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THE ECONOMIC IMPACT OF INVESTMENT IN INTEGRATED PEST MANAGEMENT

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Introduction

Following World War II, pest control largely shifted from a biological discipline to a chemical one. Unilateral dependence on pesticides has also resulted in concentrating effort on developing high-yield crop varieties with disregard for loss of characters for tolerance or resistance to pests. The broad ecological dictum of considering the whole interacting system was generally ignored and, thus, the importance of natural enemies and the plant's own factor for resisting pests. Excessive reliance on pesticides for the last three decades has destroyed natural enemies and caused some pests to develop resistance to pesticides. Consequently, the use of frequent treatments with increasing dosages was adopted in an effort to control pests. This development, however, increased production costs of many crops without alleviating the problem (Huffaker and Smith).

The rise of energy and pesticide costs combined with growing ecological and social concern about excessive pesticide use have encouraged scientific and public attention to initiate coordinated research on agricultural pests that consider the biological, cultural, and ecological aspects of controlling pests. The United States International Biological Program (IBP) initiated in 1971 with the cooperation of the National Science Foundation, the Environmental Protection Agency, and the U.S. Department of Agriculture, and 18 land-grant universities has set the foundation for the development and implementation of coordinated pest control programs which are more efficient and less harmful to public health and the environment.

Direct techniques and methods of control utilized in integrated pest management (IPM) include: crop plant resistance, biological control, cultural control, pesticide use, attractants and repellants, and growth regulation. In addition to the direct pest control methods, collecting the necessary information by monitoring or sampling the pest population and its principal natural enemies at appropriate times of the year is required for effective management decisions. Through monitoring and short-term weather prediction it was possible in 1976 to reduce insecticide treatments of cotton from 10 to two applications per year (Huffaker and Smith). In general, IPM uses the best combination of all known control techniques and concentrates on the plants themselves rather than the pests.

Relevant Literature

Economic analysis of pest control has emphasized the timing and application of pesticides. Headley defined the economic threshold within the framework of a single pest population growth model and a single application of pesticides. Hall and Norgaard studied the optimal timing and pesticide application. Smith showed that pests exposed to intensive pesticide application will develop resistance, and thus optimal pest control should take pest resistance into consideration. Taylor and Headley considered pest resistance in the optimal control of pest population. Hueth and Regev investigated the effect of increasing pest resistance to insecticides on the optimal control of a pest population by constructing a single-pest, single-crop management model. Talpaz et. al. estimated optimal pesticide application for controlling the boll weevil on cotton, Rumker, et. al. evaluated 19 cotton pest management programs, three peanut pest management programs, and three tobacco pest management programs in the United States. The programs were evaluated in regard to costs, effect on crop yield, pesticide use, production costs, and grower's profits. The environmental impact and the biological and economic feasibility of each program were analyzed.

Implementation of IPM programs on 3,600 acres of cotton in four areas of Texas (the lower Rio Grande Valley, South Texas, the Texas Blackland, and Trans-Pecos) in 1973 and 1974

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has resulted in an estimated 82,000-lb. reduction in pesticide use and a 4,200-bale increase in cotton yield. The implementation of the program increased net return per acre for participants by \$55.31 in the Rio Grande Valley, \$17.95 in the Blackland, and \$30.59 in the Trans-Pecos in 1973. A further increase in net return of \$15.73, \$18.89, and \$61.84 for these areas was noted in 1974 (Frisbie et. al.). Evaluation of integrated cotton pest management program in Texas for 1964-1974 shows that producer net return increased by \$7.33 and \$4.60 for each dollar of program costs for 1973 and 1974, respectively. The estimated effect of the program on production was an increased yield of 60 lbs. of lint per acre in 1973 and 36 lbs. per acre in 1974. Implementation of the program increased participant insecticide use by about 1 pound per acre in 1973 compared to a reduction of 2.25 lbs. per acre in 1974. For both 1973 and 1974, lint yield per pound of insecticide use was increased (Lacewell et. al.).

Objective of the Study

The primary objective of this study is to evaluate the economic impact of investments in integrated pest management research and extension programs by commodities in the United States. Specifically, the following objectives are sought: (1) to estimate the benefit-cost ratio of investment in IPM; (2) to estimate the internal rate of return to investment in IPM; (3) to estimate the reduction in pesticide use resulting from the implementation of IPM; and (4) to evaluate the extent of technology transfer between and within regions of the United States.

Method and Procedures

Two basic approaches have been used in evaluating agricultural research and extension: (1) the ex post approach, and (2) the ex ante approach. Most evaluation studies have used the ex post approach. Ex ante evaluation is based on the projected future benefits of research and extension. In this study, the ex ante approach was adopted to evaluate the economic impact of present and future investments in IPM programs.

Current and planned IPM programs in the United States were evaluated. A set of questionnaires was developed to assess present and future costs associated with each program for each commodity and the expected benefits from the implementation of the technical knowledge forthcoming from current and future research and extension programs. Personal interviews were conducted with researchers and extension specialists actually involved in the development and implementation of IPM programs in leading agricultural research and extension centers in the four regions of the United States in 1978. The following information was obtained for each project and aggregated across projects for each commodity: (1) initiation and termination dates of research and extension projects for each commodity; (2) the probability of research success; (3) the probability, time lag, and rate of adoption of research results with and without extension; (4) maximum expected adoption and the percentage of crop or livestock affected in each year of adoption; (5) research, extension, and private resources required to develop, implement, and maintain the new technology; (6) the expected elimination of active toxic material from the environment that would result from the implementation of the new technology; (7) the expected changes in yield, quality, and cost of production ensuing from the implementation of the new technology; and (8) the pattern of technology transfer within each region and between regions. In order to account for research and extension costs in supporting fields, all research and extension expenditures allocated to pest management programs in each commodity for the duration of the program were used to estimate the rates of return to investment.

The Model

The flow of benefits from each research project was estimated by the following equation:

$$(1) \quad B_{jt} = A_{jt}\,[(1+\Delta P_{jt})V_t - V_o - \Delta C_{jt}]$$

where: B_{jt} = benefits accruing to the jth technology in year t,

A_{jt} = expected total production affected by the jth technology in year t,

ΔP_{jt} = expected change in net productivity of the affected crop or livestock due to the jth new technology in period t,

V_t = expected price of each unit of output of the affected crop or livestock in year t, and $V_t = [V_o + V_o\,(f.\Delta P_t)]$ where f is the flexibility ratio, and V_o is price per unit in the base year,

V_o = price per unit of output in the base year,

ΔC_{jt} = expected change in production cost of the affected crop or livestock due to the jth new technology in year t.

B_{jt} is the maximum benefit that could accrue to society as a result of implementing the research findings. However, the outcome B_{jt} is probabilistic in nature because it depends on the proability of research success, P(S), and the probability of adoption, P(A). Thus, the expected flow of benefits from research and extension is defined as:

$$(2) \quad E(B_j) = \sum_{t=1}^{N} B_{jt} P \{(A_t \cap S_t)\}$$

where N is the number of years for which the research technology, j, affects production and/or cost.

The present value of the expected flow of benefits from the research and extension investment is obtained by "discounting" the right-hand side of equation 2:

$$(3) \quad E(B_j) = \sum_{t=1}^{N} B_{jt} \cdot P(A_t \cap S_t)/(1+r)^t$$

where r is the social discount rate.

Similarly, the present value of the flow of the research and extension costs may be expressed as:

$$(4) \quad Z_j = \sum_{t=1}^{N} (M_{jt} = I_{jt} + E_{jt} + R_{jt})/(1+r)^t$$

where:

Z_j = the present value of the total costs associated with investment in, and implementation of, the jth technology,

M_{jt} = the costs of maintenance research required to sustain output at previously achieved levels for technology j,

I_{jt} = implementation costs incurred by the farmer in adopting the jth technology,

E_{jt} = extension costs involved in transferring the jth technology to the farmer, and

R_{jt} = annual expenditure for research investment for the jth new technology for the affected crop or livestock in year t.

