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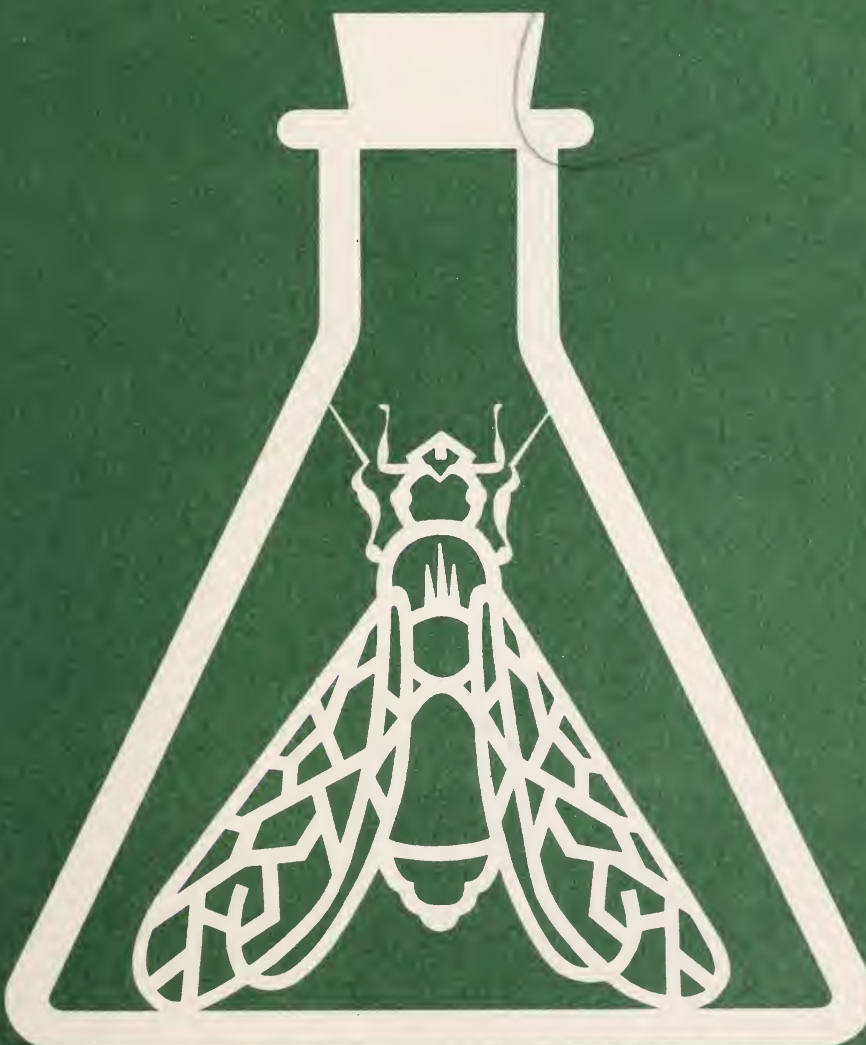
The Economics of Agricultural Pest Control

An Annotated Bibliography, 1960-80

Craig D. Osteen
Edward B. Bradley
L. Joe Moffitt



The Economics of Agricultural Pest Control: An Annotated Bibliography, 1960-80, by Craig D. Osteen, Edward B. Bradley, and L. Joe Moffitt. Natural Resource Economics Division; Economics and Statistics Service; U.S. Department of Agriculture. Bibliographies and Literature of Agriculture No. 14

Abstract

This bibliography, a listing and annotation of 123 papers, reports, and books concerned with the economics of pest control, covers (1) damages caused by pests, (2) benefits and costs of pest control methods, (3) comparisons of biological and chemical methods of control, (4) economically efficient applications of pesticides, (5) economic thresholds, (6) resistance to pesticides, (7) externalities of pesticide use, (8) impacts of risk on pest control decisions, (9) static and dynamic methods of analysis, and (10) institutional concerns such as pesticide regulation, implementation programs, and information distribution. General literature on principles of integrated pest management is also included.

Keywords: Pest control, Integrated pest management, Bibliography, Pesticides, Regulation

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Contents

The Economics of Agricultural Pest Control: An Annotated Bibliography, 1960-80

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Introduction

This bibliography presents literature in the developing field of pest control economics, with the application of economic principles to the problems of agricultural pest control.

The use of pesticides to increase crop yields has increased greatly since the end of World War II. However, several problems have developed. Through natural selection, many pests developed a resistance to pesticides following repeated applications, making control more difficult. If pesticides are successful in greatly reducing a pest population, other organisms, which formerly caused little damage, can become pest problems. Because natural predators of the pests can also be killed by pesticides, later generations of the pests can multiply unregulated by natural enemies, thereby requiring even greater applications of pesticides.

Pesticides have other undesirable impacts. They may affect human health through direct exposure to pesticides, consumption of food on which the chemical was applied, or proximity with an object to which the chemical was applied. Pesticides can also reduce populations of desirable fauna and flora.

As a result of these problems, environmentalists, agriculturalists, and the general public have become concerned over pesticide use.

Some groups have sought to decrease or eliminate pesticide use, while other groups stress beneficial aspects such as high food production. Attempting to balance the detrimental and beneficial impacts of pesticide use through pesticide regulation and the development of new methods of pest control is an important public policy issue.[1]

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[1] The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) gives the Environmental Protection Agency the responsibility of registering pesticides.

Biological methods of pest control represent a successful alternative to chemical control in many situations, according to numerous biologists. Examples include the release of natural predators and sterile males, the use of pheromones to attract pests, and cultural methods such as crop rotation.

Integrated pest management is another recent development. This approach emphasizes the integration of biological, cultural, and chemical methods to control pests in an optimal manner. The approach also emphasizes the development of pest management systems using a variety of methods in concert to control a number of pests. Some of the literature relating to the principles of integrated pest management is listed in this bibliography.

In applying economic principles to pest control problems, economists have addressed such problems as: (1) damages caused by pests, (2) benefits and costs of pest control methods, (3) economic comparisons of biological and chemical methods of control, (4) economically efficient applications of pesticides, (5) economic thresholds, (6) resistance to pesticides, (7) spillover effects or externalities of pesticide use, (8) impacts of risk on pest control decisions, (9) static and dynamic methods of analysis, and (10) institutional concerns such as pesticide regulation, implementation programs, and information distribution.

English-language economic and entomological professional journals, research reports, and books were examined to find literature discussing the basic principles of pest management and economic principles applied to pest control. The earliest article included in this bibliography is "The Economic Theory of the Use of Pesticides" by Patricia M. Hillebrandt, published in the *Journal of Agricultural Economics* in January 1960. This is considered the first work in pest control economics.

The 123 annotations are organized alphabetically by senior author, and numbered sequentially. A subject index, as well as an author index identifying all junior and senior authors, is also included.

Annotations of quantitative, empirical applications are broken down into five sections and referred to by the capital letters shown in parentheses below:

Topic (T): Subject or problem addressed.

Data (D): Type of data used.

Model (M): Model or approach used to investigate the problem. Dependent and independent variables are listed where possible.

Estimation technique (E): Technique used for statistical estimation.

Results (R): Empirical results and conclusions.

Where a section is not applicable, it is omitted.

Other annotations, such as theoretical discussions, simply describe the topic and contents in paragraph form.

Annotated Bibliography

1. Andres, L.A. "The Economics of the Biological Control of Weeds," *Aquatic Botany,* Vol. 3, 1977, 111-23.
Examines the costs of developing and implementing a biological control program for aquatic weeds. Covers costs of the assessment of the problem; costs of survey, study, and production of natural enemies; costs of implementing biological control; and hidden costs. Discusses cases of biological control of aquatic weeds and documents specific costs.

2. Bartsch, Reinhart. *Economic Problems of Pest Control: Examined for the Case of the Gezira/Sudan.* Munich, Germany: Weltforum-Verlag, 1978.
Analyzes short- and long-term efficiency of controlling cotton pests with chemical pesticides. Estimates annual net returns from cotton production and annual benefit-cost ratios for alternative pest control strategies for 20 years, using standard budgeting methods. According to the author, chemical control increases the pesticide resistance of pest populations, which increases future control cost. He also indicates that if pesticide resistance increases at its present quadratic rate, chemical pesticides will remain an efficient method of control in Gezira for at least 30 years.

3. Baum, Kenneth H., and Ronald W. Tillman. *The Economics Behind Integrated Pest Management.* Va. Agr. Econ. No. 297, Co-op. Ext. Serv., Va. Polytech. Inst. & State Univ., Dec. 1978.
Reviews the implications of profit-maximizing behavior for the adoption of an integrated pest control program. Presents a popular version of the comparison between the economic injury threshold and optimal pest management, and provides a decision criterion for applying pesticide or biological control inputs.

4. Beck, A.C. "Simulation as an Aid to Decision-Making in Animal Disease Control Campaigns—A Case Study," *Proceedings of the Third National Conference of the Australian Society for Operations Research,* Adelaide, Australia: Aug. 1977, 413-28.
The author describes a stochastic simulation model that has facilitated the planning of a large-scale program to eradicate bovine brucellosis in Australia. He reports that planners of large-scale disease control or eradication programs confront complex problems involving uncertain interactions among epidemiological, environmental, and institutional variables. Simulation analysis, because of its capacity to handle stochastic variables and relationships, is useful for projecting the outcomes of alternative disease control strategies. According to Beck, planning becomes easier when decision-makers understand the likely outcomes of alternative strategies.

5. Bradbury. F.R., and B.J. Loasby. "Cost-Benefit Analysis and Investment Appraisal in Relation to Pest Control Measures," *Pesticide Science,* Vol. 8, No. 4, Aug. 1977, 366-76.
Discusses and compares the types of costs considered in private investment decisions versus benefit-cost analyses. Emphasizes the divergence of private and social costs in pesticide use. Discusses alternative decision frameworks, including system and cost effectiveness analysis, and stresses shortcomings of benefit-cost criteria.

6. Bullen, F.T. "Benefit/Cost Analysis of Various Degrees of Crop Protection," *Proceedings of the Ecological Society of Australia,* Vol. 5, 1970, 63-75.
T: Examines the insecticide use decisions of farmers.
D: Uses U.S. data for several crops to suggest suboptimal behavior in pesticide application.
M: Uses diagrammatical analysis to determine a producer's optimal chemical control strategy (budgeting).
R: Finds overuse (underuse) of pesticides on high-value (low-value) crops.

7. Cammell, M.E., and M.J. Way. "Economics of Forecasting for Chemical Control of the Black Bean Aphid, *Aphis Fabae,* on the Field Bean, *Vicia Faba," Annals of Applied Biology,* Vol. 85, No. 3, 1977, 333-43.
T: Estimates the value of forecasting black bean aphid populations for determining when to apply pesticides on field beans (an economic threshold approach).
D: Uses 1970-75 costs for developing and operating a forecasting method, pesticide application and crop production costs, crop

prices, crop yields, and pest forecasts resulting from an English forecasting system.

M: Uses Bayesian decision analysis.

R: Shows the economic benefits of basing pesticide applications upon a forecasting method to be substantially greater than routine chemical treatment or no treatment. Finds that cost/benefit ratios average 1:27 for the overall study area with regions varying from 1:31 to 1:9.

