per acre [5]. Net returns were estimated as follows for the alternative methods: $100 per acre for the non-persistent insecticides strategy; $114.80 per acre for the scouting program strategy; $140.10 per acre for the strip cropping strategy, and $62.00 for no insect control.[1] Assigning +5.00 to the strip cropping strategy, since it has the highest economic return (also it is 40 percent larger than the current or base), and zero for the base or present strategy, we have a ratio of 0.1295 for the raw score per a $1.00 change in the raw score, net return ($140.10 - $101.50 = $38.60; 5.00 - 38.60 = 0.1295). Therefore, the raw score for the non-persistent insecticide strategy is -0.20 ($101.50 - $100.00 = 1.50 x 0.1295). The raw score for the scouting program is +1.70 ($114.80 - $101.50 = $13.30 x 0.1295). The raw score for the no insecticide strategy ($62.00 - $101.50 = -39.50 x 0.1295 = -5.10) is less than -5.00; however -5.00 is the lowest possible value for the predetermined scale.

The raw scores were multiplied by their respective parameter weights to obtain a weighted score for the subvariables and variables for each of the three major parameters. The sum of the weighted scores for each alternative strategy for each major area (economic, environmental and social well-being) indicates the effect of the alternative on the parameter. The economic impact of the alternative strategies ranges from -29.00 for no controls to 14.25 for strip cropping (Table 1). Thus, with respect to the estimated economic impact, the strategies were ranked from best to worst as follows: (1) strip cropping; (2) scouting program; (3) present system (with a neutral value of zero); (4) non-persistent pesticides, and (5) no controls. Since each alternative is implicitly compared to the present system of control in developing the raw scores, the overall economic impact implicitly includes the present system of control.

The total of all the weighted scores for an alternative indicated its net overall impact on society. If the net overall impact was positive, the alternative is more desirable than the current system of pest control. Conversely, if the net overall impact was negative, the alternative is less desirable than the present method of control.

Since each alternative analyzed has a net overall value for its impact on society, the alternatives could be ranked from highest to lowest or best to worst. The overall impact ranking of the five strategies analyzed was: (1) strip cropping; (2) scouting program; (3) present system; (4) use of non-persistent pesticides; and (5) no controls. Assuming society prefers the alternative that provides the greatest positive overall impact, the preferred alternative is strip cropping cotton.

SUMMARY AND CONCLUSIONS

The major problem encountered by agricultural economists in analyzing pesticide use has been that data associated with their use are qualitative as well as quantitative. An environmental impact matrix is an alternative methodology to analyze pesticide use that incorporates both quantitative and qualitative data. The environmental impact matrix can be used to analyze alternative pest control strategies that include pesticide use and non-use. The socially preferred pest control strategy thus can be determined.

By developing additional parameters for the matrix to fit the specific problem under study, an environmental impact matrix can be used to analyze many socio-economic problems. Some possible uses of the environmental impact matrix are for analysis of fertilizer use, pesticide use on other crops, development of irrigation projects, major land reclamation projects and drainage projects.

It is interesting that the final ranking of the strategies is the same as the ranking on the economic variables alone. This means the socially preferred strategy is the same as the strategy preferred by the private sector. Although this result was not expected a priori, it is probable that the use of the newest

[1] In Southwestern Oklahoma, cotton produced under irrigation has a greater population of harmful insects than dryland cotton. Our survey of irrigated cotton producers indicated that if no insecticides could be used, no cotton would be planted. The next best crop from net return per acre is irrigated grain sorghum or wheat, both about $62.00 per acre.