The 1978 production year was used as the base year to calculate changes in productivity, cost, and price due to research and extension. Expenditures in each research problem area prior to 1978 were compounded at 6% to bring the costs to the 1978 level. All measures of benefit were calculated with and without extension to estimate the contribution of cooperative extension to research effectiveness.

Measures of Benefit

Several measures of benefit were calculated in this report. The benefit-cost ratio B/C is defined as the ratio of the present value of the expected flow of benefits from the implementation of research results to the present value of the flow of expenditures. This benefit-cost ratio is expressed as:

$$(5) \quad B/C = E(B_j)/Z_j$$

The internal rate of return (IRR) is defined as the rate of return that equates the present value of the expected flow of expenditures in the development, implementation, and maintenance of technology and the present value of the expected flow of benefits. The internal rate of return is calculated by an iterative process using the following equation:

$$(6) \quad E(B_j) - Z_j/(1+IRR)^t = 1$$

where:

IRR = internal rate of return.

The net present worth (N.P.W.) is defined as the present value of the expected flow of benefits $E(B_j)$ minus the present value of the flow of expenditures (Z_j). These measures of benefit were calculated for each research and extension problem area and aggregated by commodity, using a social discount rate of 10%.

Analysis of Results

The adoption profile, probability of adoption and probability of research success of integrated pest management were estimated for the commodities considered in this study. The adoption profile considers the year of adoption, adoption rate with and without extension involvement, probability of adoption, and probability of research success. For example, for alfalfa, the first expected year that research results will be adopted is 1983. Only 10% of alfalfa acreage is expected to adopt the research results with extension involvement. No adoption is expected without extension in the first year. An estimated 75% of the alfalfa acreage will adopt the research results with extension involvement in the fifth year compared to only 25% without extension. The extension role consists of conducting field trials to demonstrate the results, advising farmers of the adoption procedure, and demonstrating the immediate and future economic and environmental benefits of the program to individual farmers and society.

The probability of adopting the results of alfalfa IPM research was estimated at 90%. Probability of research success was estimated to range between a low of 80% to a high of 90%. The estimated probability of adoption and the lower probability of research success was applied to the annual rate of adoption to estimate the actual acreage of alfalfa that is expected to adopt the program annually.

Technology transfer from one area to another was evaluated (Figures 1-6). The results show that 60% of the alfalfa acreage in Arizona, 50% of the acreage in Oregon and Washington, 40% of the acreage in Idaho, and 30% of the acreage in

Figure 1. Technological Transfer from Integrated Pest Management Research: California, Alfalfa (——); Indiana, Alfalfa (—·—); New York, Alfalfa (– – –)

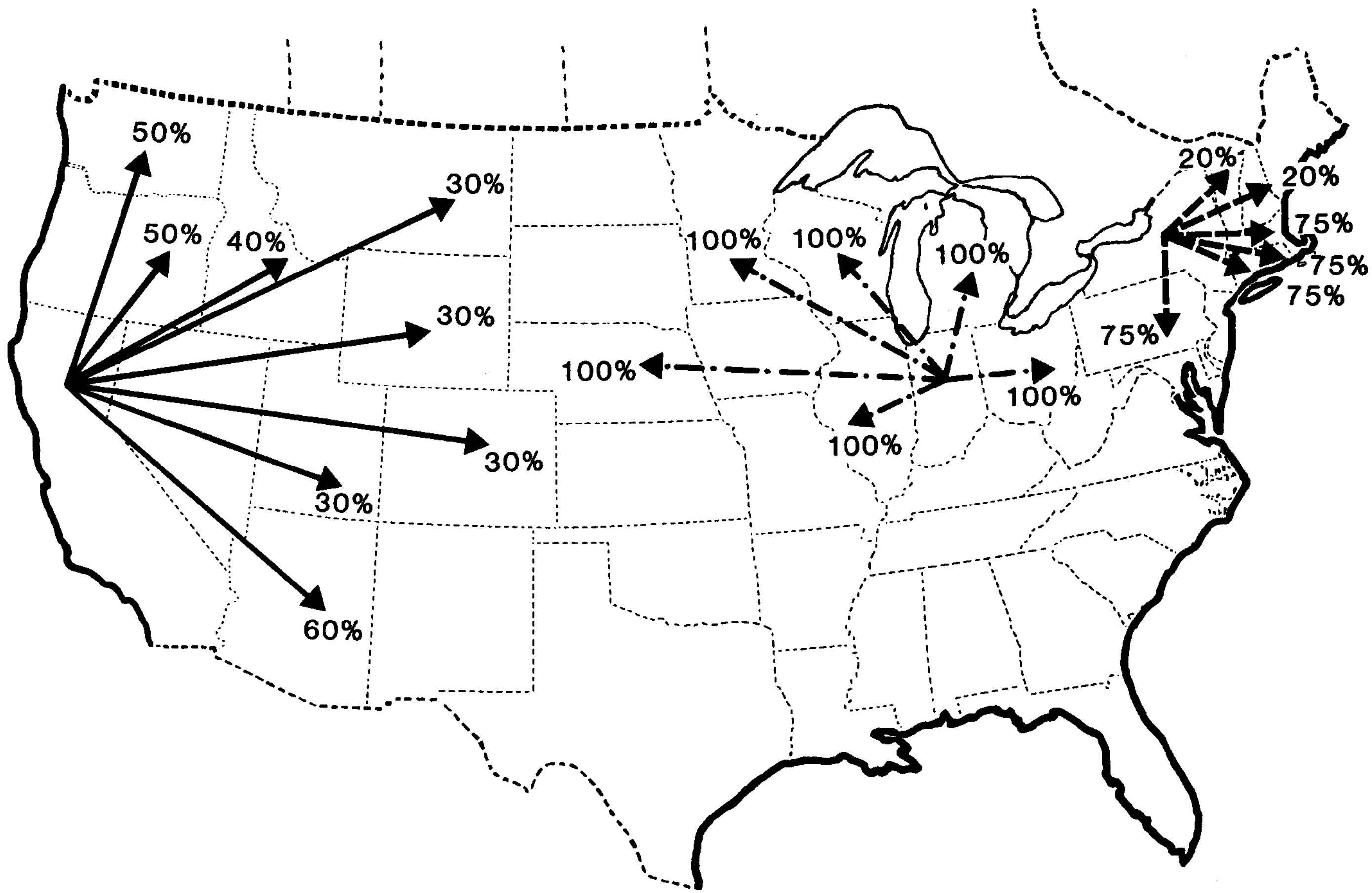


Figure 2a. Technological Transfer from Integrated Pest Management Research : California, Grapes (——), Apples (—··—), Pears, (— — —)