8. Campbell, H.F. "Estimating the Marginal Productivity of Agricultural Pesticides: The Case of Tree-Fruit Farms in the Okanagan Valley," *Canadian Journal of Agricultural Economics,* Vol. 24, No. 2, 1976, 13-23.

T: Estimates the marginal productivity of agricultural pesticides used on tree-fruit farms to: (1) examine the efficiency of agricultural production, and (2) indicate the opportunity cost of limiting pesticide use in the interest of environmental protection.

D: Uses input data (values of services of land, buildings, capital equipment and values of inputs of irrigation water, labor, fertilizers, and pesticide sprays) and output data (value of fruit production) from a survey of 57 orchards in British Columbia.

M: Uses the log-linearized Cobb-Douglas production function. Specifies value of output to be a function of all economic inputs plus differences in soil and climatic data.

E: Uses ordinary least squares (OLS) and OLS with factor analysis regression to remove variables and reduce multicollinearity.

R: Finds that the marginal value of $1 worth of pesticide is significantly greater than $1 (approximately $12). Finds that the marginal costs of reducing pesticide use in the interest of environmental protection are relatively high.

9. Carlson, G.A. "A Decision Theoretic Approach to Crop Disease Prediction and Control," *American Journal of Agricultural Economics,* Vol. 52, No. 2, May 1970, 216-22.

T: Applies Bayesian decision theory to pesticide use by California peach growers to determine optimal disease control practices.

D: Bases subjective prior probabilities of disease loss on a sample of 76 farmers. Other data include yields, costs, prices, pesticide applications, and rainfall.

M: Uses decision theory to determine optimal pesticide spraying strategies by maximizing expected income under different disease forecasts. Examines risk-averting strategies and finds disease loss to be a function of climate, crop condition, and fungal spore density.

E: Uses ordinary least squares to estimate disease loss.
R: Finds that spraying increases expected income over not spraying. Determines that the adjusting of applications to disease forecasts can substantially reduce pesticide applications. Basing pesticide applications on disease forecasting is useful when disease control costs are high relative to product prices, especially when damage varies from year to year, and when epidemics can be predicted with some reliability.

10. ______________. "Control of a Mobile Pest: The Imported Fire Ant," *Southern Journal of Agricultural Economics,* Vol. 7, No. 2, Dec. 1975, 35-41.
T: Examines public abatement programs for the case of the imported fire ant.
D: Uses annual observations for several States on acreages infested and treated, per capita expenditures for abatement, and per capita income.
M: Uses regression analysis to estimate the impact of public abatement programs on the spread of the imported fire ant and the public's willingness to pay for abatement.
E: Uses ordinary least squares regression.
R: Finds that private suppression may be preferable to large-scale abatement.

11. ______________. "Economic and Biological Variables Affecting Demand for Publicly and Privately Provided Pest Information." Paper presented at the annual meeting of the American Agricultural Economics Association, University of Illinois, 1980.
T: Presents estimates of the impact of various factors in explaining the number of pest control consultants and describes changes in data collection which may permit better model specification.
D: Uses regional data on farm size, pesticide expenditures, cotton production, number of publicly employed pest control consultants, crop value, and number of private consultants.
M: Estimates a reduced-form equation for the number of private pest control consultants by regression analysis.
E: Uses ordinary least squares regression.
R: Finds a negative net effect of public consulting services on the number of private consultants. Reports positive impacts in the cases of expected number of pests, farmer knowledge, farm size, and crop value. Finds that the knowledge variable, measured by cotton production, is highly significant.

12. ________________. "Insurance, Information, and Organizational Options in Pest Management," *Annual Review of Phytopathology,* Vol. 17, 1979, 149-61.
The author discusses how transaction costs, pest control costs, and organizational structure constrain future institutional approaches to pest management. He also notes the characteristics of the market for pest damage insurance and why the low costs of pest control methods present difficulties to private firms selling the insurance. A number of insurance innovations are also discussed as well as information about crop damage and pest populations which is useful for pest control and insurance decisions. He notes that a number of organizational options are available to deal with such problems as mobile pests and pesticide drift which individuals cannot easily control. However, he explains that few studies have been conducted concerning information, insurance, and organizational options.

13. ________________. "Long-Run Productivity of Insecticides," *American Journal of Agricultural Economics,* Vol. 59, No. 3, Aug. 1977, 543-48.
T: Examines empirically the productivity of insecticides over time and estimates individual insecticide demand equations.
D: Uses annual insecticide and other input expenditures for cotton, insecticide price, and LD-50 levels of pesticides resistance.
M: Uses log-linearized Cobb-Douglas production and demand functions.
E: Uses ordinary least squares.
R: Shows that marginal productivity of insecticides falls over time because of pest population resistance to pesticides. Finds that demand equation estimates for insecticide groups tend to be price-elastic. A resistance variable exhibits significance. Carlson states that policy implications include the need for policy-makers to consider resistance in decisions which restrict the array of available chemical controls.

See also: Carlson, G.A. "Estimates of Some Impacts of Pesticide Users Charges," *Empirical Research in Environmental Economics.* Ed. B.F. Long and G.A. Carlson. Southern Land Economics Research Committee Pub. No. 11, Oct. 1973, 37-52.

14. ________________, and E.N. Castle. "Economics of Pest Control," *Pest Control Strategies for the Future.* Washington, D.C.: National Academy of Sciences, 1972, 79-99.
The authors discuss measures of benefits and hazards of pest control as well as an economic asset approach to pest control technol-

ogy and public policies appropriate for pesticide issues. They also review the concepts of externalities and market failure and discuss the marginal productivity of pesticides along with potential hazards. They depict resistance as an economic asset which may affect future productivity through accumulation and depletion. Lastly, the authors describe a variety of pesticide policy controls, including socialization, standards, taxes, and subsidies.

15. ________________, and C.E. Main. "Economics of Disease Loss Management," *Annual Review of Phytopathology,* Vol. 14, 1976, 381-403.
Focuses on the economics of managing pest problems and reviews relevant literature. Presents some of the causes of increased pest problems, concerns for short-term crop loss management and long-term adjustments, as well as economic research, techniques, and results. Makes the strongest presentation in the area of risk analysis.

See also: Carlson, G.A. "Economics of Forest Pest Management," *Proceedings for the Integrated Pest Management Colloquium,* Gen. Tech. Rpt. WO-14. U.S. Dept. Agr., Forest Serv., Mar. 1979, 51-56.

16. Casey, J.E., and R.D. Lacewell. "Estimated Impact of Withdrawing Specified Pesticides from Cotton Production," *Southern Journal of Agricultural Economics,* Vol. 5, No. 1, July, 1973, 153-59.
T: Evaluates the effect of specified pesticide cancellations on regional and national cotton production.
D: Uses production cost data and demand elasticities developed from a Delphi procedure, and published regional acreage data.
M: Uses a simulation model of U.S. cotton production disaggregated into eight producing regions. Simulation results are obtained under rigid cotton acreage and optimal cropping assumptions.
R: Shows aggregate impacts on net revenue of specified pesticide withdrawals to be minimal. Finds that regional effects are substantial.

17. ________________, R.D. Lacewell, and W. Sterling. "An Example of Economically Feasible Opportunities for Reducing Pesticide Use in Commercial Agriculture (Cotton)," *Journal of Environmental Quality,* Vol. 4, No. 1, 1975, 60-64.
T: Examines pesticide use and yield for Texas cotton under alternative pest management strategies.
D: Uses actual farm data on yields, pesticides, and other inputs; and enterprise budget cost and return data.

M: A simulation model compares two pest management strategies with respect to yield, pesticide use, cost, and return.
R: Finds significant benefits in terms of producer net return, yield, and decreased pesticide use from a pest management strategy designed to preserve beneficial insects.

See also: ________________. *Economic and Environmental Implications of Cotton Production Under a New Pest Management System.* Tex. Agr. Expt. Sta., Tex. A&M Univ., June 1974.

18. Chatterjee, Samprit. "A Mathematical Model for Pest Control," *Biometrics,* Vol. 29, No. 4, Dec. 1973, 727-34.
Formulates an optimal control model for determining the timing and intensity of pesticide use for an optimal pest-control strategy. Defines the cost of a pest control program as the sum of the direct cost of control, the losses from crop damage, and the non-market externalities generated by a control action. Specifies cost components by mathematical functions and incorporates them into a cost-minimization optimal control model.

19. Chiarappa, Luigi, Huai C. Chiang, and Ray F. Smith. "Plant Pests and Diseases: Assessment of Crop Losses," *Science,* Vol. 176, May 1972, 769-73.
Points out the absence of and need for reliable information on crop losses caused by pests and describes the potential value of crop loss data and efforts underway to develop such data.

20. Conway, G.R. "The Utility of Systems Analyses Techniques in Pest Management and Crop Protection," *Proceedings of the 15th International Congress of Entomology,* Washington, D.C., Aug. 19-27, 1976, 541-52.
The author discusses progress made in pest modeling at the Imperial College in Britain. A generalized model of pest control that has pest resistance, pest population models, and the linkage of economic and ecological models as components is also presented. Applications of specific models to the sugarcane froghopper and the cattle tick are presented. The author points to Bayesian analysis as a practical method for farmers' pest control decisions.

21. Council for Agricultural Science and Technology. *Evaluation of the Socioeconomic Cost from Restricting Pesticide Use in Agriculture.* Rpt. No. 83, Apr. 1980.

The Council identifies the major types of socioeconomic impacts resulting from pesticide use restrictions and discusses alternative methods for quantifying these socioeconomic impacts. Three types of economic effects usually result from pesticide use restrictions: (1) changes in the direct net social benefits associated with producing and consuming affected commodities (that is, economic surplus unadjusted for nonmarket effects); (2) local and broader area changes in the income distribution among consumers and producers; and (3) changes in the magnitude of nonmarket valued environmental costs. Pesticide use restrictions also may affect society by causing a reallocation of production resources from affected commodities. Partial budgeting, simulation, and mathematical programming are some of the empirical techniques which can be used for impact assessments of pesticide regulations.

22. ________________. *Pesticides for Minor Uses: Problems and Alternatives.* Rpt. No. 69, Aug. 1977.
The authors outline not only the regulatory problems that exist for "minor uses" of pesticides, but also ways to avoid some of the undesirable consequences of the Federal Environmental Pesticide Control Act of 1972 (FEPCA). The authors state that if FEPCA had been strictly enforced after the October 21, 1977 deadline for pesticide reregistration, most minor uses of pesticides would have ceased. Minor uses are those involving all agricultural commodities, except corn, soybeans, cotton, and small grains. The authors make suggestions that would enable the Environmental Protection Agency to register and reregister pesticides for more minor uses, without endangering public health and the environment.

23. ________________. *Review of the 68 Recommendations in the California Report on Environmental Assessment of Pesticide Regulatory Programs.* Rpt. No. 78, Apr. 1979.
The reviewers evaluate and comment on the 68 recommendations made in the California Environmental Assessment Team's "Report on Environmental Assessment of Pesticide Regulation Programs." The reviewers appeal for more regulatory flexibility and more attention to noninsect pests, than is exhibited in the California recommendations. The reviewers also advise against using integrated pest management (IPM) as a regulatory device. Given the current state of the art in pest control, the reviewers appeal for increased emphasis on IPM research and education.

