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# Evaluation of Alternative Pest Control Technologies for Grain Crops and Soybeans*

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This is a report of a research activity in progress. As such, this research is a part of a larger research effort by Resources for the Future, Inc. in which an attempt is being made to (1) evaluate alternative demand projections for U.S. crop, animal and forestry products to the end of this century, (2) to translate these projections into demand by major producing regions for land, water, fertilizers, pesticides and other inputs with potentially important impacts in the environment, (3) to assess the nature and importance of these environmental impacts and (4) to discuss principal policy issues suggested by the analysis as well as problems needing additional research. The research being done at Missouri is directed toward the examination of the demand for pest control techniques that may be used over the next decade or so to control pests in grain crops and soybeans.

Specific objectives being pursued are:

1. Determine when and if the alternatives might become economically competitive with current techniques.

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2. Compare environmental consequences of the viable alternatives if any with current techniques.

3. Determine the extent to which pest control may serve as a constraint on the production of grain crops and soybeans.

4. Suggest policies designed to guide farmers to choose pest control techniques that are both financially feasible and environmentally acceptable.

The level of food production in the United States will be increasingly important for world food supplies far into the future. It is important to know whether pest control may serve as a constraint on the production system due either to its high financial cost or to an environmental burden which society would not be willing to bear. Therefore, various alternatives to current pest control practices and the value of current practices need to be evaluated in order to make such a judgement.

## Methodology

In order to provide an assessment of the economic and environmental consequences of alternative pest control technologies, it was first necessary to ascertain the state of the art for the various possibilities. Four broad categories of types of pest control technologies are available. These are (1) chemical poisons, (2) biological controls, (3) mechanical methods and (4) cultural methods. Available literature was consulted to determine which specific practices, found within each category, might be available for use on grains and soybeans within the next 15 years and to determine which practices stand a good chance of being operationally feasible on a large scale by approximately 1990.

A second part of the methodology involves the economic evaluation. Once a set of alternatives can be identified as an operational possibility, they will be placed in a national linear programming-spatial equilibrium model to determine which techniques might be used on what scale, in what locations and for what grain crops. The model will maximize the sum of the consumers' plus producers' surplus, net of transportation costs, indicate impacts on farm income, prices, cropping patterns as well as keep an account of the amount of pesticides used under various scenarios.

When the results of the economic evaluations are known, the likely environmental consequences will be developed in as much detail as possible to be considered as possible tradeoffs for various economic results.

Finally, all of the results will form the basis for policy development to encourage farmers to adopt selected techniques which are judged to be socially "better" and to suggest the need for research and development on promising techniques.

## Sources of Data

Literature assessing the importance of pest control methods published by the National Academy of Science [3], and Midwest Research Institute [2] and data from extension personnel throughout the country provide the basis for deciding which techniques to include in the evaluation. These will be discussed in detail later.

Data for use in the linear programming-spatial equilibrium model were derived from several sources. Budget information relating to base acreages, variable costs of production, yields, pest control costs, etc. for the benchmark model regions are from the U.S.D.A. Crop Budgets for 1975. Estimates of the impact of various classes of pesticides (herbicide, insecticide and fungicide) on yields of corn, wheat, sorghum and soybeans came from a mail survey of some 79 professional pest control experts including researchers and extension personnel. Information was also obtained on these experts' opinions of the expected growth of no-till farming as well as the effect of no-till on yields and pesticide use. Additional information on the yield impact of insecticides and herbicides based on research was obtained to use as an alternative set of estimates to the data obtained from the survey.

Reliable data reflecting the yield effect of pest control methods are universally scarce. Experimental data by entomologists, weed scientists and plant pathologists has, in the main, focused on efficacy on the pest organism often under the most adverse of pest infestations and, therefore, is not very useful in estimating the yield impacts across the broad spectrum of crop conditions, soils and infestation levels found in operating agriculture. Most difficult of all to obtain are data estimating the mean infestation levels of the various pests on a regional basis.

It is therefore necessary to rely on these rather rough opinion-type estimates of yield affects.

Selection of Pest Control Techniques For Evaluation

To choose the options open to agriculture over the next decade or two, we have relied on the judgement of our research team, experts we surveyed as well as reports by the National Academy of Science [3] and the Midwest Research Institute [2] to select pest control alternatives that will be ready for use by user groups by 1990.