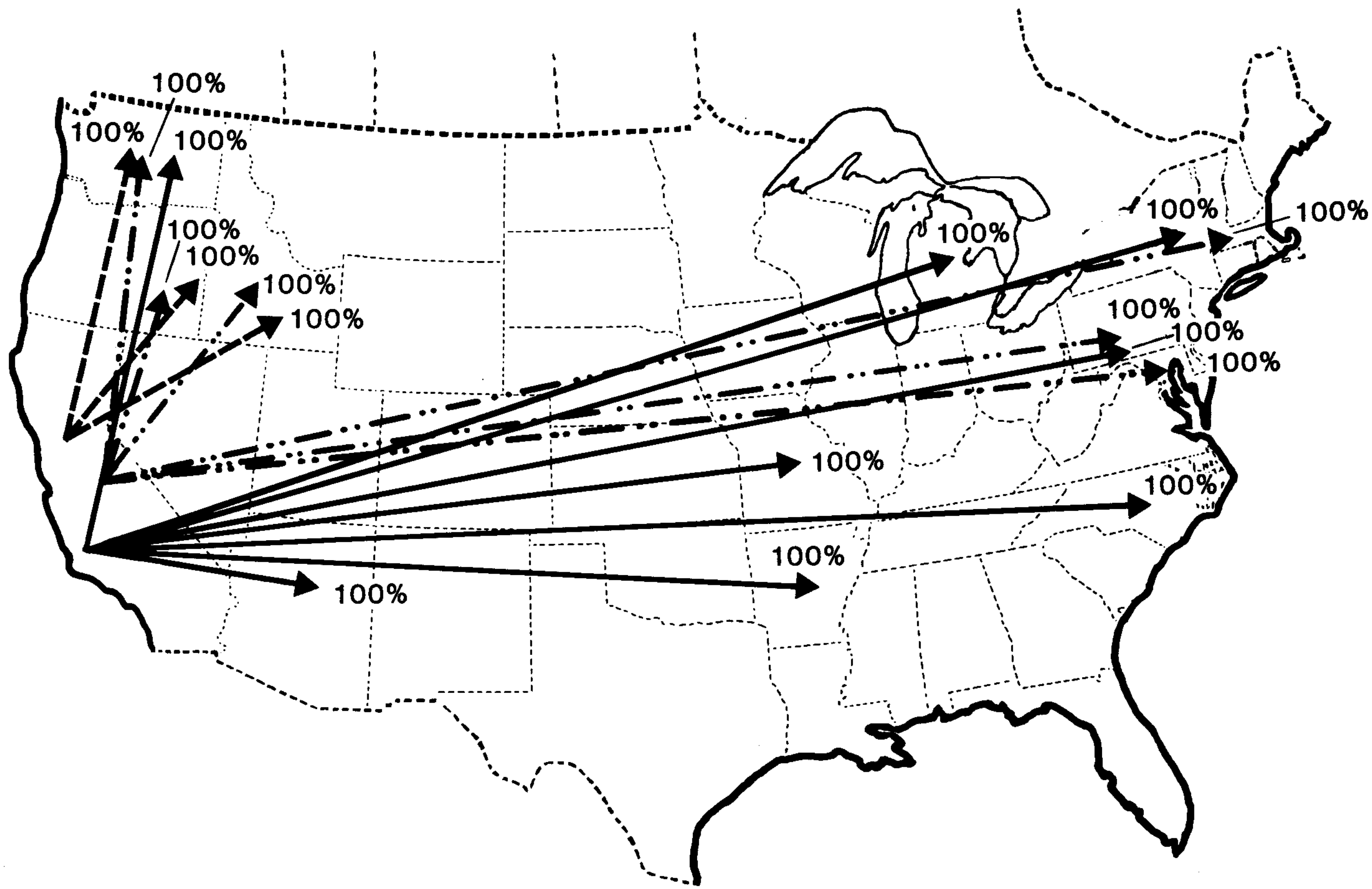


Figure 2b. Technological Transfer from Integrated Pest Management Research: New York, Pears (• • •); Apples (—·—); Grapes (~ ~)

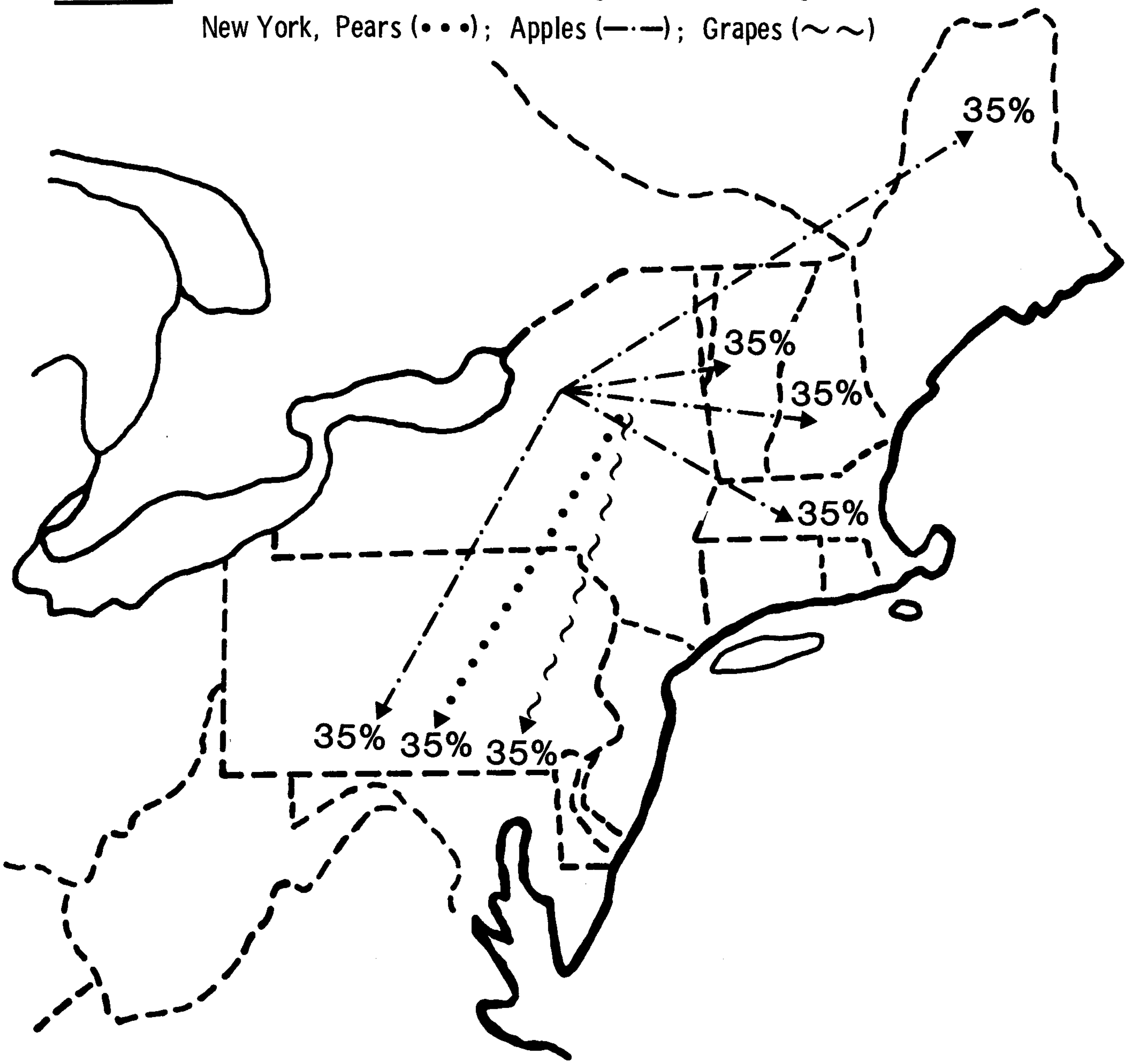


Figure 3a. Technological Transfer from Integrated Pest Management Research: Michigan, Peppermint (~ ~); Texas, Cattle (---); California, Cotton (-·-)