24. Croft, B.A. "The Economics of Integrated Pest Management in Orchards," Mich. State Univ. Agr. Expt. Sta., Unnumbered journal article, 1976.
T: Reviews existing studies of the cost of integrated pest management techniques for deciduous-fruit pest control.
D: Uses cost data corresponding to spraying, scouting, sterile male release, and pheromone controls.
M: Examines five alternative integrated control techniques for cost effectiveness (partial budgeting).
R: Shows integrated mite control, improved spray timing and application, and scouting as the most promising pest management techniques. Stresses the tentativeness of conclusions and need for further research.

25. Davidson, B.R. "Economics Aspects of Weed Control," *Proceedings of the Weed Society of New South Wales,* Sydney, Australia: Vol. 6, 1974, 34-43.
Explains a decision process for selecting the optimal amount(s) of one or more weed control inputs. Presents and discusses a simple decision process, based upon the elementary principles of production economics. Shows that weed control methods should be used less intensively in Australia than in Europe and the United States, because of the relatively low land values in Australia.

26. DeBord, D.V., G.A. Carlson, and R.C. Axtell.*Demand for and Cost of Coastal Salt March Mosquito Abatement.* Tech. Bull. No. 232, N.C. Agr. Expt. Sta., Mar. 1975.
T: Examines the responsiveness of mosquito population density to permanent and temporary abatement procedures and identifies factors which significantly affect the demand for mosquito control.
D: Analyzes cross-sectional time-series data relating to mosquito abatement programs for 30 east coast abatement districts for 1959 through 1971.
M: Uses logarithmic specifications of the following functions:
(1) Mosquito density = f(acres chemically controlled, storm rain, sequence rain, temperature, and stock of permanent control acreage).
(2) Acres chemically controlled = f(mosquito density, abatement districts budget, and human population density).
(3) New permanent control acreage = f(acres chemically controlled and stock of permanent control acreage).

(4) Local expenditure = f(mosquito density, per capita income, State grants, tourism, wage rates, and human population density).

E: Uses two-stage least-squares.

R: Reveals that both temporary and permanent mosquito control procedures significantly reduced mosquito density during the period of analysis. Finds that temporary control (insecticide use) is more efficient than permanent control procedures and that demand for mosquito abatement is income elastic.

See also: Carlson, G.A., and D.V. DeBord, "Public Mosquito Abatement," *Journal of Environmental Economics and Management,* Vol. 3, 1976, 142-53.

27. Delvo, Herman W. "Economic Analysis of Herbicide Use Policies on Nebraska Cash-Grain Farms," *Proceedings: North Central Weed Control Conference.* Kansas City, Mo., Vol. 26, Dec. 7-9, 1971, 24-8.

T: Evalutes herbicide restrictions on typical Nebraska cash-grain farms.

D: Uses production budgets and prices, cropping activities, herbicide application rates, irrigation, labor requirements, and inputs for other farming practices.

M: Uses linear programming to determine optimal farm management practices on different farms in irrigated and dryland regions.

R: Finds that cropping patterns are quite similar on typical dryland and irrigated farms: corn and grain sorghum are grown when preemergent or post-emergent pesticides are available, and wheat is grown when only cultivation is allowed. Finds that labor for cultivation increases on dryland farms but remains fairly constant on irrigated farms when herbicide use is restricted. Finds that returns to operator labor and management drop when herbicide use is restricted.

28. ________. "Economic Impact of Discontinuing Aldrin Use in Corn Production." ERS-557. U.S. Dept. Agr., Econ. Res. Serv., June 1974.

T: Estimates shortrun economic impact of discontinuing the use of the insecticide aldrin on corn.

D: Uses data on aldrin use and production costs in 1971, assumes pesticide effectiveness (pest damages with different pesticides), production costs.

M: Estimates corn acreage treated with aldrin. Chooses alternative pesticides and estimates their costs. Uses price elasticities to estimate price impacts of changes in production.

R: Author finds that, in 1971, had no additional corn land been brought into production and had all soil insects been controlled by pesticides, corn production would have decreased by 21.1 million bushels and corn farmers' net income would have decreased by $12.3 million. Had insecticides not been used to control cutworm and wireworm, corn production would have decreased by 55.1 million bushels and corn farmers would have lost $54.5 million.

Had additional land been brought into corn production to keep prices stable, corn farmers would have lost $25.9 million, had all soil insects been controlled by pesticides. Had wireworm and cutworm not been controlled, corn farmers would have lost $31.5 million.

USDA staff wrote several reports on the economic impacts of cancelling pesticide uses. The reports were similar to "Economic Impact of Discontinuing Aldrin Use in Corn Production." Hence, we are not annotating them:

Delvo, Herman W., Austin S. Fox, and Robert P. Jenkins. "Economic Impact of Discontinuing Farm Uses of Heptachlor." ERS-509. U.S. Dept. Agr., Econ. Res. Serv., Jan. 1973.

Delvo, Herman W., Robert P. Jenkins, and Austin S. Fox. "Economic Impact of Discontinuing Farm Use of Lindane and BHC." ERS-524. U.S. Dept. Agr., Econ. Res. Serv., July 1973.

Fox, Austin S., Robert P. Jenkins, John T. Holstun, and Dayton L. Klingman. "Restricting the Use of 2,4,5-T: Costs to Domestic Users." Agr. Econ. Rpt. No. 199. U.S. Dept. Agr., Econ. Res. Serv. and Agr. Res. Serv., Mar. 1971.

Gerlow, Arthur R. "The Economic Impact of Cancelling the Use of 2,4,5-T in Rice Production." ERS-510. U.S. Dept. Agr., Econ. Res. Serv., Mar. 1973.

Jenkins, Robert P., Herman W. Delvo, and Austin S. Fox. "Economic Impact of Discontinuing Farm Use of Chlordane." Agr. Econ. Rpt. No. 231. U.S. Dept. Agr., Econ. Res. Serv., Aug. 1972.

29. Dixon, Orani, Peter Dixon, and John Miranowski. "Insecticide Requirements in an Efficient Agricultural Sector," *Review of Economics and Statistics,* Vol. 55, No. 5, Nov. 1973, 423-32.

T: Analyzes regional variations in insecticide usage within the United States, and simulates how insecticide usage would change if the spatial distribution of agricultural activities were adjusted to maximize efficiency.

D: Uses cross-sectional data set of insecticide use on 22 crops in 10 U.S. regions.

M: Specifies regional per acre insecticide usage = f(location, crop mix, interaction between location and crop mix). Uses linear programming to determine the optimal regional distribution of agricultural activities.
E: Uses ordinary least squares.
R: Shows that the Southeast requires relatively high insecticide use while the requirements of the Southern Plain and Pacific regions are relatively low. Shows that if agricultural activities are relocated to maximize efficiency, insecticide usage declines approximately 50 percent.

30. Edwards, W.F., M.R. Langham, and J.C. Headley. "Pesticide Residues and Environmental Economics," *Natural Resources Journal,* Vol. 10, Oct. 1970, 719-41.
The authors develop a conceptual framework whereby the social welfare implications of pest management policies can be evaluated. The authors state that pesticide usage creates certain nonmarket costs which are not borne by pesticide users—that is, the private cost of pest control differs from the true social cost of pest control. Consequently, private pest control decisions may fail to produce socially optimal levels of pest control activities. The authors state that pesticide usage should be managed to equate its marginal social cost with its marginal social benefit. The authors then use this decision rule to examine the social welfare implications of several alternative pest management policies.

31. Emerson, P.M., and G.E. Plato. "Social Returns to Parasite and Disease Control in Agriculture: the Case of Witchweed in the United States." Paper presented at American Agricultural Economics Association meeting. Pa. State Univ., Aug. 1976.
T: Analyzes the USDA witchweed program to examine the desirability of its continuation.
M: Projects price and quantity of corn and sorghum with a 21-commodity simulation model from 1977 to 2000. Computes the net present value as well as the internal rate of return. Estimates social benefits of the program as additions to consumers' surplus from increased corn and sorghum production.
R: Obtains high benefit-cost ratios and rates of return to determine that the program should be continued at the current level.

32. Epp, Donald J., E. Roger Tellefsen, Gary A. Shute, Robert M. Bear, and Kenneth P. Wilkenson. *Identification and Specification of Inputs for Benefit-Cost Modeling of Pesticide Use.* EPA-600/5-77-012.

U.S. Environmental Protection Agency, Office of Research and Development, Aug. 1977.
Identifies both beneficial and detrimental effects of pesticide use and specifies these effects in a manner that is conducive to the evaluation of pesticide use decisions. Shows that the value of some pesticide use effects cannot be quantified without risk of bias given the present state of the art techniques for measuring environmental and aesthetic impacts. Demonstrates how both quantifiable and nonquantifiable effects can be incorporated into a comprehensive evaluative framework for analyzing pesticide use decisions.

33. Farris, D.E., and J.M. Sprott. "Economic and Policy Implications of Pollution from Agricultural Chemicals," *American Journal of Agricultural Economics,* Vol. 53, No. 4, Nov. 1971, 661-62.
The authors show that acreage allotment programs to reduce food production encourage high levels of pesticide use as farmers substitute pesticides for land. Thus, if food production is to be controlled, market quotas would encourage less pesticide use than allotment does. Producers in the Southern States, especially cotton producers, will be affected most by pesticide regulation. Restrictions expected in the seventies on pesticides will result in higher costs to the producer. The market system will not pass these costs on to consumers because export crops are primarily affected.

34. Feder, Gershon. "Pesticides, Information, and Pest Management Under Uncertainty," *American Journal of Agricultural Economics,* Vol. 61, No. 1, Feb. 1979, 97-103.
The author investigates the impact of uncertainty on pesticide use decisions made by risk-averse farm managers. Assuming risk aversion and expected utility maximization, the author introduces randomness, one step at a time, into the components of a farm management decision model. He uses the first-order conditions of the model to evaluate the effect of improved information on pesticide use levels and shows that a reduction in pesticide application occurs when information is improved.

35. ________________, and Uri Regev. "Biological Interactions and Environmental Effects in the Economics of Pest Control," *Journal of Environmental Economics and Management,* Vol. 2, 1975, 75-91.
T: Examines the general economic implications of centralized and decentralized pest management for a prey-predator ecosystem.
M: The objective functionals of the optimal control models are:

(1) Shortrun private economic costs = (minimize) $\sum_{t=0}^{1}$ F(pest damage, pest control cost),

(2) Longrun public economic costs = (minimize) $\sum_{t=0}^{\infty}$ H(pest damage, pest control cost, environmental cost, discount rate).

R: The author shows that in a prey (pest)-predator ecosystem, both prey and predator are common property resources. From society's viewpoint, decentralized pest control is suboptimal for two reasons. First, decentralized managers fail to consider pest control as a multiperiod problem because most pest populations are mobile. Second, decentralized managers are not concerned about the externalities created by pesticide residues.