A tabulation of the various techniques and their importance for grain crops and soybeans over the next 15 years is given in Table 1. This table shows what seems to be the preponderance of opinion by scientists and agricultural extension workers. The conclusion is that chemical controls will continue to be the major method of controlling pests in grain crops and soybeans for the greater part of the remainder of this century and that the alternatives really consist of using chemicals as carefully and efficiently as possible. Support for this position is found in the work of Pimentel et al [5] where they concluded that for corn there are very few alternatives to the insect control in corn. Their findings conclude that rotations can be used to control the rootworm complex, but at a cost of about $80 million.

Resistant varieties are now in use in a major way, especially in small grains in the form of resistance to rust and are likely to continue, but varieties that are proven with resistance to insects are still a long way off. Parasites

Table 1. Estimated Importance of Pest Control Methods for Grain Crops and Soybeans U.S. Agriculture 1978-1992.

| Pest Control Technique | Likely Importance | Change in Importance* |
|---|---|---|
| Chemical Pesticides | | |
| Insecticides | major | - |
| Herbicides | major | + |
| Fungicides | major | + |
| Mechanical Methods | minor | - |
| Biological Methods | | |
| Parasites and Predators | minor | 0 |
| Bacteria | minor | + |
| Viruses | not significant | + |
| Phermones | not significant | 0 |
| Insect Growth Regulators | not significant | 0 |
| Resistant Varieties | major | + |
| Pest Genetics | minor | 0 |
| Cultural Methods | | |
| Crop Rotations | minor | - |
| Trap Crops | minor | 0 |

Source: Judgement of Authors

* A "+" sign means that the technique will become more important, a "-" sign means a diminution in importance and a "0" means no change is expected.

and predators, bacteria, cultural methods and pest genetics are also in use in certain areas for pest control. The most significant examples however are not in grain crops. Viruses, pheromones and growth regulators such as juvenile hormones are still experimental and cannot be counted on for the next decade and a half at least unless some major unpredictable breakthrough occurs. There will continue to be major incentives to develop new technology. If we are indeed to rely on chemicals for the next 15-20 years, the phenomenon of insect resistance is sure to remain and with it higher and higher control costs. If society, through its regulatory programs, continues to stress environmental aspects and an unwillingness to tolerate anything but lowers chemical residuals the incentive for new, non-chemical and otherwise environmentally satisfactory pest control should be even stronger.

It therefore appears that the principal strategies that remain open to agriculture and society are (1) continue as we have with the liberal use of chemical pesticides with cultural methods such as rotations mixed in to achieve a kind of integrated control, (2) make changes in crops grown and their location to minimize the ecological advantage of pests combined with the use of chemicals and some cultural methods, which might include no-till, especially on land that, while advantageous from a pest control standpoint, might not be suited to farming due to lack of moisture or serious erosion problems or (3) ban pesticides and make adjustments in cropping systems and locations of production to minimize the ecological advantages of pests.

The above strategy list will form the basis for the problem which the numerical model will address. The effects of each of these on consumers and producers will be evaluated and the likely consequences for agricultural output, regional cropping patterns and the environment will be enumerated and compared with the present or benchmark model.

Estimating Yield Effects of Pesticides.

As was mentioned earlier, a questionnaire was sent to 79 persons consisting of pest control scientists in agricultural experiment stations and state extension specialists in weed science, entomology and plant pathology. A copy of the questionnaire is attached. A total of 39 responses were received for a response rate of 49 percent. Many of the questionnaires returned expressed frustration because they said they disliked giving their opinion, but did not know of any good data on which to base their response. This underscores the basic data problem we face in this area.

We sorted the opinion estimates by producing region and then selected what appeared to be the modal estimate. Since there was so much variance in the estimates, we concluded that a mean estimate would instill even less confidence.

Estimates of yield effects based on research were also obtained. In most cases, these estimates tended toward smaller impacts of yield effects of pesticides than did the opinion estimates from the survey.

The modal opinion estimates and the research estimates are shown in Tables 2 and 3 respectively.

## The Economic Evaluation Model

In order to perform the economic evaluation, a linear programming-spatial equilibrium model which maximized the consumers' plus producers' surplus less transportation costs from the production of corn, wheat, oats, rye, sorghum, barley and soybeans. Cotton was also included as an activity of interest, since grain crops can be an alternative to cotton in most areas. This model was developed by C. R. Taylor and has been used for a number of evaluation studies, including nitrogen limitations, hail suppression and boll weevil control [8].