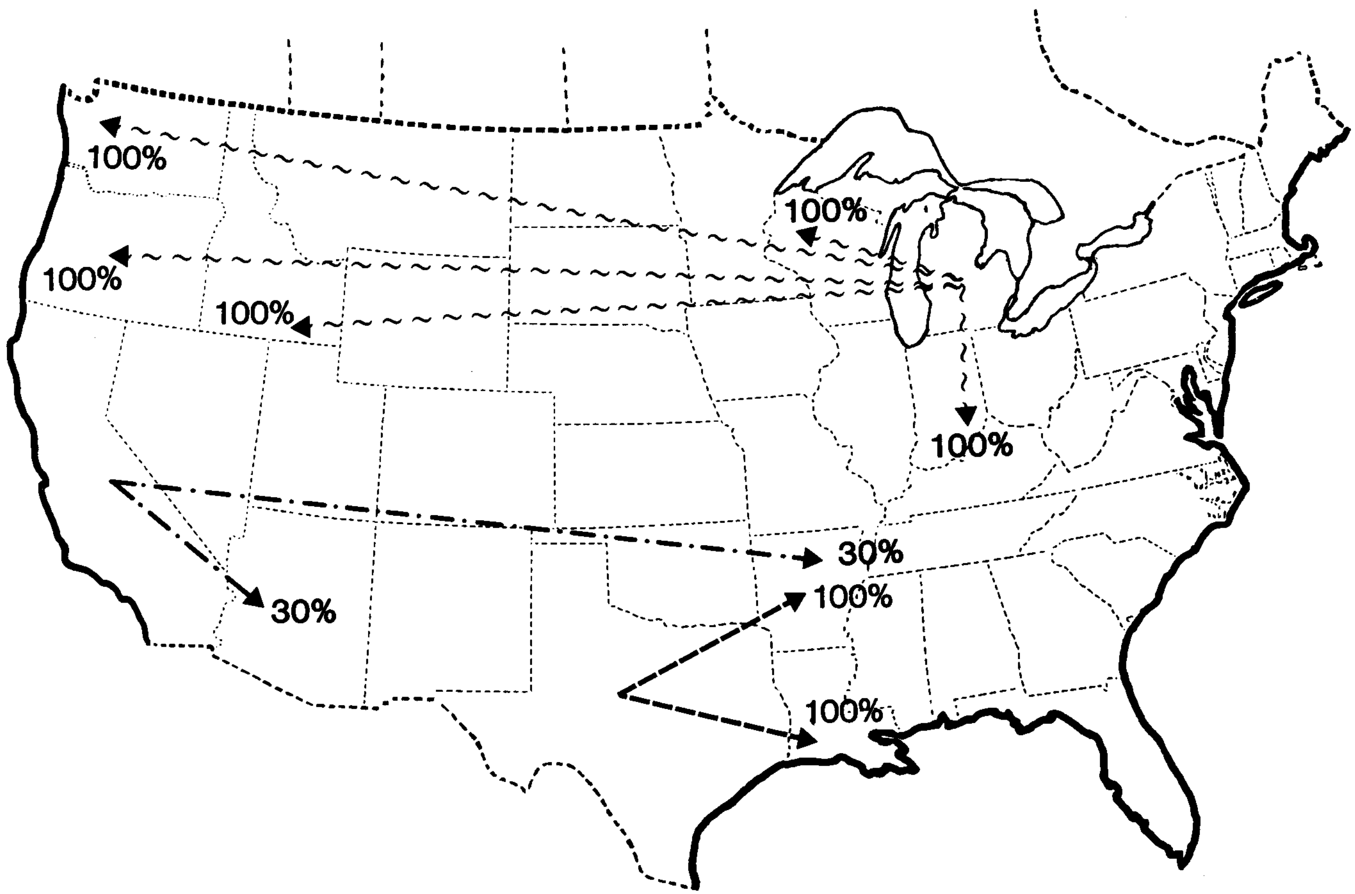


Figure 3b. Technological Transfer from Integrated Pest Management Research: Michigan, Forest (——); New York, Potatoes, Beans, Sweet Corn, Onions (—··—)

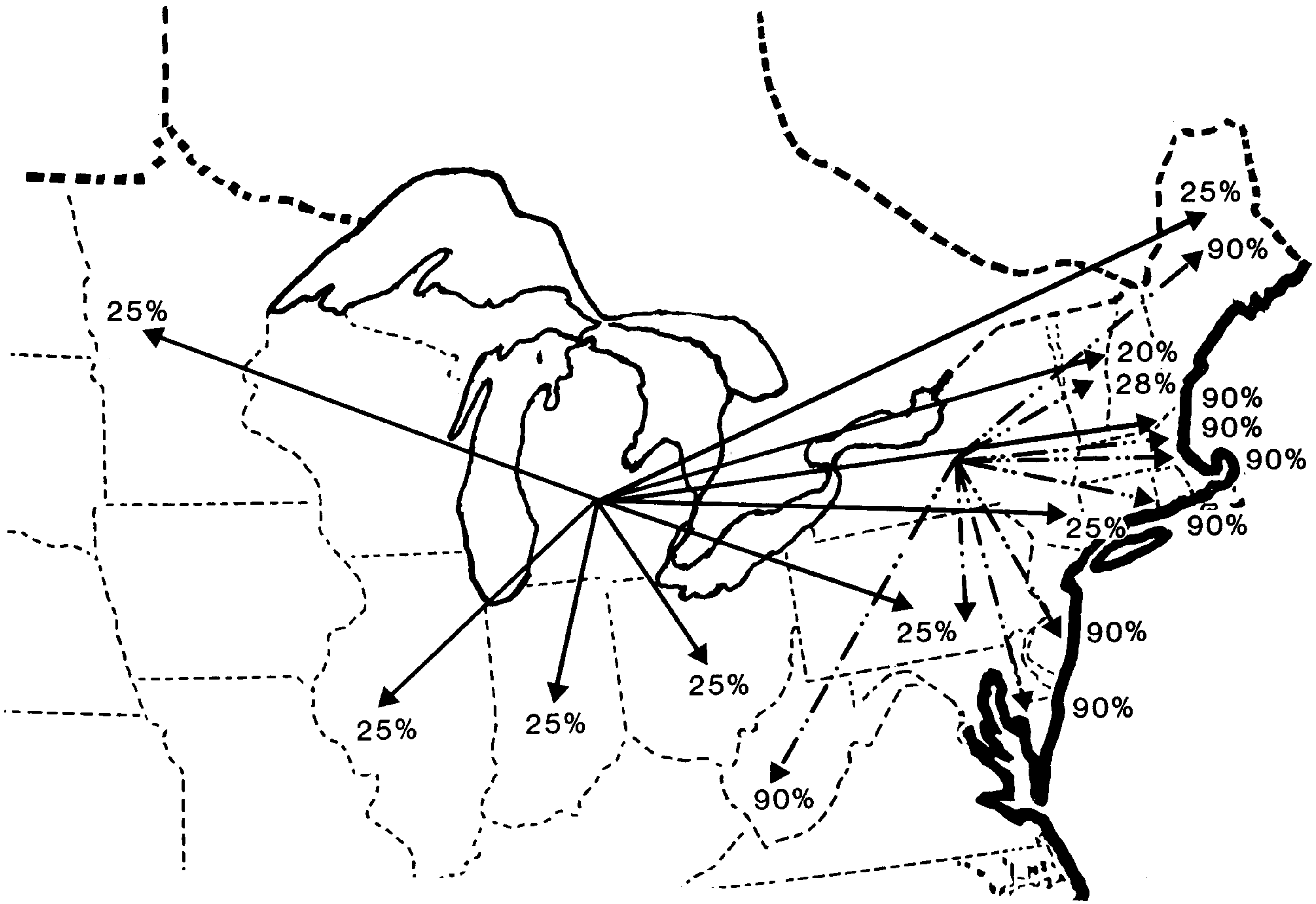


Figure 4. Technological Transfer from Integrated Pest Management Research: Michigan, Peaches, Apples, Plums, Pears