36. Fell, H.R., "A Farmer's Approach to the Socio-Economic Aspects of Crop Protection," *Pesticide Science,* Vol. 8, No. 4, Aug. 1977, 377-79.
An individual farmer in England presents his view of the tradeoff between agricultural production and environmental quality.

37. Fischer, L.A. "The Economics of Pest Control in Canadian Apple Production," *Canadian Journal of Agricultural Economics,* Vol. 18, No. 3, Nov. 1970, 89-96.
T: Investigates the effects of pesticide applications on apple production in Canada.
D: Uses data on labor, pesticides, and other inputs data from a survey of farmers.
M: Uses log-linearized Cobb-Douglas production function to relate value of production to pest control inputs, capital investment, and other inputs.
E: Uses ordinary least squares.
R: Shows that small growers' outlays for pest control per tree are higher than large- and medium-sized growers' outlays, except in British Columbia (economies of scale). The author's estimates of marginal productivities of pesticide applications show that a $1 pesticide expenditure has a return of $13 in Nova Scotia, $5 in Quebec, and $2.34 in Ontario.

38. ________________. "Pest Control—An Economic Approach," *Economic Planning,* Vol. 1, No. 2, 1965, 8-15.
Discusses the economic implications of pests as well as the importance of pest control measures. Discusses the magnitude of dam-

ages caused by crop pests, and the tradeoffs involved in pest control. Highlights the balance between crop protection and pesticide cost.

39. Fox, Austin S. "Economic Impact of Restricting Herbicide Use." *Journal of Environmental Quality*. Vol. 1, No. 4, 1972, 349-52.
The author uses diagrams of production functions, marginal cost curves, and supply and demand curves to discuss a conceptual basis for examining the impacts of restricting herbicide use. The impacts involved are changes in prices and production and the distribution of costs and benefits between producers and consumers. However, because economic evaluations often compare production costs of a given quantity of a commodity with and without herbicide use, production functions are not always available. Lastly, the results of previous studies on herbicide restrictions and the impacts of price support programs are discussed.

40. Frisbie, R.E. "Implementation and Economic Returns from the Systems Approach to Pest Management in Cotton." *Proceedings of the 15th International Congress of Entomology*, Washington, D.C., Aug. 19-27, 1976, 587-90.
The use of cotton pest management in Texas changed from one of reliance on cultural practices to pesticide use in the fifties. However, the boll weevils' resistance to pesticides and outbreaks by secondary pests started a breakdown in the reliance on pesticides. From this breakdown has evolved an integrated system which depends on short-season, pest-resistant cotton, and better timing of pesticides, an approach that has increased farmers' incomes according to Frisbie.

41. Gage, S.H., and M.K. Mukerji. "Crop Losses Associated with Grasshoppers in Relation to Economics of Crop Production," *Journal of Economic Entomology*, Vol. 71, No. 3, June 1978, 487-98.
T: Estimates the economic impact of grasshoppers on grain producers in Saskatchewan.
D: Uses time series data on grasshopper population, crop yields, and weather for 1943-74.
M: Specifies two yield-estimation models; one with grasshopper population as an explanatory variable and one without.
(1) Crop yield = f(year, precipitation, and a heat-precipitation ratio)
(2) Crop yield = g(grasshopper population, year, precipitation, and a heat-precipitation ratio)

Uses simulation model to estimate crop damages and grasshopper control costs.

E: Uses ordinary least squares.

R: The grasshopper population model explains a higher portion of yield variance than the model without grasshopper population. The total annual impact of grasshoppers is simulated as the sum of grasshopper control costs and grain production losses. In general, severe grasshopper impacts (as high as $40 million, annually) occur during times of drought. Simulation results indicate that the probability of economic loss due to the combined effects of grasshoppers and drought in any year is 0.48, 0.72 and 0.32 for wheat, oat, and barley enterprises, respectively.

42. Giese, R.L., R.M. Peart, and R.T. Huber. "Pest Management," *Science,* Vol. 187, No. 4177, Feb. 21, 1975, 1045-51.
The authors describe an experimental pest management project being conducted at Purdue University. The computer-oriented, pest management model is depicted diagramatically, data base requirements of the model indicated, and the need for a whole crop system stressed. The existing system incorporates feedback from area extension offices where the pest management information generated by the computer model is distributed. Results for alfalfa pest control are described as successful and reliable.

43. Gilbert, C.H. "Industry's View on the Benefits and Risks of the Pesticide Business," *Proceedings of the Southern Weed Science Society, 31st Annual Meeting,* Jan. 17-19, 1978, 14-27.
Discusses the factors which affect the decisions to develop and produce new pesticides. Reviews the research and development costs that are increasing to the point where fewer companies will want to develop pesticides or even remain in the business.

44. Gilliam, H.C., J.R. Martin, W.G. Bursch, and R.B. Smith. *Economic Consequences of Banning the Use of Antibiotics at Subtherapeutic Levels in Livestock Production.* Tech. Rpt. No. 73-2. Dept. Agr. Econ. & Rural Sociology, Tex. Agr. Expt. Sta., Tex. A&M Univ., 1973.

T: Estimates economic impact of a ban on the use of all antibiotic feed additives for cattle and hogs.

D: Uses production budgets from various sources.

M: Analyzes budgets for three alternative modes of producer behavior, and simulates effects of a ban on antibiotics over time.

R: Finds that producer costs would rise least if longer feeding periods were instituted and herd size maintained. Finds that feeding additional animals to maintain supply appears as the most expensive alternative for producers. Shows that net returns to livestock producers increase only if supply is curtailed in response to a ban.

45. Good, J.M., Ralph E. Hepp, Paul O. Mohn, and Donald L. Vogelsang. *Establishing and Operating Grower-Owned Organizations for Integrated Pest Management.* PA-1180. U.S. Dept. Agr., Ext. Serv., Mar. 1977.
Describes and compares the structure and services of four grower-owned organizations for integrated pest management. Reviews structural models that farmers can consider when starting new grower-owned organizations. Stresses how developing grower-owned organizations is particularly useful in situations where neither private consultants nor extension personnel are providing pest control services for a reasonable cost.

46. Grube, Arthur H., and Gerald A. Carlson. *Economic Analysis of Cotton Insect Control in North Carolina.* Econ. Info. Rpt. No. 52. Dept. Econ. & Bus., N.C. State Univ., Jan. 1978.
Provides a conceptual framework for appraising pesticide use and pesticide regulation. Assesses the agricultural, human health, and environmental consequences in terms of social welfare. Certain costs and benefits are only partially assessed because of measurement problems and data unavailability.

47. Hafez, M. "Economic and Environmental Implications of Various Pest Control Measures," *First FAO/SIDA Seminar on the Improvement and Production of Field Food Crops,* United Nations, Food and Agricultural Organization, 1974, 598-604.
Reviews alternative methods of pest control and problems brought about by relying heavily upon pesticides. Discusses important points to be considered in an integrated pest control program. Presents Egyptian practices used to control cotton pests.

48. Hall, Darwin C. "The Profitability of Integrated Pest Management: Case Studies for Cotton and Citrus in the San Joaquin Valley," *Bulletin of the Entomological Society of America,* Vol. 23, 1977, 267-74.
T: Examines the impact of integrated pest management on cotton and citrus growers in California.
D: Uses survey data on yield, profit, and pesticide use for 1970-74.

M: Compares cotton and citrus yields, profits, and pesticide use under supervised and conventional chemical control. Estimates risk effects by comparing the variance of yield under the two control strategies.
E: Uses analysis of variance.
R: Finds a significant decrease in pesticide use, total pest management expenditure, and risk while yield and producer profit are maintained under supervised control.

49. ________________, and R.B. Norgaard. "On the Timing and Application of Pesticides," *American Journal of Agricultural Economics,* Vol. 55, No. 2, May 1973, 198-201.
The author develops a model that determines the pest population level at which pesticides should be applied (the economic threshold), the quantity of pesticide applied, and the timing of applications to maximize profits. He explains how the timing and quantity of pesticide applications affect pest populations. He also shows the relationship of the economic threshold to the time of harvest, the rate of pest population growth, the rate of damage to crops per pest, the effectiveness of the pesticide, the cost of pesticides, and the price of the crop. Therefore, if, for some reason, the quantity of pesticide per application is fixed, changes in the prices of pesticide and product would not affect the timing of the application. Thus, only the pest population growth rate and pesticide effectiveness would be important determinants of timing according to Hall.

50. ________________, R.B. Norgaard, and P.K. True. "The Performance of Independent Pest Management Consultants," *California Agriculture,* Vol. 29, No. 10, Oct. 1975, 12-14.
Discusses the use of pest management consultants by cotton and orange growers. Examines the differences between users and nonusers to show how the costs and returns vary. Shows that California growers can expect their profits to increase by following the advice of pest management consultants.

51. Hawkins, D.E., F.W. Slife, and E.R. Swanson. "Economic Analysis of Herbicide Use in Various Crop Sequences," *Illinois Agricultural Economics,* Vol. 17, No. 1, Jan. 1977, 8-13.
T: Examines the profitability of using herbicides on typical Illinois crop rotations.
D: Uses crop yield and cost of production data from a 10-year study of rotations and herbicide applications.

M: Uses simple statistical analysis of mean and standard deviation of crop yields and probability of financial loss.

R: Finds that profitability of herbicide use is very high, that crop rotations have little impact on profitability, and that herbicide use and crop diversification reduce the risk of financial loss.

52. Headley, J.C. "Economics of Pest Control: Have Priorities Changed?" *Farm Chemicals,* Vol. 142, No. 2, Apr. 1979, 55-57.
Shows the need for public and private efforts in developing integrated pest management. Discusses a survey by agricultural extension workers that indicates chemical pesticides are expected to dominate pest control strategies over the next 15 years. Recommends cooperative efforts and crop insurance to help avoid this possibility with its associated negative biological and environmental effects.

53. ________________. "The Economics of Pest Management," *Introduction to Insect Pest Management.* Ed. R.L. Metcalfe and W.H. Luckman. New York, N.Y.: John Wiley, 1975.
Incorporates time and uncertainty into pest management theory at the micro level. Conceptualizes the formulation of multiseason pest control strategies as an exercise of Bayesian decisionmaking, where the objective of pest control is the maximization of expected net returns. Concludes that pest control strategies with higher expected net returns are obtainable by conceptualizing pest control as a multiseason problem rather than an independent series of one-season problems.

54. ________________. "The Economics of Pest Management by Individual Growers," *Iowa State Journal of Research,* Vol. 49, No. 4, May 1975, 623-28.
Examines the pest control decisions of individual producers, within static and dynamic decisionmaking frameworks. Presents specific decision rules and information needs for single and multiple time period problems. Shows that static decision rules only apply when the pest populations in successive decision periods are independent of each other.

55. ________________. "Defining the Economic Threshold," *Pest Control Strategies for the Future.* Washington, D.C.: National Academy of Sciences, 1972, 100-08.
The author defines economic threshold as the pest population level where the marginal cost of control is equivalent to the marginal value product of control. This definition is more rigorous than the

definitions found in earlier entomological literature. Headley deduces several implications and conclusions from his definition. First, economic threshold is related to and determined by the prices of both affected crops and control inputs. Second, the economic threshold level of pest population is the profit-maximizing population. Suppressing the pest population when it is below its economic threshold or allowing it to exceed its economic threshold reduces net crop revenue.