The model has 115 producing regions and 21 consuming regions. (See Figure 1). Maximization of the objective function subject to the resource constraints provides a competitive market and spatial equilibrium solution [7]. Each pest control alternative is evaluated by changing the per acre production cost and yield of each production activity defined by the 1975 U.S.D.A. budgets. In total, there are about 524 different producing activities in the basic model reflecting regional differences in crops and cultural practices such as irrigation. In addition, there are transportation activities for each of the three product groups feed grains, food grains and oilmeal and 18,900 activities for the demand function steps, with a different demand function for each product group. So, altogether there will be approximately 20,000 activities. However, not all activities will apply to every region.

Table 2. Estimates of Percent Impact on Average Yield, Level of Cultivation and Replant from Banning Chemical Pesticides from Sruvey of Agricultural Scientists and Extension Workers, U.S.

| Region | Crop | Yield | Cultivation | Replant |
|---|---|---|---|---|
| Northeast and Appalachia | Soybeans | -15 | +15 | 0 |
| | Corn | -5 | +20 | +10 |
| | Grain Sorghum | -5 | +20 | 0 |
| | Wheat | -5 | +10 | 0 |
| Southeast and Delta | Soybeans | -45 | +100 | +15 |
| | Corn | -25 | +75 | +20 |
| | Grain Sorghum | -25 | +75 | +50 |
| | Wheat | -35 | 0 | 0 |
| Corn Belt and Lake States | Soybeans | -25 | +100 | 0 |
| | Corn | -30 | +100 | +25 |
| | Grain Sorghum | -15 | +100 | +25 |
| | Wheat | -15 | +10 | +10 |
| Northern Plains | Soybeans | -25 | +100 | +10 |
| | Corn | -45 | +80 | +50 |
| | Grain Sorghum | -40 | +80 | +50 |
| | Wheat | -25 | 0 | +15 |
| Southern Plains | Soybeans | -40 | +200 | +5 |
| | Corn | -30 | +150 | +20 |
| | Grain Sorghum | -25 | +150 | +10 |
| | Wheat | -15 | 0 | 0 |
| Pacific and Mountain | Soybeans | -45 | +40 | +30 |
| | Corn | -45 | +50 | +30 |
| | Grain Sorghum | No Data | | |
| | Wheat | -45 | +5 | +20 |

Source: Survey responses from 39 Agricultural Experiment Stations.

Table 3. Estimates of Percent Yield Impact on Treated Acres of Banning the Use of Herbicides and Insecticides on Selected Grain Crops, by Region U.S.