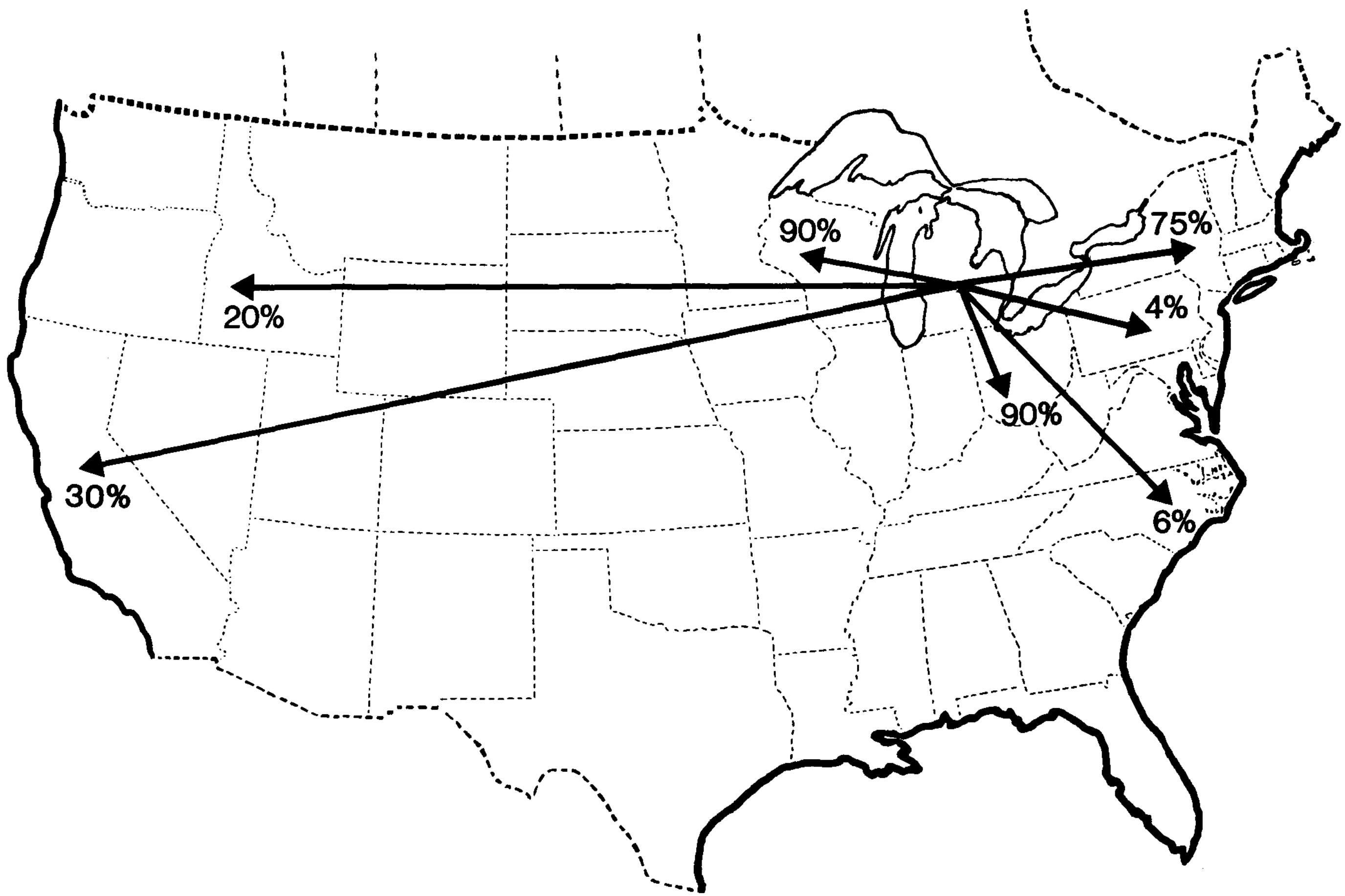


Figure 5. Technological Transfer from Integrated Pest Management Research : Indiana, Corn (——); Soybeans (—·—), Soft Red Winter Wheat (– – –)