56. _______________. "Economics of Agricultural Pest Control," *Annual Review of Entomology,* Vol. 17, 1972, 273-86.
Headley discusses problems associated with estimating the benefits and costs of pest control. He defines the benefits of pest control as the discounted value of pest damage abatement over time. Similarly, the cost of pest control is defined as the discounted value of pest control expenditures over time. Due to the likelihood that pesticide use will cause secondary pest outbreaks, Headley hypothesizes that many benefit-cost analyses of pesticides are biased. Therefore, if the cost of controlling secondary pest outbreaks is included as a cost of pesticide use, the benefit-cost ratio for using a pesticide declines.

57. _______________. "Estimating the Productivity of Agricultural Pesticides," *American Journal of Agricultural Economics,* Vol. 50, No. 1, Feb. 1968, 13-23.
T: Estimates the aggregate and marginal contribution of pesticides in the production of American agricultural commodities.
D: Uses USDA farm income and expense series data for each of the 48 coterminous States for 1963.
M: Specifies total output = f(total labor, land and buildings, machinery, fertilizer, pesticides, and other). Specifies this relationship as both a double-log function and a third-degree polynomial function.
E: Uses ordinary least squares.
R: Estimates that the marginal value product of a $1 expenditure for chemical pesticide is approximately $4 and that the total benefit of agricultural pesticides is estimated as $1.8 billion for 1963.

See also: _______________. "A Dilemma for Consumers: Pesticide Use vs. Food Costs," *The Journal of Consumer Affairs,* Vol. 1, No. 2, Apr. 1967, 161-69.

58. _______________, and A.V. Kneese, "Economic Implications of Pesticide Use," *Annals of the New York Academy of Sciences,* Vol. 160, 1969, 30-9.

Discusses the benefits to society of higher agricultural production and of pesticide use, as well as some of the undesirable side effects on human health and wildlife. Estimates of the marginal value of pesticides for crop production suggest that pesticides are probably underutilized if the side effects are not considered.

59. ______________, and J.N. Lewis. *The Pesticide Problem: An Economic Approach to Public Policy.* Baltimore, Md.: Johns Hopkins Press, 1967.
Provides an economic appraisal of pesticide use and suggests pesticide policy changes to reduce the social costs associated with pesticides. Assesses the agricultural, human health, and environmental consequences within an economic framework which includes both market and nonmarket valued effects. Does not assess certain effects fully because of measurement problems and data unavailability.

60. Hepp, Ralph E. *Alternative Delivery Systems for Farmers to Obtain Integrated Pest Management Services.* AER-298. Dept. Agr. Econ., Mich. State Univ., June 1976.
Describes and compares alternative pest management delivery systems. Hepp states that most farmers do not have the technical knowledge to implement integrated pest management practices by themselves. Recommends that every State develop a statewide program to promote integrated pest management through grower-owned organizations, agribusiness firms, and/or private consultants.

61. Hillebrandt, Patricia M. "The Economic Theory of the Use of Pesticides," *Journal of Agricultural Economics,* Vol. 13, 1960, 464-72.
The author presents a method for determining the optimal rate of pesticide use for static cases where only one pesticide application is made annually. Because most functions that relate pest mortality with pesticide dosage (pesticide kill functions) are sigmoidally shaped, the relationship between crop yield and pesticide dosage, graphically displayed as a "dosage response curve" in this article, is also signoidally shaped—like a standard production function with one variable input. Hillebrandt also examines the economic implications of a dosage response curve, using conventional microeconomic theory. Optimal pesticide dosage is determined by equating the marginal costs and benefits of pesticide use.

62. Hueth, D., and U. Regev. "Optimal Agricultural Pest Management with Increasing Pest Resistance," *American Journal of Agricultural Economics,* Vol. 56, No. 3, Aug. 1974, 543-52.

Hueth and Regev specify a discrete time, optimal control model for managing a pest population with exhaustible susceptibility to pesticides. The model contains potential plant production, pest population density, and a pest susceptibility index as state variables. The model's control variables are pesticide use and aggregate use of nonpesticide inputs. The model is used to determine the optimal timing of optimal quantities of pesticides when pest resistance is increasing. The authors deduce that the economic threshold for pest control varies during a growing season rather than being constant, and that neglecting to consider pest resistance leads to pesticide overuse only under restrictive assumptions.

63. Huffaker, C.B., R.F. Luck, and P.J. Messenger. "The Ecological Basis of Biological Control." *Proceedings of the 15th International Congress of Entomology.* Aug. 1976, 560-86.
The authors describe the aspects of natural control and the balance of nature which underly biological pest control. They define and discuss attributes which describe an effective natural enemy. The authors analytically and diagrammatically depict theoretical models including the logistic growth model, several predator-prey models, and periodic rather than continuous growth models, while stressing the concept of stability. They also show a more general model incorporating both parasite and other mortality factors. Finally, they specify guidelines based on the desirable characteristics of a natural enemy to form a plan for pre-introduction investigations.

64. Hussey, N.W., "Some Economic Considerations in the Future Development of Biological Control," *Technological Economics of Crop Protection and Pest Control.* Monograph No. 36. Society of Chemical Industry, London, England: Staples Printers, 1970.
Surveys, in brief, some experiments in biological pest control. Notes the need for stability in the market for natural enemies, if biological control is to develop commercially. Discusses the Federal Govenment's role in financing biological control research.

65. Jones, Lawrence A. "Insuring Crop and Livestock Losses Caused by Restricted Pesticide Use: An Appraisal." ERS-512. U.S. Dept. Agr., Econ. Res. Serv., Jan. 1973.
The author discusses insurance programs to protect farmers and ranchers against economic losses caused by restrictions on pesticides, specifically DDT. He shows that an insurance program con-

cerned solely with pesticide losses probably would not be feasible as it would be difficult to measure crop and livestock losses attributed to pesticide restrictions. Therefore, it would be hard to establish premium rates and coverages and to measure and verify indemnity payments. The most practical type of insurance would be one utilizing an all-risk insurance program to cover crop and livestock losses. However, the use of all-risk insurance would be hampered by a lack of actuarial data, the possibility of heavy losses, and inadequate ways of verifying losses. Jones maintains that the program probably would attract farmers with a high chance of crop loss and discourage those with a low chance of crop loss.

66. Johnston, J.H., and G. Mason. *A Cost-Benefit Study of Alternative Policies in the Control or Eradication of the Cattle Tick in New South Wales*. Misc. Bull. 22, Div. Mktg. & Econ., New South Wales, Australia, Dept. Agr., June 1976.
    T: Compares the conventional tick-control policy in New South Wales with two eradication policies.
    D: Uses secondary data on the cost and effectiveness of alternative tick control practices.
    M: Uses standard cost-benefit procedures.
    R: Finds that an eradication policy involving property inspection and spot eradication would be more efficient than either the conventional tick-control policy or a more intensive, blanket eradication policy.

67. Khan, Mahmood Hasan. "Economic Aspects of Crop Losses and Disease Control," *Economic Nematology*. Ed. John M. Webster. New York, N.Y.: Academic Press, 1972.
    Discusses, by applying elementary economic principles, the economic impacts of agricultural pests on farmers, consumers, and society. Shows that the economic impacts of crop pests depend upon the extent of crop damage, the price elasticities of demand for affected crops, the efficiency of disease control methods, and the opportunity cost of resources used in producing affected crops.

68. King, N.B., and A.D. O'Rourke. "The Economic Impact of Changes in Pesticide Use in Yakima Valley Orchards," Wash. State Univ., Agr. Res. Cen., Bull. 841, Mar. 1977.
    T: Examines the feasibility of reducing pest control costs by use of integrated pest management.
    D: Uses pesticide use and cost data from a sample of 52 Yakima Valley farmers.
    M: Uses budgeting analysis.

R: Finds that integrated pest management (IPM) techniques would reduce pest control cost by 10 percent for apples and increase them by 20 percent for pears. Shows that the application of IPM would be economically and environmentally sound for apples but not for pears.

69. Langham, Max R., Joseph C. Headley, and W. Frank Edwards. "Agricultural Pesticides: Productivity and Externalities," *Environmental Quality Analysis—Theory and Methods in the Social Sciences.* Ed. Allen V. Kneese and Blair L. Bower, Baltimore, Md.: Johns Hopkins Press, 1972.

The authors examine how alternative restrictions on chemical pesticide use would affect agricultural production and social welfare. The study shows that the economic implications of substituting either cropland for pesticides or chlorinated hydrocarbon insecticides for organic phosphate insecticides are deduced from the results of previously conducted empirical studies. The elasticity of substitution of cropland for insecticides is approximately -6 to -7 for the United States. The substitution of organic phosphates for 10 percent of the chlorinated hydrocarbons used in Dade County, Florida affected net social welfare insignificantly in the short-run. However, the long-run social costs associated with the pesticide residuals of chlorinated hydrocarbons such as DDT would be reduced by this substitution.

See also: _______________, and W.F. Edwards. "Externalities of Pesticide Use," *American Journal of Agricultural Economics,* Vol. 51, No. 5, Dec. 1969, 1195-1201.

70. Larson. S.L., R.D. Lacewell, J.E. Casey, M.D. Heilman, L.N. Namkin, and R.D. Parker. "Economic, Environmental, and Energy Use Implications of Short-Season Cotton Production: Texas Lower Rio Grande Valley," *Southern Journal of Agricultural Economics,* Vol. 7, No. 1, July 1975, 171-77.

T: Compares the costs and returns of short-season versus conventional cotton production, particularly for pesticide and energy use.

D: Uses experimental cotton yields, production costs, pesticide applications, and energy use.

M: Uses a budget generator developed at Texas A&M University.

R: Finds that short-season cotton production results in significant decreases in energy use with little or no reduction in cotton yields and revenue, and that net revenues increase because production costs decrease.

71. Lawrance, N.A., and R.C. Angus. "An Evaluation of Innudative Pest Control Versus Integrated Cotton Pest Management," *Southern Journal of Agricultural Economics,* Vol. 6, No. 1, July 1974, 45-7.

T: Examines the costs of inundative pesticide applications versus integrated pest management for cotton.

D: Uses pest infestations, pesticide material and application costs, cultural practices, yields from computerized records of a pest management program, a field survey, and findings of previous studies.

M: Uses budgeting and break-even analysis.

R: Finds that adopters of integrated pest management (IPM) had slightly higher pest damages and lower costs than nonadopters ($10.58/acre) and that yields under IPM can decrease by 20.2 pounds per acre before the costs for the two approaches break even.

72. LeBaron, Allen. "Economics as a Basis for Policy Decisions," *Utah Science,* Vol. 32, No. 2, June 1971, 63-72.

Discusses pesticide issues and economic policy alternatives. Analyzes the welfare effects of pesticide use in free and regulated markets. Discusses the problems in measuring external effects.

73. Lee, J.Y., and M. Langham. "A Simultaneous Equation Model of the Economic-Ecologic System in Citrus Groves," *Southern Journal of Agricultural Economics,* Vol. 5, No. 1, July 1973, 175-80.

T: Estimates the effectiveness of changes in the quantity of pesticides and other productive inputs on pest populations and yields of fruit produced.