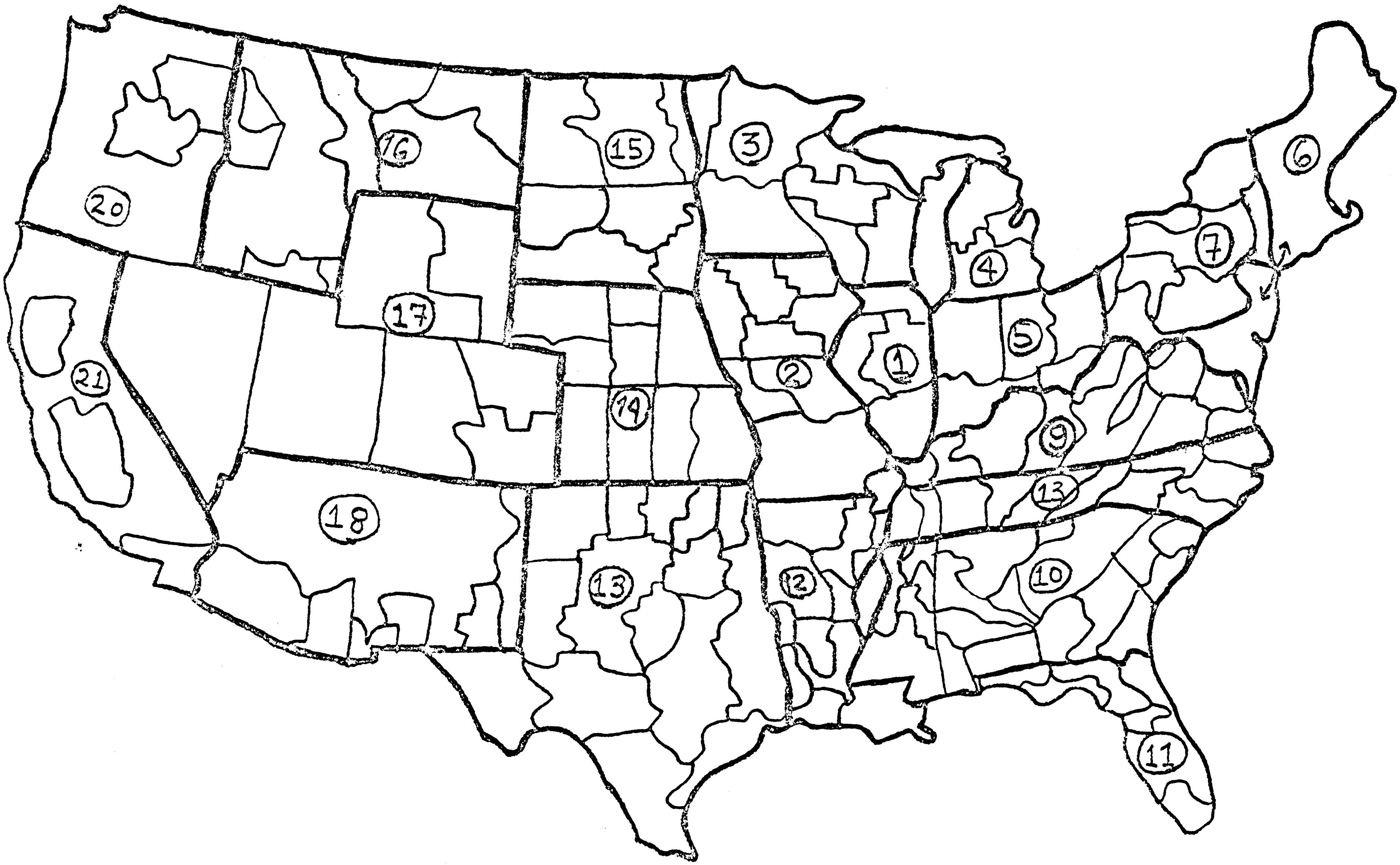
| Region | Crop | Pesticide Type | Yield Impact | % Acreage Treated (e) |
|---|---|---|---|---|
| Northeast | Corn (a) | Herbicide | -20.0 | 86 |
| | Corn (b) | Insecticide | -0.18 | 9 |
| | Soybeans (a)- | Herbicide | -22.0 | 52 |
| | Grain Sorghum (c) | Herbicide | -25.0 | 14 |
| Appalachian | Corn (a) | Herbicide | -20.0 | 73 |
| | Corn (b) | Insecticide | -0.90 | 9 |
| | Soybeans (a) | Herbicide | -22.0 | 55 |
| | Grain Sorghum (c) | Herbicide | -25.0 | 50 |
| | Grain Sorghum (d) | Insecticide | -0.50 | 12 |
| | Wheat (c) | Herbicide | -3.0 | 1 |
| Southeast | Corn (a) | Herbicide | -20.0 | 32 |
| | Corn (b) | Insecticide | -0.27 | 1 |
| | Soybeans (a)- | Herbicide | -45.0 | 45 |
| | Grain Sorghum (c) | Herbicide | -25.0 | 13 |
| | Grain Sorghum (d) | Insecticide | - 2.0 | 79 |
| | Wheat (c) | Herbicide | - 3.0 | 4 |
| Delta | Corn (a) | Herbicide | -20.0 | 59 |
| | Corn (b) | Insecticide | - 0.9 | 4 |
| | Soybeans (a)- | Herbicide | -45.0 | 63 |
| | Grain Sorghum (c) | Herbicide | -25.0 | 54 |
| | Grain Sorghum (d) | Insecticide | - 2.00 | 36 |
| Corn Belt | Corn (a) | Herbicide | -20.0 | 87 |
| | Corn (b) | Insecticide | - 4.3 | 45 |
| | Soybeans (a) | Herbicide | -22.0 | 77 |
| | Grain Sorghum (c) | Herbicide | -25.0 | 58 |
| | Grain Sorghum (d) | Insecticide | - 3.0 | 24 |
| | Wheat (c) | Herbicide | -10.0 | 71 |