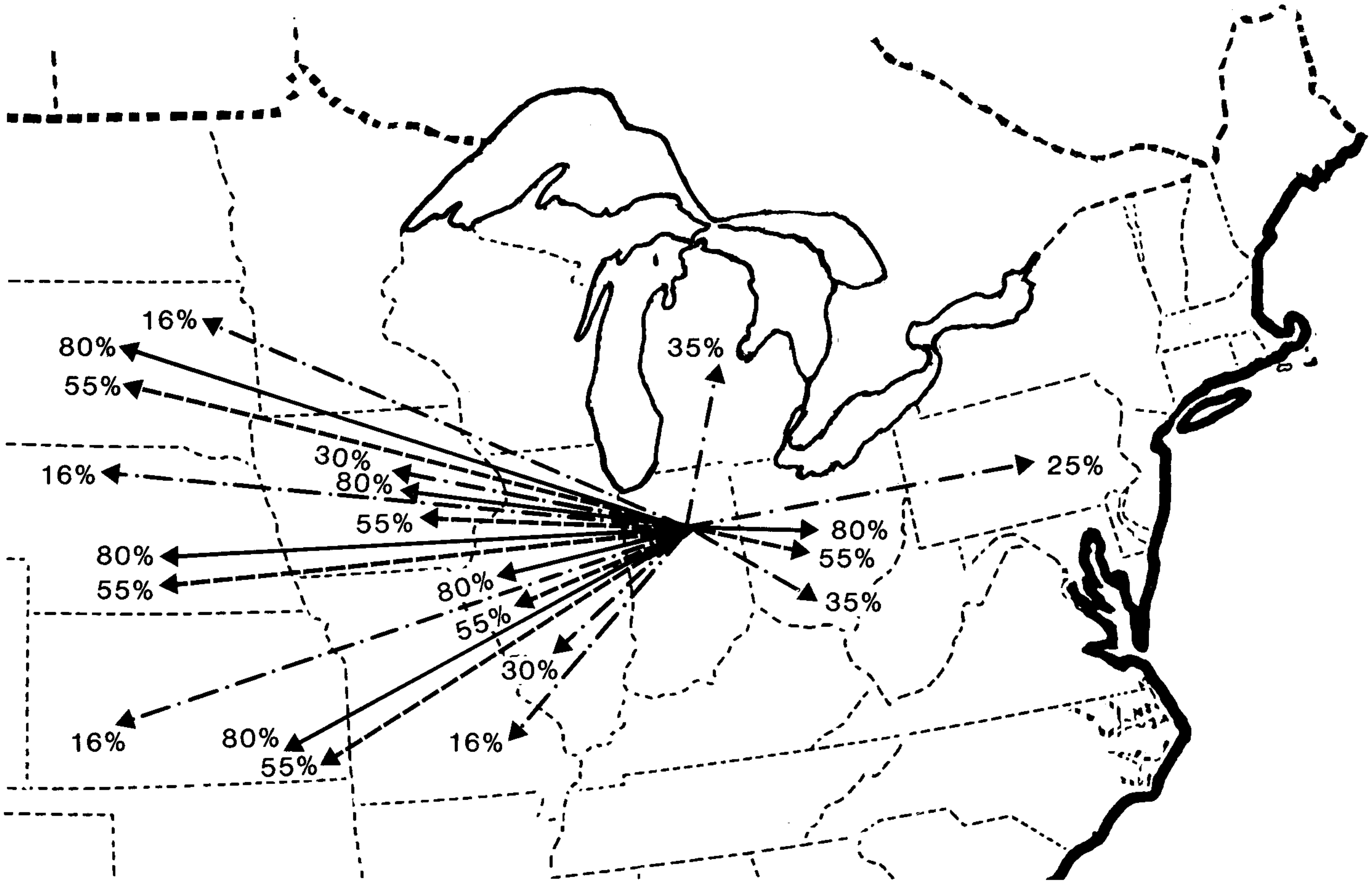
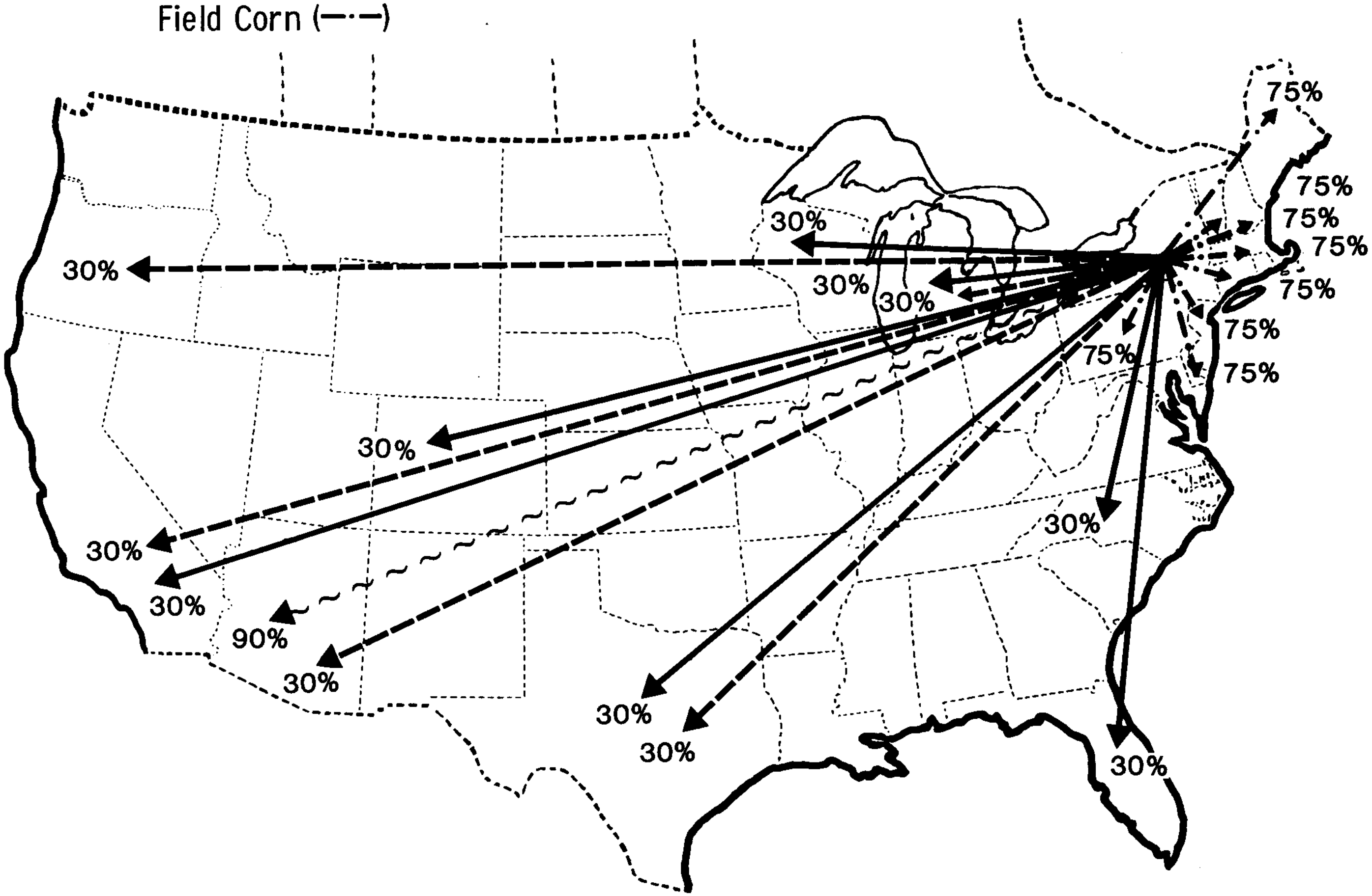


Figure 6. Technological Transfer from Integrated Pest Management Research: New York, Cabbage (——), Califlower (– – –), Lettuce (~ ~), Field Corn (—·—)



each of Montana, Wyoming, Utah, and Colorado will benefit directly from the IPM research conducted in California. The adoption profile was applied to the proportion of acreages in these states to estimate the total acreage of alfalfa that will adopt the program.

The extent of technology transfer within regions and between regions varies from crop to crop and is influenced by the nature of the IPM program being developed. An estimated 100% of the results of IPM programs for fruit trees such as grapes, apples, and pears developed in the California station is transferable to other states. Similar estimates were obtained for IPM research for cotton from California to other states, for cattle from Texas to other states, for peppermint from Michigan to other states, for alfalfa from Indiana to other states, and for grapes from New York to other states. The types of pest for which IPM is being developed influence the extent of technology transfer.

The estimated benefit-cost ratios, net present worth and internal rate of return in investments in IPM for the commodities considered in this study are shown in Table 1. Returns to investment were estimated for flow of benefits to years 1990, 1995, and 2000 with and without extension participation. Internal rate of return for the flow benefits to year 1990 with extension participation range from a high of 190% for soft red winter wheat to a low of less than zero for sweet corn. Extending the flow of benefits to year 1995 and year 2000 increased the internal rates of return slightly. The payoff to investments in pest management programs varies by commodities and is influenced by the pattern and magnitude of technology transfer within and between regions, the number of acres affected, the value of the output, the type of pest involved and the damage it causes, the adoption profile, and probability of research success. For the major agricultural commodities such as alfalfa, cotton, corn, cattle, potatoes, apples, fruits, and onions, the internal rates of return are in the 20% to 60% range.

Analysis of the results indicate that significant returns to investment in experiment station pest management research will not be realized without coordinated extension involvement in the dissemination and implementation of research results. Depending on the commodity and the estimated flow of benefits, approximately 7.2% to 100% of the expected benefit from pest management research will not be realized without extension participation (Table 2).

The importance of cooperative extension is influenced by the degree of risk associated with any change in the present practice of pesticide use. For pests that cause extensive damage on certain crops and for which changes in present practices of chemical control cause significant crop loss, the successful implementation of new pest management programs will totally depend on the development of a well-designed extension program to convince producers of the values and the risks associated with the implementation of the new pest management program. The expected benefits from IPM for such crops as apples, grapes, citrus, pears, sweet corn, carrots, lettuce, peppers, cabbage, cantaloupe, asparagus, peppermint, sugarbeets, soybeans, and cotton will entirely depend on a well coordinated extension program (Table 2).

The Environmental Impact of Investment in Integrated Pest Management

Current and planned pest management programs are expected to reduce pesticide use significantly. The results of this study show an estimated 37.04 million lbs. of active toxic ingredients will be eliminated annually from use on 20 agricultural commodities (Table 3). The reduction in pesticide use is primarily due to the implementation of monitoring systems, proper timing of pesticide application, development of resistent varieties, and the introduction of biological control.

The reduction of an estimated 37.04 million lbs. of active toxic materials will lead to further future reduction in the use of pesticides by enhancing the effectiveness of biological control. Reduction in the use of pesticides will increase the population of the parasite species that are presently being destroyed by excessive toxic materials in the environment. The scientific judgment of the researchers and extension specialists interviewed for the purpose of this study suggest that the impact of IPM programs on the reduction of active toxic materials from the environment, development of resistent varieties, and the implementation of proper management systems will lead to a potential 50-70% reduction in the present pesticide use in the United States.