D: Uses crop yields, pest populations, physical attributes of groves, and pesticide and fertilizer applications for 130 citrus groves in Florida.

M: Specifies a model where citrus production = f(physical attributes of the grove, weather conditions, fertilizer applications, pest populations, yield of previous year) and pest populations = f(physical attributes of the grove, weather conditions, pesticide applications, citrus production, previous year's population).

E: Uses two-stage least squares.

R: Estimates the rates of technical substitution among factors of production and shows how the time paths of exogenous variables generate the time paths of endogenous variables. Finds that pesticides and fertilizers are overused in the sampled citrus fruit production units.

74. Lewis, T., and G.A. Norton. "Aerial Baiting to Control Leaf-Cutting Ants (Formicidae, Attini) in Trinidad. III. Economic Implications," *Bulletin of Entomological Research,* Vol. 63, Dec. 1973, 289-303.

T: Examines the damage function for leaf-cutting ants on cocoa and citrus, costs of individual firm control, and benefits resulting from large-scale control.
D: Uses damage and control cost data.
M: Tabulates an infestation level/yield loss relationship, onfarm control costs, and large-scale aerial control costs for the leaf-cutting ant that attacks cocoa and citrus in Trinidad. Considers probable environmental impacts under onfarm and large-scale control.
R: Finds that results appear to favor large-scale control on both economic and environmental grounds.

75. Lindquist, D.A. "Social and Economic Aspects of Alternative Insect Control Methods," *Pesticide Science,* Vol. 8, No. 4, Aug. 1977, 385-93.
Shows that because of pest mobility, areawide programs are desirable for applying pest control techniques that rely less on pesticide use. Determines that the important barriers to implementing such programs are a lack of government requirements for areawide programs and a lack of organization within private business to service them.

76. Mann, Stuart H. "Mathematical Models for the Control of Pest Populations," *Biometrics,* Vol. 27, No. 2, June 1971, 357-68.
Describes optimal pest control strategies that maximize expected net income within both single- and multiple-period time frames, given that control cost and pest mortality are either linearly or nonlinearly related. Applies dynamic programming to hypothetical pest problems to demonstrate how this technique can improve the management of pest populations.

77. Metcalf, R.L. "Selective Use of Insecticides in Pest Management," *Proceedings of The Summer Institute on Biological Control of Plant Insects and Diseases,* Oxford, Miss.: Univ. Miss. Press, 1974, 150-203.
Classifies pest management practices based upon two criteria: (1) intrinsic value for pest control, and (2) frequency of intervention. Discusses examples of each class and how ecologically selective applications of insecticides can play a major role in pest management, particularly in seed treatments.

78. Michalson, E.L. "Economic Impact of Mountain Pine Beetle on Outdoor Recreation," *Southern Journal of Agricultural Economics,* Vol. 7, No. 2, Dec. 1975, 43-50.

T: Estimates the economic impact of the mountain pine beetle on outdoor recreation in the Targhee National Forest.

D: Uses survey data on round trip mileage, estimated travel time, and cost per visitor day from visitors of infested and noninfested campgrounds.

M: Visits = f(round trip mileage, travel time, and cost/visitor day) for all campgrounds, infested campgrounds, and noninfested campgrounds.

E: Uses ordinary least squares.

R: The author's estimates of the differences in value per visitor day between infested and noninfested campgrounds are based upon changes in consumers' surplus. The estimated losses in consumers' surplus and campground fees caused by pest infestations show the potential annual benefit of a pest control program.

79. Miranowski, John A. "Estimating the Relationship Between Pest Control and Energy Costs, and the Implications for Environmental Damage." Paper presented at the annual meeting of the American Agricultural Economics Association, University of Illinois, 1980.

T: Examines the relationship between pesticide use and fuel costs and pesticide use and pest management information for Iowa corn production.

D: Uses cross-sectional observations for 3 years on acres treated, pesticide price, fuel price, corn acres, and corn price as well as yield coefficients and enterprise budget data.

M: Uses a pesticide demand model and a simulation model to evaluate pest monitoring activities.

E: Uses ordinary least squares.

R: Finds that fuel price increases lead to additional pesticide treatments and more scouting. Shows that the number of acres treated may rise or fall as fuel prices go up depending on how much monitoring increases relative to the increase in pesticide inputs.

80. National Research Council. *Pest Control Strategies for the Future.* Washington, D.C.: National Academy of Sciences, 1972.
Reproduces 24 articles from a National Research Council symposium on current and future pest control methods. The articles deal with pest control, human health and environmental risks, and other aspects of pest control economics.

81. Newton, C.M., and W.A. Leushner. "Recognition of Risk and Utility in Pest Management Decisions," *Bulletin of the Entomological Society of America,* Vol. 21, No. 3, 1975, 169-71.

Presents the expected value approach to making decisions under risk. Shows how an ordinal scale could be substituted for the case in which monetary values are not easily available for the outcomes of decisions.

82. Norgaard, R.B. "Integrating Economics and Pest Management," *Integrated Pest Management*. Ed. J.L. Apple and R.F. Smith, New York, N.Y.: Plenum Press, 1976.
Discusses farm and regional economic aspects of pest control. Examines the concept of the economic threshold diagrammatically, both under certainty and under risk. Stresses producer interrelationships in discussing regional strategies.

83. ______________. "The Economics of Improving Pesticide Use," *Annual Review of Entomology*, Vol. 21, 1976, 45-60.
The author presents a general economic framework to analyze the misuse of pest control inputs and information, and reviews economic research in the area of pest management. His economic problems for pest control include imperfect knowledge and its associated risk, decisionmaking costs (including costs of gathering information), transactions costs of social interactions, and perfect competition. Economic research for each of these topics is also reviewed. Norgaard states that pesticide use will not be improved until the farmers' knowledge base improves and appropriate feedback mechanisms are established.

84. ______________, and D.C. Hall. "Environmental Amenity Rights, Transactions Costs, and Technological Change," *Journal of Environmental Economics and Management*, Vol. 1, No. 4, Dec. 1974, 251-67.
The authors examine societal choice in the assignment of property rights under conditions of technological change. They also provide a diagrammatical and analytical analysis of the transaction costs associated with alternative legal environments under technological change. Assuming that technological change is more prevalent in the production of material goods than environmental amenities, they show that society will eventually prefer a legal structure that assigns property rights to pollutees if society prefers to maintain a constant ratio between amenities and materials, or if the social indifference curves satisfy other criteria.

85. Norton, G.A. "Analysis of Decision Making in Crop Protection," *Agro-Ecosystems*, Vol. 3, 1976, 27-44.

Examines the decision to apply pest control from the viewpoints of the economic threshold concept and decision theory. Points to satisficing as a decisionmaking approach under imperfect information. Discusses means by which decisions can be improved.

86. ______________. "Multiple Cropping and Pest Control: An Economic Perspective," *Mededelingen van de Faculteit Landbouwwetenschappen Rijksuniversiteit Gent.,* Vol. 40, 1975, 219-28.
Shows that multiple-cropping systems have innate pest management properties that must be studied and integrated into pest management decisions as well as other economic goals such as minimizing weather-related losses. Finds that attempts to intensify agriculture in less developed countries could result in crop rotations which encourage increased pest problems.

87. ______________, and D.E. Evans. "The Economics of Controlling Froghopper on Sugarcane in Trinidad," *Bulletin of Entomological Research,* Vol. 63, June 1974, 619-27.
The authors demonstrate how less than complete information may be utilized in making control decisions in Trinidad regarding the froghopper which attacks sugarcane. They develop a control decision criterion for the case in which the damage function is unknown and recommend, given this objective function, a spraying procedure which includes choice and timing of spray as decision variables. They also stress the need for research to develop information useful to economic analysis.

88. Ordish, G. "Economics and Pest Control," *World Review of Pest Control,* Vol. 1, 1963, 31-38.
Discusses how marginal analysis and cost-benefit analysis can be applied to pest control decisions and how price elasticity can affect farmers' profits when they apply pest controls.

89. Otte, J.A., J.P. Jones, and A.J. Overman. *Tomato Yield Response to Fumigation in Old Land and Estimated Costs to Fumigate.* Rpt. No. 70. Food & Resource Econ. Dept., Univ. Fla., Apr. 1977.
T: Discusses the yield and cost implications of soil fumigation tests.
D: Uses fumigation cost and yield data.
M: Presents fumigation costs and estimates (through field experiments) the yield increase needed to justify fumigation.
R: Finds significant yield increases due to fumigation. Furthermore, yield appears to increase sufficiently to justify fumigation costs.

90. Pate, T.L., J.J. Hefner, and C.W. Neeb. "A Management Program to Reduce Costs of Cotton Insect Control in the Pecos Area," Tex. Agr. Expt. Sta., Tex. A&M Univ., Feb. 1972.
T: Reports the results of an experimental cotton insect control program.
D: Uses insecticide expenditures and yield data.
M: Examines an insect control program based on supervised chemical control, limited fertilization, and diversified cropping during a 3-year experiment.
R: Shows that normal yield and substantially decreased insecticide expenditures are possible through this type of program.

91. Pimentel, D., and C. Shoemaker. "An Economic and Land Use Model for Reducing Insecticides on Cotton and Corn," *Environmental Entomology,* Vol. 3, No. 1, 1974, 10-20.
T: Evaluates the impact on crop prices and land use of producing cotton and corn, both with and without pesticides.
D: Uses an update of the Iowa State National Agricultural Model to account for corn and cotton yields and production costs with and without insecticide use.
M: Uses an Iowa State cost-minimizing linear programming model of U.S. agricultural production.
R: Estimates cotton and corn production costs with and without insecticide bans and with and without acreage retirement programs. Finds that land retirement program would have a greater impact on crop production costs than an insecticide ban and that the impacts of an insecticide ban on corn and cotton prices would be slight.

92. ________________, ________________, Eddy L. La Due, Robert B. Rovinsky, and Noel P. Russell. *Alternatives for Reducing Insecticides on Cotton and Corn: Economic and Environmental Impact.* EPA-600/5-79-007a. U.S. Environmental Protection Agency, Environmental Research Laboratory, Athens, Ga., Aug. 1979.
T: Conducts an economic analysis of insect control technologies which could reduce insecticide use on cotton and corn.
D: Uses "best estimates" of costs, benefits, and pesticide use patterns of alternative controls (current and potential) from knowledgeable entomologists, pesticide use data from the USDA, and the National Academy of Sciences.
M: Presents three analyses: (1) an analysis of the impact of control technologies on pesticide use, (2) an analysis of technologies on cotton yields and production costs, and (3) an analysis of the technologies on corn and cotton production using a linear programming

model which minimizes production and transportation costs and allows shifts of production between regions.

R: The authors show that insecticide use can be significantly reduced on cotton but much less on corn. They found that if production and location of cotton were allowed to change, available control strategies could reduce insecticide use by as much as 16 to 34 percent and reduce total control and production costs as well. The development of short-season cotton and resistant varieties would reduce insecticide use by 50 to 60 percent and reduce production costs by as much as $28 million per year. Insecticide use and production costs for cotton could also be reduced significantly more by allowing regional shifts in production. They maintain that scouting and rotation could significantly decrease insecticide use on corn by significantly increase production costs.