Table 3 (continued)

| Region | Crop | Pesticide Type | Yield Impact | % Acreage Treated (e) |
|---|---|---|---|---|
| Lake States | Corn (a) | Herbicide | -20.0 | 92 |
| | Corn (b) | Insecticide | - 1.7 | 25 |
| | Soybeans (a) | -Herbicide | -22.0 | 71 |
| Northern Plains | -Corn (a) | Herbicide | -20.0 | 70 |
| | Corn (b) | Insecticide | - 3.2 | 43 |
| | Soybeans (a) | -Herbicide | -22.0 | 56 |
| | Grain Sorghum (c) | Herbicide | -25.0 | 59 |
| | Grain Sorghum (d) | Insecticide | - 3.0 | 37 |
| | Wheat (c) | Herbicide | -12.0 | 48 |
| Southern Plains | Corn (a) | Herbicides | -20.0 | 12 |
| | Corn (b) | Insecticide | - 0.05 | 6 |
| | Soybeans (a) | -Herbicide | -22.0 | 39 |
| | Grain Sorghum (c) | Herbicide | -25.0 | 39 |
| | Grain Sorghum (d) | Insecticide | - 5.0 | 42 |
| | Wheat (c) | Herbicide | - 5.0 | 3 |
| Mountain | Corn (a) | Herbicide | -20.0 | 48 |
| | Corn (b) | Insecticide | - 2.8 | 39 |
| | Grain Sorghum (c) | Herbicide | -25.0 | 24 |
| | Grain Sorghum (d) | Insecticide | - 2.0 | 40 |
| | Wheat (c) | Herbicide | -10.0 | 68 |
| Pacific | Corn (a) | Herbicide | -20.0 | 34 |
| | Corn (b) | Insecticide | - 2.7 | 19 |
| | Grain Sorghum (c) | Herbicide | -25.0 | 11 |
| | Grain Sorghum (d) | Insecticide | - 1.0 | 79 |
| | Wheat (c) | Herbicide | -10.0 | 67 |

(a) Source: Fred Slife [6]
(b) Source: Pimentel and Shoemaker [4]
(c) Source: Morris Merkle, telephone conversation with C. R. Taylor
(d) Source: George Teetes, telephone conversation with C. R. Taylor
(e) Source: Paul Andrilenas [1]

Figure 1. Map of 21 Consuming Regions and 115 Producing Regions for National Linear Programming-Spatial Equilibrium Model. U.S. 1975.



The constraint set will consist of about 800 equations representing total cropland, irrigated cropland, supply-demand balances for the product groups, cotton lint production, upper and lower crop product bounds, a concave combination constraint for demand for each product group as well as accounting constraints for the amounts of pesticides used in each region.

Since the model is a surplus maximization model, the objective function consists of variable cost coefficients with negative signs for the production activities in each consuming region and the coefficients for the step demand functions for food grains, feed grains and oilmeals measuring the area under those demand functions. So that the difference then is the consumers' plus producers' surplus less transportation costs. For more detail on the model, see Taylor et al [8] .

Since the economic phenomenon with which we are dealing is one of a shifting supply curve for agriculture, a surplus maximizing model is more appropriate than a cost minimizing model. We are interested in two things: (1) finding equilibrium prices and quantities and (2) estimating the change in the surpluses as a measure of the aggregate welfare effects as well as the division of the welfare effects between consumers and producers. Taylor et al [8] points out that a cost minimizing model can provide equilibrium solutions and measures of welfare effects when the supply curve shifts, they also point out that the model is much more expensive to solve than the surplus formulation.

Summary

This research will provide an assessment of the outlook for pest control as a possible constraint on the production of grain crops and soybeans for the balance of the twentieth century. It will also suggest some of the environmental and economic consequences of what appears to be the set of strategies open to society in attempting to maintain food production within the institutional setting of the last quarter of this century. To some it may seem myopic and overlyblessed with the status quo. But until more resources are allocated to the development of the more environmentally-pleasing non-chemical alternatives, and, in spite of pest resistance problems, it seems unrealistic to project the placing of chemical pesticides in a minor role in the control of pests in grain crops and soybeans.

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