Summary

Extensive reliance on pesticides for the last three decades has resulted in frequent treatments with increasing dosages of chemicals. The broad ecological dictum of considering the whole interacting system in pest control was generally ignored. The practice increased production costs of many crops without alleviating the problem. The rising energy and pesticide costs combined with growing ecological and social concern about excessive pesticide use have focused scientists attention to the development of IPM programs that consider the biological, cultural, and ecological aspects of controlling pests. The United States International Biological Program (IBP) initiated in

Table 1. Return to Investment in Pest Management Research and Extension Program by Commodity[1/].

	Alfalfa	Cotton	Corn	Grapes	Soybeans
1990[2/]					
Without extension					
B/C ratio	0.8581	0.1173	1.3448	0.1335	---
N.P.W. ($ million)	-3.2	-59.7	1.9	18.5	---
I.R.R. (%)	8.07	<0	14.63	<0	---
1995[3/]					
without extension					
B/C ratio	1.6991	0.1299	1.6041	0.2121	---
N.P.W. ($ million)	17.8	-67.9	3.4	-1.9	---
I.R.R. (%)	15.48	<0	16.40	<0	---
2000[4/]					
without extension					
B/C ratio	2.1576	0.1361	1.7651	0.2521	---
N.P.W. ($ million)	30.9	-72.9	4.3	-19.5	---
I.R.R. (%)	17.21	<0	17.04	<0	---
1990[2/]					
with extension					
B/C ratio	4.1927	2.2483	24.2404	4.9953	16.9464
N.P.W. ($ million)	75.0	84.5	131.1	85.5	19.6
I.R.R. (%)	36.66	61.00	59.02	76.63	125.11
1995[3/]					
with extension					
B/C ratio	6.0981	2.4118	30.1247	5.6736	38.1756
N.P.W. ($ million)	130.1	110.1	164.3	113.6	45.8
I.R.R. (%)	38.25	61.21	59.26	76.80	128.83
2000[4/]					
with extension					
B/C ratio	7.1375	2.4933	33.7784	6.0186	51.3573
N.P.W. ($ million)	164.3	126.1	185.0	131.1	62.02
I.R.R. (%)	38.51	61.23	59.28	76.81	128.88

1/The rates of return estimates are based on the low probability of research success shown in Appendix-Table 1.
2/The flow of benefits is assumed to continue to 1990.
3/The flow of benefits is assumed to continue to 1995.
4/The flow of benefits is assumed to continue to 2000.

1971, has set the foundation for the development and implementation of IPM programs. The concept of IPM has received wide acceptance and is being implemented on several crops. The primary objective of this study is to evaluate the economic and environmental impact of investments in IPM in the United States.

An *ex-ante* approach was used to evaluate current and planned pest management programs in the United States. A set of questionnaires was developed to obtain the following information: (1) initiation and termination dates of research and extension projects for each commodity; (2) the probability of research success; (3) the probability and the adoption profile of research results with and without extension; (4) research, extension, and private resources required to develop, implement, and maintain the new technology; (5) the expected elimination of active toxic ingredients from the environment; (6) the expected changes in yield, quality, and cost of production ensuing from the implementation of the new technology; and (7) the pattern and extent of technological transfer. Personal interviews were conducted with researchers and extension specialists in the leading research and extension centers in IPM in the Northeast, the Northcentral, the South, and the Western Regions.

Analysis of the results shows that internal

Table 1. Continued

	Cattle	Sorghum	Wheat	Potatoes	Sugarbeets
1990[2/] without extension					
B/C ratio	0.5773	7.5647	15.7918	0.5228	---
N.P.W. ($ million)	-3.4	2.9	10.2	-7.0	---
I.R.R. (%)	<0	73.75	133.76	1.05	---
1995[3/] without extension					
B/C ratio	0.7694	10.5322	20.4702	0.8307	---
N.P.W. ($ million)	-1.9	4.4	162.2	-3.3	---
I.R.R. (%)	5.94	74.42	134.19	7.80	---
2000[4/] without extension					
B/C ratio	0.8765	12.3336	22.6437	1.0063	---
N.P.W. ($ million)	-1.1	5.2	199.5	.01	---
I.R.R. (%)	8.18	74.46	134.20	10.06	---
1990[2/] with extension					
B/C ratio	1.5634	15.1302	27.3882	4.5804	89.5012
N.P.W. ($ million)	4.5	6.4	182.0	6.7	23.1
I.R.R. (%)	18.95	112.88	190.91	39.82	161.24
1995[3/] with extension					
B/C ratio	2.0740	15.1302	35.0591	6.8347	123.9740
N.P.W. ($ million)	9.3	6.4	346.9	9.9	32.1
I.R.R. (%)	22.24	112.88	191.04	40.75	161.27
2000[4/]					
B/C ratio	2.3589	21.0654	38.6229	8.1434	145.379
N.P.W. ($ million)	12.2	9.2	346.9	1.4	37.7
I.R.R. (%)	23.35	113.06	191.04	44.90	161.27

1/The rates of return estimates are based on the low probability of research success shown in Appendix-Table 1.
2/The flow of benefits is assumed to continue to 1990.
3/The flow of benefits is assumed to continue to 1995.
4/The flow of benefits is assumed to continue to 2000.

rates of return to investment in pest management research and extension programs range from a high of 191% for soft red winter wheat to a negative return for sweet corn. The payoff to investment in pest management programs varies by commodity and is influenced by the magnitude of technology transfer within and between regions, number of acres involved, the value of the output, the type of pest and the damage it causes, the adoption profile, and the probability of research success. For the major agricultural commodities such as alfalfa, cotton, corn, cattle, potatoes, fruits, and onions, the internal rates of return are in the 20% to 60% range. The results also show that technology developed by a state experiment station is transferred and adopted by other states. The pattern and magnitude of technology transfer is affected by the nature of the technology and the type of crops and pests involved.

The results also show that significant returns to investment in experiment station pest management research will not be realized without extension involvement in the dissemination and implementation of the results. Depending on the commodity, approximately 7.2% to 100% of the expected benefits from research will not be realized without extension participation.

Significant environmental impacts are expected from the implementation of current and

Table 1. Continued

	Tomatoes	Apples	Beans	Citrus	Forest
1990[2/] without extension					
B/C ratio	6.3456	0.2141	0.4309	---	4.3344
N.P.W. ($ million)	2.2	-1.4	-1.8	---	5.7
I.R.R. (%)	48.00	<0	<0	---	60.19
1995[3/] without extension					
B/C ratio	8.3767	0.2431	0.6425	---	5.8086
N.P.W. ($ million)	3.2	-1.5	-1.1	---	9.5
I.R.R. (%)	49.19	<0	4.85	---	61.33
2000[4/] without extension					
B/C ratio	9.5336	0.2580	0.7714	---	6.5299
N.P.W. ($ million)	3.8	-1.6	-.8	---	12.0
I.R.R. (%)	49.34	<0	7.30	---	61.43
1990[2/] with extension					
B/C ratio	33.9104	1.0663	0.6617	5.4236	7.2704
N.P.W. ($ million)	13.6	.1	-1.4	15.7	10.7
I.R.R. (%)	108.36	11.88	3.91	101.76	86.56
1995[3/] with extension					
B/C ratio	45.7806	1.4908	0.9731	6.0742	97.208
N.P.W. ($ million)	19.6	1.0	-.1	22.0	17.4
I.R.R. (%)	108.53	18.84	9.66	102.49	86.95
2000[4/] with extension					
B/C ratio		1.7095	1.1599	6.5840	10.9197
N.P.W. ($ million)		1.5	.7	29.1	215.5
I.R.R. (%)		20.46	11.61	102.59	86.97

1/The rates of return estimates are based on the low probability of research success shown in Appendix-Table 1.
2/The flow of benefits is assumed to continue to 1990.
3/The flow of benefits is assumed to continue to 1995.
4/The flow of benefits is assumed to continue to 2000.

planned pest management programs. The results of this study show that an estimated 37.04 million lbs. of active toxic ingredients will be eliminated from use annually on 20 agricultural commodities. This reduction in toxic materials is expected through the implementation of monitoring systems, proper timing of pesticide application, development of resistant varieties, and the introduction of biological control.