93. Regev, Uri, Andrew P. Gutierrez, and Gershon Feder. "Pests as a Common Property Resource: A Case Study of Alfalfa Weevil Control," *American Journal of Agricultural Economics,* Vol. 58, No. 2, May 1976, 186-97.

T: Develops optimal spraying practices for the alfalfa weevil.

D: Examines pest population and plant growth parameters, crop price, and pesticide cost data.

M: Incorporates pest and plant growth dynamics in an economic simulation model to derive spraying practices which are optimal from the standpoint of the firm. Includes interseasonal pest dynamics to develop optimal societal spraying practices accounting for pest mobility among fields. Effects of pest resistance to chemical pesticides are not incorporated into the analysis.

R: Shows that the socially optimal time to apply pesticides is earlier in the season than the application time selected by a private decisionmaker.

94. Reichelderfer, Katherine H. "Production and Cost Implications of a Multi-Pest Management Program for Pecans." Staff Paper. U.S. Dept. Agr., Econ. Stat. Coop. Serv., Apr. 1979.

T: Compares the effectiveness and profitability of an experimental multipest management program for Southeastern pecans to the conventional control program for pecan pests.

D: Uses a 3-year series of pecan production and cost data furnished by the USDA's Southern Fruit and Tree Nut Research Station in Byron, Georgia.

M: Analyses, statistically, the yield differences among pest control programs and estimates the net revenue associated with each program by enterprise budgeting.
E: Uses analysis of variance.
R: A significant yield difference occurred in 1 of 3 years studied which suggests that the multipest management program can be more profitable than conventional pest management.

95. ________________, and Filmore E. Bender. "Application of a Simulative Approach to Evaluating Alternative Methods for the Control of Agricultural Pests," *American Journal of Agricultural Economics,* Vol. 61, No. 2, May 1979, 258-67.
T: Analyzes the efficiency of alternative biological and chemical pest control strategies for reducing soybean losses due to Mexican bean beetles.
M: Uses an intraseasonal simulation model with five major components to estimate soybean yields in the presence of Mexican bean beetle populations. Components within the simulation model include:

(1) a population growth model for the pest,
(2) a crop growth model for the host,
(3) a vegetation consumption model for the pest, and
(4) a defoliation model for the host, and
(5) a yield loss function for the host.

Specifies, within the simulation model, initial pest population and pest control inputs exogenously. Uses a submodel to estimate the parasite's population and parasitization levels. Uses benefit-cost analysis to evaluate the efficiency of alternative control strategies.
R: Presents benefit-cost ratios for 11 different control strategies and three levels of initial pest infestation. Finds the parasitic wasp (*Pediobius foveolatus*) to be an economically competitive alternative to conventional chemical control, when compared from either the private or social viewpoint.

See also: ________________, and Filmore E. Bender. *A Simulative Approach to Controlling Mexican Bean Beetle on Soybeans in Maryland.* MP No. 935. Agr. Expt. Sta., Univ. Md., Oct. 1978.

96. ________________. Economic Feasibility of a Biological Control Technology. AER-430. U.S. Dept. Agr., Econ. Stat. Coop. Serv., Aug. 1979.

T: Evaluates the economic feasibility of using a parasitic wasp, *Pediobius foveolatus* to control the Mexican bean beetle (MBB) throughout all U.S. soybean-producing areas where MBB is the primary insect pest of soybeans.

D: Uses regional enterprise budgets and pesticide use data for soybean growers in 1976, and cost information for biological control and insect scouting.

M: Constructs soybean enterprise budgets by region for three MBB control scenarios—conventional, biological, and biological plus insect scouting. Compares the costs and net revenues associated with each region's MBB control scenarios to determine the economic feasibility of biological control.

R: The authors show that the estimated profitability of biological control is highest in the Delmarva Peninsula region. Soybean net revenue per acre in this region is $1.37 (or $0.71 for biological control plus insect scouting) more than for conventional control. The analysis shows biological MBB control to be economically feasible, in varying degrees, in all U.S. regions where MBB is the major soybean insect pest. Furthermore, the analysis shows that little or no redistribution of income or soybean production would occur from a substitution among MBB control methods.

97. ________________, and Dewey M. Caron. "Honey Bees and Soybean Production," *American Bee Journal,* Vol. 119, No. 5, 2 and 3, Feb. and Mar. 1979, 107-09 and 202-03.

The authors discuss the economic externalities between honey and soybean producers in the Delmarva Peninsula. The analysis shows that soybeans provide a good source of pollen for bees, and bees improve soybean pollination. These mutually beneficial relationships, however, can be disrupted by the use of insecticides to control soybean pests. Bee colony destruction and damage due to carbaryl use on soybeans is a significant problem for beekeepers in Delmarva, and the loss of bees may adversely affect production of soybeans and other crops.

98. Richardson, J.W., and D.D. Badger. "Analyzing Pest Control Strategies for Cotton With an Environmental Impact Matrix," *Southern Journal of Agricultural Economics,* Vol. 6, No. 1, July 1974, 179-83.

T: Determines economic benefits and costs for alternative pest control strategies in the case of cotton produced in four Oklahoma counties.

D: Uses economic, environmental, and social well-being parameters such as recreational, anxiety, and human life considerations.

M: Uses an environmental impact matrix with weights assigned to economic, environmental, and social well-being parameters to assess pest control alternatives.

R: Shows biological trap crop control as the most desirable approach.

99. Rovinsky, R.B., and K.H. Reichelderfer. "Interregional Impacts of a Pesticide Ban Under Alternate Farm Programs: A Linear Programming Analysis," ESCS Staff Paper. U.S. Dept. Agr., Econ. Stat. Coop. Serv., Data Serv. Center, Apr. 1979.

T: Presents estimates of the impact of a ban on toxaphene for use on cotton under different cotton acreage allotment programs.

D: Uses Firm Enterprise Data Systems budgets at 1973 levels for price, cost, and yield parameters.

M: Uses a cost-minimizing linear programming model (PESTDOWN) to estimate acreage shifts and cost changes.

R: Finds a substantial shift of cotton production from the south to the west under a toxaphene ban. Shows that if cotton acreage restrictions are imposed, the results imply an increase in total variable production cost.

100. Ridgway, R.L., J.C. Tinney, J.T. MacGregor, N.J. Starler. "Pesticide Use in Agriculture," *Environmental Health Perspectives,* Vol. 27, Dec. 1978, 103-12.

Discusses trends and new developments in the production, use, and regulation of agricultural pesticides. Presents a substantial amount of cross-sectional and time-series information on the production and use of agricultural pesticides and a comprehensive list of effects to consider in assessing pesticide regulations and policies.

101. Ruesink, W.G. "Status of the Systems Approach to Pest Management," *Pest Control Strategies for the Future.* Washington, D.C.: National Academy of Sciences, 1976.

The author presents an elementary discussion of systems analysis and its application to pest management. The development of models for pest species, crops, natural enemies, microclimate and weather, and tactics (management variables) is also discussed. As of 1972, the systems approach to pest management concentrated on developing models to describe the existing system, with little effort spent on evaluating alternative strategies. The author notes that, in the future, more effort must be directed to developing models for data acquisition and decision making.

102. Salkin, M.S., V.R. Eidman, and W.B. Massey, Jr. "An Economic Analysis of Some Alternative Pest Control Strategies for Grain Sorghum in the Oklahoma Panhandle," Okla. Agr. Expt. Sta., Okla. State Univ., 1975.

T: Examines current greenbug control practices and formulates and evaluates alternatives.

D: Uses budget, yield, and input data for each of a set of pest control practices.

M: Uses budgeting analysis to compare alternatives according to different criteria for acceptance.

R: Compares five alternatives with current practices. Low pesticide dosages with scouting and resistant hybrids are two currently available methods that are superior to current practices in terms of profitability, assurance of pest control, pollution reduction, and other criteria.

103. Sarhan, M., R.E. Howitt, and C.V. Moore. "Pesticide Resistance Externalities and Optimal Mosquito Management," *Journal of Environmental Economics and Management*, Vol. 6, No. 1, 1979, 69-84.

T: Develops an empirical model of mosquito abatement in a public district to derive optimal treatment strategies.

D: Uses physical parameters of mosquito populations and control actions from annual data on climate, river flow, and land use.

M: Uses a simultaneous equation model of pest populations (3 species), treatment locations, agricultural improvements, and pesticide effectiveness (10 equations which provide data for the constraints of a cost-minimizing linear programming model to determine an optimal pest control strategy).

E: Uses two-stage least squares.

R: Finds that the marginal costs determined from the econometric models indicate that pesticides are overused and drainage is underused. The linear programming model computes the optimal mix of control activities under different goals for pest control. Finds that substantial increases in drainage, relative to pesticide applications, are needed.

104. Shaw, W.C., and L.L. Jansen. "Chemical Weed Control Strategies for the Future," *Pest Control Strategies for the Future*. Washington, D.C.: National Academy of Sciences, 1972, 197-215.

The authors review the performance of chemical weed control from 1940 to 1970, and discuss means for improving weed control and herbicide regulation in the future. Many economic and ecological aspects of weed control, which are generally unknown or misunderstood by the general public, are also discussed. Herbicides not only increase the productivity of crop, range, and forest lands, but also enable large amounts of labor and land to be diverted from agriculture. The authors note that herbicides have not caused serious environmental risks in the past, but suggest further research on their toxicological effects.

105. Shoemaker, Christine. "Optimization of Agricultural Pest Management," Parts I, II and III: *Mathematical Biosciences,* Vols. 16, 17, and 18, 1973 and 1974, 143-75, 357-65 and 1-22.
The author investigates the application of optimal control techniques to decisionmaking in agricultural pest management. In Part I, Shoemaker reviews current pest control methods and some of the mathematical models of pest population interaction and control that have been developed. Later, in Part II, pest control is formulated as an optimal control problem by the author. Methods for specifying the key components of an agro-ecosystem in an optimal control model are also discussed and the technique of dynamic programming briefly explained. In Part III, a model is developed to find the optimal strategy of biological and chemical control of a pest which has a predator in its natural environment. Ways to incorporate additional factors in the optimal control model (effects of time and weather, multiple crops, insecticide residue, insect age and sex classes, and multiple pest populations) are also reviewed.

106. Siebert, J.W. "Beekeeping, Pollination, and Externalities in California Agriculture," *American Journal of Agricultural Economics,* Vol. 62, No. 2, May, 1980, 165-71.
T: Evaluates the economic impact of pesticide-induced beekills on beekeepers and almond and citrus growers in Tulare County, California.
D: Uses cross-section data on beekeeping revenue, labor input, and colony numbers for 1968. Uses 1974 cross-section data on almond production, pruning expenditure, almond acreage pollination, cultivation fertilizer expenditure and pest control expenditure, and cost estimates of beekills in Tulare County, California, 1974-78.
M: Uses log-linearized Cobb-Douglas beekeeper revenue and almond production functions; the latter estimated using three alternative specifications of variables.
E: Uses ordinary least squares.