Table 1. ANALYSIS OF SELECTED ALTERNATIVE METHODS TO CONTROL INSECTS IN COTTON IN SOUTHWESTERN OKLAHOMA

Parameters	Parameter Weights	Use Non-Persistent Insecticides[a] Raw score	Use Non-Persistent Insecticides[a] Weighted score	A Scouting Program to Monitor Insect Levels[b] Raw score	A Scouting Program to Monitor Insect Levels[b] Weighted score	Strip Crop Cotton With Other Crops[c] Raw score	Strip Crop Cotton With Other Crops[c] Weighted score	Use No Controls[d] Raw score	Use No Controls[d] Weighted score
I. Impact on Economic Factors	10.00								
A. Change in quantity of output	1.00	0	0	0	0	0	0	-5.00	-5.00
B. Change in quality of output	0.50	0	0	0	0	0	0	0	0
C. Change in cost of goods for consumers	2.50	0	0	0.55	1.40	0.90	2.25	-5.00	-12.50
D. Change in farm income	2.50	-0.20	-0.50	1.70	4.25	5.00	12.50	-5.00	-12.50
E. Change in employment in the region	0.50	0	0	1.00	0.50	-1.00	-0.50	-2.00	-1.00
F. Change in the number of farms	1.00	0	0	0	0	0	0	-1.00	-1.00
G. Change in number of acres farmed	2.00	0	0	0	0	0	0	0	0
Economic Impact			-0.50		6.15		14.25		-32.00
II. Impact on Environmental Factors	10.00								
A. Effect on rare and endangered species	2.00	-1.00	-2.00	0.50	1.00	4.00	8.00	1.00	2.00
B. Plant and animal habitat	3.00								
1. Change in number of acres available for wildlife	1.00	0	0	0	0	0	0	0	0
2. Change in soil erosion	1.00	0	0	0	0	0	0	0	0
3. Change in food and cover	1.00	0	0	1.00	1.00	2.00	2.00	1.00	1.00
C. Diversity and Stability	2.50								
1. Change in aquatic environment	1.25	1.00	1.25	0.50	0.60	2.00	2.50	2.00	2.50
2. Change in vegetation	1.25	0	0	1.00	1.25	0	0	-1.00	-1.25
D. Direct Effect on Fish and Wildlife	2.50								
1. Change in the type of fish and wildlife in ecosystem	0.75	-1.00	-0.75	0	0	2.00	1.50	1.00	0.75
2. Change in acute effects on fish and wildlife	1.00	-0.50	-0.50	0.50	0.50	2.00	2.00	2.00	2.00
3. Change in chronic effects on fish and wildlife	0.50	1.00	0.50	0.50	0.25	2.00	1.00	2.00	1.00
4. Change in parasites on animals	0.25	0	0	0	0	-1.00	-0.25	-2.00	-0.50
Environmental Impact			-1.50		4.60		16.75		7.50
III. Impact on Social Well-Being	10.00								
A. Recreational Opportunities	3.00								
1. Change in water based recreation	1.50	0	0	0	0	0	0	0	0
2. Changes in land based recreation	1.50	-0.50	-0.75	0.50	0.75	1.00	1.50	-1.00	-1.50
B. Anxiety Factors	3.50								
1. Change in anxiety due to pesticide residues in food	0.70	0	0	0	0	1.00	0.70	1.00	0.70
2. Change in air pollution	0.70	1.00	0.70	0.50	0.35	2.00	1.40	2.00	1.40
3. Change in drift damage	0.70	-0.50	-0.35	0	0	2.00	1.40	2.00	1.40
4. Change in stream water quality	0.70	0.50	0.35	0.50	0.35	2.00	1.40	2.00	1.40
5. Change in number of pests in the environment	0.70	0.50	0.35	0.25	0.15	-1.00	-0.70	-1.00	-0.70
C. Other Human Life Considerations	3.50								
1. Change in aesthetics	0.75	0	0	0	0	-0.50	-0.40	-1.00	-0.75
2. Change in number of poisonings (not fatal)	1.25	-0.50	-0.62	0.50	0.60	4.00	5.00	5.00	6.25
3. Change in number of deaths from pesticides	1.50	-0.50	-0.75	0.50	0.75	4.00	6.00	5.00	7.50
Social Well-Being Impact			-1.07		2.95		16.30		15.70
Overall Impact			-3.07		13.70		47.30		-10.80
Rank			3		2		1		4

[a]Using non-persistent insecticides involved farmers refraining from using toxaphene and using primarily methyl-parathion.

[b]A scouting program involved monitoring levels of beneficial and harmful insects and recommending insecticide application when harmful insects reached an economic threshold.

[c]Strip cotton with other crops involved planting four rows of grain sorghum between each 24 rows of cotton to gain an interaction of insects.

[d]Use no controls typifies the short-run effect of restricting all insecticides.

technology available through research (strip cropping) inherently considered both environmental and economic impacts.

The authors recognize many of the weaknesses and simplifying assumptions of the environmental impact matrix discussed here. A major problem is the assignment of weights both for the variable raw scores and for the major parameters. Hopefully, future interdisciplinary research efforts will develop better cardinal and/or ordinal measurements for weighting selected, economic, environmental, and social well-being parameters.

REFERENCES

[1] Edwards, W. F. "Economic Externalities in the Farm Use of Pesticides and an Evaluation of Alternative Policies." Unpublished Ph.D. thesis, University of Florida, 1969.

[2] Headley, J. B., and J. N. Lewis. *The Pesticide Problem: An Economic Approach to Public Policy.* Baltimore: John Hopkins Press for Resources for the Future, Inc., 1967.

[3] Horne, Lawrence Thad. "An Economic Investigation of the Impact of Alternative Insecticide Strategies on Cotton Production in the Sunflower River Basin, Mississippi." Unpublished Ph.D. thesis, Oklahoma State University, 1972.

[4] Lacewell, Ronald D., and William R. Masch. "Economic Incentives to Reduce the Quantity of Chemicals Used in Commercial Agriculture." *Southern Journal of Agricultural Economics,* Vol. 4, No. 1, pp. 203-208, July 1972.

[5] Richardson, James W. "Enviro-Economic Analysis of Present and Alternative Methods of Pest Management on Selected Oklahoma Crops." Unpublished M.S. thesis, Oklahoma State University, 1973.

[6] U.S. National Archives. "Water Resources Council Water and Related Land Resources Establishment of Principles and Standards for Planning." *Federal Register,* Vol. 38, No. 174, Part III, Sept. 10, 1973.