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Table 1. Continued

	Edible Tree Nuts	Stone Fruit	Sweet Corn	Onions	Peaches
1990 2/ without extension					
B/C ratio	0.7877	0.3729	0.2350	1.5182	1.1505
N.P.W. ($ million)	-1.9	-1.7	-2.3	2.3	.06
I.R.R. (%)	5.86	<0	<0	16.27	13.33
1995 3/ without extension					
B/C ratio	1.0048	0.5346	0.3206	1.9879	1.4169
N.P.W. ($ million)	.04	-1.3	-1.2	4.9	.1
I.R.R. (%)	10.07	3.16	<0	19.15	17.07
2000 4/ without extension					
B/C ratio	1.1174	0.8574	0.3020	2.2435	1.5639
N.P.W. ($ million)	1.2	-.4	-1.3	6.5	.2
I.R.R. (%)	11.59	8.27	<0	20.00	18.23
1990 2/ with extension					
B/C ratio	4.4983	2.6505	0.4283	4.1689	5.1774
N.P.W. ($ million)	31.5	4.6	-.9	14.4	1.5
I.R.R. (%)	52.49	30.47	<0	46.96	62.21
1995 3/ with extension					
B/C ratio	4.3125	3.5777	0.5907	4.8237	6.3763
N.P.W. ($ million)	33.5	7.6	-.8	18.9	2.1
I.R.R. (%)	52.55	33.04	<0	47.36	62.86
2000 4/					
B/C ratio	4.2167	4.1153	0.6692	5.1788	7.0377
N.P.W. ($ million)	34.7	9.4	-.7	2.1	2.5
I.R.R. (%)	52.55	33.54	1.72	47.42	62.91

1/The rates of return estimates are based on the low probability of research success shown in Appendix-Table 1.
2/The flow of benefits is assumed to continue to 1990.
3/The flow of benefits is assumed to continue to 1995.
4/The flow of benefits is assumed to continue to 2000.

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Table 1. Continued

	Pears	Carrots	Lettuce	Peppers	Pecans
1990 2/					
without extension					
B/C ratio	---	---	---	---	2.4275
N.P.W. ($ million)	---	---	---	---	1.0
I.R.R. (%)	---	---	---	---	35.24
1995 3/					
without extension					
B/C ratio	---	---	---	---	3.0495
N.P.W. ($ million)	---	---	---	---	1.6
I.R.R. (%)	---	---	---	---	38.00
2000 4/					
without extension					
B/C ratio	---	---	---	---	3.3584
N.P.W. ($ million)	---	---	---	---	2.0
I.R.R. (%)	---	---	---	---	38.45
1990 2/					
with extension					
B/C ratio	2.0146	1.4188	47.9763	9.2298	6.4804
N.P.W. ($ million)	.4	.01	1.2	2.1	3.8
I.R.R. (%)	33.37	15.56	96.65	55.87	76.42
1995 3/					
with extension					
B/C ratio	15.6945	1.6981	57.4237	12.7847	8.0535
N.P.W. ($ million)	5.4	.02	1.5	3.0	5.6
I.R.R. (%)	79.04	17.47	96.69	56.75	77.23
2000 4/					
with extension					
B/C ratio	23.6742	1.8624	62.9817	14.9921	8.8349
N.P.W. ($ million)	8.6	.02	1.6	3.6	6.8
I.R.R. (%)	80.21	18.13	96.69	56.84	77.27

1/The rates of return estimates are based on the low probability of research success shown in Appendix-Table 1.
2/The flow of benefits is assumed to continue to 1990.
3/The flow of benefits is assumed to continue to 1995.
$/The flow of benefits is assumed to continue to 2000.

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Table 1. Continued

	Cabbage	Cauliflower	Asparagus	Cantaloupe	Peppermint
1990 2/ without extension					
B/C ratio	---	1.6988	---	---	---
N.P.W. ($ million)	---	.3	---	---	---
I.R.R. (%)	---	22.09	---	---	---
1995 3/ without extension					
B/C ratio	---	5.2759	---	---	---
N.P.W. ($ million)	---	2.0	---	---	---
I.R.R. (%)	---	36.69	---	---	---
2000 4/ without extension					
B/C ratio	---	8.1941	---	---	---
N.P.W. ($ million)	---	3.5	---	---	---
I.R.R. (%)	---	38.92	---	---	---
1990 2/ with extension					
B/C ratio	3.6385	1.6988	11.9149	22.0702	3.6088
N.P.W. ($ million)	3.8	.3	14.3	5.5	10.3
I.R.R. (%)	34.98	22.09	138.19	85.23	101.11
1995 3/ with extension					
B/C ratio	4.3623	6.5732	12.6429	30.5708	3.6832
N.P.W. ($ million)	5.1	2.7	16.2	7.7	12.1
I.R.R. (%)	35.85	40.33	138.19	85.54	101.11
2000 4/ with extension					
B/C ratio	4.7810	9.4714	13.0385	35.8491	3.7212
N.P.W. ($ million)	5.9	4.1	18.1	9.1	13.1
I.R.R. (%)	36.02	41.93	138.19	85.56	101.11

1/The rates of return estimates are based on the low probability of research success shown in Appendix-Table 1.
2/The flow of benefits is assumed to continue to 1990.
3/The flow of benefits is assumed to continue to 1995.
4/The flow of benefits is assumed to continue to 2000.

Table 2. Estimated decrease in internal rates of return to investment in experiment station research without extension participation, by commodity.

Commodity	1990 (%)	1995 (%)	2000 (%)
Tomatoes	55.7	54.7	54.5
Potatoes	97.4	80.9	77.6
Apples	100	100	100
Grapes	100	100	100
Beans	100	49.8	37.1
Cattle	100	73.3	65.00
Citrus	100	100	100
Forest	30.5	29.5	29.4
Edible Tree Nuts	88.8	80.8	77.9
Stone Fruit	100	90.4	75.3
Sweet Corn	100	100	100
Corn	75.2	71.9	71.3
Onions	65.4	59.6	57.8
Pears	100	100	100
Carrots	100	100	100
Lettuce	100	100	100
Peppers	100	100	100
Sorghum	34.7	34.1	34.1
Pecans	53.39	50.8	50.2
Cabbage	100	100	100
Cauliflower	0	9	7.2
Cantaloupe	100	100	100
Sugarbeets	100	100	100
Asparagus	100	100	100
Peaches	78.6	72.8	71.00
Peppermint	100	100	100
Soybeans	100	100	100
Alfalfa	78.00	58.9	55.3
Cotton	100	100	100
Wheat	29.9	29.7	29.7

Table 3. Estimated reduction in active toxic ingredients resulting from the implementation of the results of current and planned pest management research and extension programs by commodity.

Commodity	Reduction in Active Toxic Ingredient (mil.lb.)
Alfalfa	1.45
Cotton	15.90
Corn	2.80
Grapes	1.15
Soybeans	5.10
Sorghum	6.00
Potatoes	1.20
Tomatoes	.01
Apples	1.15
Beans	.05
Citrus	.12
Edible Tree Nuts	.40
Stone Fruit	1.17
Sweet Corn	.10
Onions	.08
Pears	.03
Pecans	.03
Cabbage	.15
Cauliflower	.05
Peaches	.10
Total	37.04