R: Conclusions include:
(1) Beekeepers incur approximately $1 million per year in damages because of pesticides.
(2) Almond growers suffer little damage from beekills and competitive conditions maintain pollination rents despite increased demand due to beekills.
(3) A mandatory bee protection program financed by a tax on bee colonies is suggested for Tulare County.

107. Simmonds, F.J. "Economics of Biological Control," *Journal of The Royal Society of Arts*, Oct. 1967, 880-98.
Discusses the advantages and disadvantages of biological control of pests. Presents several case studies of biological control, both successful and unsuccessful, from the standpoint of economic costs and benefits. Urges additional public investment in biological control research.

108. Smith, R.F. "Economic Aspects of Pest Control," *Proceedings: Tall Timbers Conference on Ecological Animal Control by Habitat Management*, No. 3, Feb. 1971, 53-83.
Pest control, just one of the several aspects of crop production, contributes to both costs and revenues. Therefore, the workings of the market and impacts of crop yields on market prices are important considerations. The report emphasizes that externalities and risks of alternative pest control methods must be considered and both economic and ecological considerations brought together in making decisions on pest management methods or pesticide applications.

109. Southwood, T.R.E., and G.A. Norton. "Economic Aspects of Pest Management Strategies and Decisions," *Insects: Studies in Population Management*. Ed. P.W. Geier, L.R. Clark, D.J. Anderson, and H.A. Nix. Canberra, Australia: Ecological Society of Australia, 1973, 168-81.
Discusses decision considerations at the farm and regional levels as well as certain forms of government action. Illustrates the impacts of pests upon product yield, quality, revenues and costs, and the relationships among pest population, control action, and cost.

110. Starler, N.H., and R.L. Ridgway. "Economic and Social Considerations for the Utilization of Augmentation of Natural Enemies," *Biological Control by Augmentation of Natural Enemies*. Ed. R.L. Ridgway and S.B. Vinson. New York, N.Y.: Plenum Press, 1977.

The authors discuss the use and cost of the biological control agents that are produced to control agricultural pests in the United State and elsewhere. Even though augmentation of biological control agents—namely parasite, predators, and microbial agents—is an uncommon pest control practice, it is, nevertheless, an important pest control practice in certain situations. The authors conclude that, for augmentation to become more prevalent, further research is needed to increase the efficiency of biological control strategies.

111. Steiner, H. "Cost-Benefit Analysis in Orchards Where Integrated Control is Practiced." Bulletin OEPP/EPPO Bulletin (European and Mediterranean Plant Protection Organisation), Vol. 3, No. 1, 1973, 27-36.
   T: Compares the variable crop protection costs of conventional and integrated control practices and documents costs of training plant protection officers and farmers.
   D: Uses pesticide, equipment, training costs, and labor costs for 25 apple orchards with integrated control and 20 with conventional control.
   M: Uses budgeting analysis.
   R: Finds that integrated pest control reduces the variable costs of pest control for apple orchards by 20 percent in the Stuttgart, Germany area. Documents the training costs needed to implement integrated control. There appear to be economic advantages for integrated control in the Stuttgart area.

112. Talpaz, Hovav, and Itshak Borosh. "Strategy for Pesticide Use: Frequency and Application," *American Journal of Agricultural Economics*, Vol. 56, No. 4, Dec. 1974, 769-75.
   T: Presents a model for estimating optimal pest control strategies in terms of both treatment frequency and intensity, and applies the model to a semirealistic cotton pest problem.
   M: Maximizes profit which is a function of the number of pesticide treatments, pesticide quantity per treatment, rates of insect population growth, crop and pesticide prices, fixed treatment cost, initial pest population, and parameters for a kill-efficiency function. All, except the first two independent variables within the above profit function, are exogenously determined. The major biological relationships involved in pest management—pesticide kill functions, pest damage functions, and pest growth functions—are incorporated within the model.
   R: The authors' partial sensitivity analysis of the model's exogenous variables and parameters reveals how optimal control strategies respond to changes in both biological and economic conditions.

113. ________________, G.L. Curry, P.J. Sharpe, D.W. DeMichele, and R.E. Frisbie. "Optimal Pesticide Application for Controlling the Boll Weevil on Cotton," *American Journal of Agricultural Economics,* Vol. 60, No. 3, Aug. 1978, 469-75.

T: Describes a model which estimates the optimal timing and quantity of pesticide application using a detailed plant-pest interactive system.

D: Uses weather conditions over a growing season, prices of cotton and pesticides for 1 year, pest population, and cotton production parameters.

M: Uses a dynamic simulation model of boll weevil populations, cotton production, the interaction between the two, and a kill function to estimate application schemes to determine the impact of alternative pesticide schemes on cotton production. Uses a modified version of the Fletcher-Powell-Davidson nonlinear optimization technique to find the optimal timing and quantity of pesticides that maximize net revenue.

R: Estimates the timing and quantity of pesticide applications for a number of different cotton and pesticide price assumptions. The timing of pesticide applications is aimed at a critical period when cotton is particularly susceptible to boll weevils. Notes that when cotton or pesticide prices change, the quantity of pesticide applied changes, which the timing does not.

114. ________________, and Ray E. Frisbie. "An Advanced Method for Economic Threshold Determination: A Postitive Approach," *Southern Journal of Agricultural Economics,* Vol. 7, No. 2, Dec. 1975, 19-26.

T: Establishes a specific economic threshold rule for the application of pesticides to cotton and demonstrates that the concept of the economic threshold is dynamic.

D: Uses cotton yield, insect populations, damage, and insecticide treatments for fields in the Texas Blacklands.

M: Regresses the net income on percent of damage levels for two plant-age intervals.

R: Finds that the farmers from which data were gathered began applying pesticides well below the economic threshold of the pest population, an observation attributed to risk factors.

115. Taylor, C.R. "The Nature of Benefits and Costs of Use of Pest Control Methods." Paper presented at the annual meeting of the American Agricultural Economics Association, University of Illinois, 1980. Provides an analytical evaluation of welfare consequences resulting from widespread adoption of integrated pest management. Finds

that overall effects are ambiguous and that empirical analysis is required to determine if current promotional claims regarding integrated pest management benefits are supported.

116. _______________, and Klaus K. Frohberg. "The Welfare Effects of Erosion Controls, Banning Pesticides, and Limiting Fertilizer Application in the Corn Belt," *American Journal of Agricultural Economics,* Vol. 59, No. 1, Feb. 1977, 25-36.

T: Examines the impact of alternative water pollution controls, including pesticide bans, on agriculture in the Corn Belt.

D: Uses crop yields, production budgets, and pesticide requirements.

M: Formulates and uses a linear programming model of Corn Belt agriculture for environmental policy analysis. Notes that a principal feature of the model is the incorporation of stepped demand functions for some crops. The objective function maximizes the economic surplus from corn and soybeans minus the costs of producing small grains and hay and a cost-term associated with small crops and pastures. The model output estimates partial welfare effects.

R: Shows a welfare loss of $1.7 billion from a herbicide ban; $99 million from an insecticide ban; and a substantial consumer welfare loss under nitrogen restrictions. Shows that per acre soil loss restrictions and a particular terrace subsidy appear more promising than other erosion controls from a combined economic and political viewpoint.

117. _______________, and J.C. Headley. "Insecticide Resistance and the Evaluation of Control Strategies for an Insect Population," *Canadian Entomologist,* Vol. 107, 1975, Mar., 237-42.

The authors present a mathematical pest population model which accounts for physiological resistance in the pest population that can be used for dynamic economic evaluation of alternative pest control strategies. They also develop a dynamic programming model that permits grouping of members of the pest population by dosage-mortality rate. The group numbers are determined each period according to laws of population genetics. In the absence of a specific benefit function, the authors suggest that Monte Carlo simulation might be informative.

118. _______________, and Ronald D. Lacewell. "Boll Weevil Control Strategies: Regional Benefits and Costs," *Southern Journal of Agricultural Economics,* Vol. 9, No. 1, July 1977, 129-35.

T: Evaluates producer impacts of alternative boll weevil control strategies at both national and regional levels, and consumer impacts at the national level.
D: Uses crop yields and production budgets.
M: Employs linear programming to evaluate alternative boll weevil control strategies. The model includes stepped demand functions for cotton lint, food and feedgrains, and oilmeals.
R: Estimates aggregate net welfare gains and producer losses under the alternatives examined. Estimates that cotton prices and land values than fall with better pest control. Concludes that integated pest management strategies would provide more social benefits that would an eradication program.

119. U.S. Department of Agriculture, Economic Research Service. *Economic Research on Pesticides for Policy Decisions.* Symposium Proceedings. Apr. 1971.
Examines the status of economic research on pesticide use and identifies high priority areas for further research. Identifies the agricultural production, social welfare, and environmental effects of pesticide use restrictions as high priority research areas. Presents 16 contributed papers and three workgroup reports.

120. U.S. Environmental Protection Agency, Office of Pesticide Programs. *Farmer's Pesticide Use Decisions and Attitudes on Alternative Crop Protection Methods.* EPA-540/1-74-002. July 1974.
The report analyzes the pest control beliefs and practices of soybean and corn producers in Iowa and Illinois, and provides information collected from 300 farmers and numerous secondary sources. The information shows that farmers primarily use chemical pest control strategies and receive pest control information from pesticide retailers, pesticide labels, and other farmers. The report recommends further integrated pest management research and extention activities to improve farmer's pest control practices.

121. Van den Bosch, R. "The Cost of Poison," *Environment,* Vol. 14, No. 7, Sept. 1972, 18-22, 27-31.
Documents the overuse of chemical pesticides, pointing to the destruction of natural enemies and subsequent uncontrolled growth of pest populations as well as the development of pest resistance to pesticides. Discusses alternative forms of pest control including biological control, microbial control, development of strains resistant to pests, sterile insect control, and cultural methods.

122. Von Rumker, R., and others. *Evaluation of Pest Management Programs for Cotton, Peanuts, and Tobacco in the United States.* EPA 540/9-75-031. U.S. Environmental Protection Agency, 1975.

T: Identifies prominent existing pest management practices for different crops and compares feasibility, biological effectiveness, and economic aspects to integrated control.

D: Uses cost, yield, insecticide, and profit data for cotton, peanuts, and tobacco in various regions.

M: Evaluates integrated pest management programs for cotton, peanuts, and tobacco in terms of operating cost, yield, insecticide use, and profit.

R: Finds, in a high percentage of the cases studied, that integrated pest management is technically and economically feasible and that it uses less insecticide than conventional control. Notes problems in evaluating environmental improvement due to pest management.

123. Webster, J.P.G. "The Analysis of Risky Farm Management Decisions: Advising Farmers About the Use of Pesticides." *Journal of Agricultural Economics,* Vol. 28, 1977, 243-59.

T: Discusses risk in farm management and decision theory, and presents an analysis of a fungal parasite problem on wheat.

D: Uses posterior probability distributions for parasite infection, distributions derived from a visual impact method. Samples farmers to obtain data for utility functions.

M: Uses the Bernoullian decision theory (Bayesian statistics) to determine expected values of spraying alternatives. Derives farmers' utility functions to determine optimal spraying strategies and compares them to other risk strategies.

R: Finds that farmers' decisions vary only slightly from the strategy of risk indifference.

Author Index

Subject Index

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