ECONOMIC RISK EFFICIENCY OF BOLL WEEVIL ERADICATION

Philip I. Szmedra, Ronald W. McClendon, and Michael E. Wetzstein

Abstract

The purpose of this study was to determine the economic risk efficiency of implementing a boll weevil (*Anthonomus grandis [Boheman]) eradication (BWE) program in cotton (Gossypium hirsutum* L.) producing regions of the Mississippi Delta. Alternative producer pest management practices and program cost sharing were incorporated into a biophysical cotton simulation model. Participation in a BWE program along with strict adherence to Cooperative Extension Service pest management guidelines proved to be the risk efficient practice.

Key words: cotton integrated pest management, boll weevil eradication, biophysical simulation, risk efficiency, *Anthonomus grandis.*

In the southeastern U.S., the boll weevil (*Anthonomus grandis* [Boheman]) eradication (BWE) program directed by the U.S. Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS) generally involves states east of the Mississippi Delta. However, APHIS is interested in expanding the program to encompass the Mississippi Delta. This expansion will require a majority of cotton (*Gossypium hirsutum* L.) producers in the region to accept the economic and management BWE program requirements. A key ingredient in gaining producer acceptance of a BWE program in the Mississippi Delta is an economic analysis indicating its possible benefits.

The present procedure for providing such an analysis is to evaluate pre- and post-BWE pesticide budgets and returns in an existing area currently under a BWE program (Carlson and Suguiyama; Carlson et al.). The observed benefits and costs of the existing BWE program are then extrapolated to the new area being considered for a BWE program such as the Mississippi Delta. A shortcoming of this approach is that the environmental conditions may differ between the two regions under consideration which could result in biased estimates of extrapolated benefits and costs. This shortcoming may be addressed by directly estimating Mississippi Delta producers' benefits and costs of a BWE program. However, only pest control costs prior to BWE program adoption are available before initiation of the program. Only after a program is established, does there exist *ex post* data on both program and nonprogram costs and returns. The use of biophysical simulation models offers a solution as the effects of both program and nonprogram costs and returns may be calculated prior to program initiation.

Biophysical simulation modeling to evaluate the benefits and costs of a BWE program has not received attention. The literature on BWE is limited to a mathematical programming approach by Simpson and Parvin and an econometric model analyzing the aggregate economic effects by Taylor et al. Furthermore, previous analyses have not considered the effect of pest management participation rates on BWE programs. Recent literature suggests that the degree of participation influences producers' returns (Smith et al.).

The BWE programs undertaken to this point have been heavily subsidized by both the federal and state governments. An important question involves the economic attractiveness of an area-wide program given lessened or no cost sharing by governmental agencies. Thus, the objective of this paper is to determine the limits of profitable participation in a BWE program by Mississippi Delta cotton producers under alternative pest management participation levels. To this purpose, data generated by a physiologically based cotton growth simulation model describing the Mississippi Delta (Brown et al.) are analyzed using risk efficiency and discounted cash flow criteria. Significant factors that producers should consider before adopting a BWE program in their region are discussed, and some important relationships that may exist between pest management practices and the environment are indicated. Specifically, the interactions of different pest management participation levels with an eradication program are investigated in terms of risk efficiency.

Philip I. Szemdra is an Agricultural Economist, USDA/ERS/RTD, on leave to the U.S. Peace Corps. Ronald W. McClendon and Michael E. Wetzstein are Associate Professor, Department of Agricultural Engineering, and Professor, Department of Agricultural Economics, respectively, University of Georgia, Athens.

HISTORICAL PERSPECTIVE

A history of the boll weevil in the southeastern U.S. is provided by McPherson and Langham. The boll weevil entered Texas in 1892 and by 1922 it had spread over the entire southeast. In 1978, after a referendum of cotton producers in North Carolina and Virginia, a BWE pilot project was initiated. Financial and directive support was provided by state agricultural departments and cotton producers. The project's purpose was to determine if eradication techniques would be effective against the cotton boll weevil. The success of this original eradication project and passage of referenda by southern North Carolina and South Carolina cotton producers prompted an expansion of the eradication zone into these regions.

Carlson and Suguiyama, in evaluating the BWE program, determined that under the program, producers' expenditures for cotton insecticides declined and net returns were enhanced when compared with expenditures prior to BWE implementation. The ability of this initial BWE program to increase producer returns while decreasing pesticide use has enhanced the acceptance of BWE throughout the cotton belt. In 1987, the BWE program was expanded into Georgia, Florida, and Alabama. BWE programs are also underway in California and Arizona (Brandon).

Each successful cotton producer referendum obliges all cotton producers to participate in the BWE program and stipulates the proportion (cost share) of total BWE cost producers will contribute. The remaining BWE program cost is borne by APHIS, state governments, and Cooperative Extension Service contributions. These program costs not only include the cost of insecticides and application but also all monitoring and administrative costs. In North Carolina, 51 percent of the program costs during the three year eradication period were paid by governmental agencies (Carlson and Suguiyama). After the initial three year period, cotton producers were assessed a ten dollar per acre maintenance fee to cover all costs associated with regional scouting, spot treatments if an area became reinfested, and program administration. In the Georgia, Florida, and Alabama expansion area, producers agreed to contribute 70 percent of the costs of eradication and up to $10 per acre maintenance fee after eradication is completed (USDA; APHIS).

BOLL WEEVIL ERADICATION PROGRAM

A BWE program is conducted by APHIS, where all program pesticide applications, surveying, and monitoring traps are implemented by APHIS. Producers' cost of a BWE program is only the share of program costs stipulated in the referendum. The time sequence of a BWE program requires approximately 24 months extending over one complete growing season and portions of the previous and subsequent seasons (USDA 1981). The Cooperative Extension Service initiates an educational program to familiarize producers with the regional severity of the boll weevil problem and with requirements and activities of a BWE program. The actual program is started by mapping cotton fields and setting out survey traps at the end of the first season from August through November to document the severity of the problem. Pesticide applications are applied in intervals of seven to 14 days depending upon the time of the year. Applications cease when the cotton plants are destroyed either by cold weather or by the producer. In the spring of the second season, traps are placed around previous season's cotton fields with an orientation to potential overwintering sites and monitored through cotton's flowering phase. If traps indicate the potential of a large boll weevil population to develop, a series of five pesticide applications at weekly intervals are administered. Phermone traps are then installed and monitored until plant maturity. If the traps indicate the potential for a large over-wintering population, additional pesticide applications are administered. The following spring, surveys are conducted around the previous year's cotton fields to gauge the potential boll weevil populations for season three. If spot infestations are detected, they are eliminated through limited pesticide applications or by intensive trapping if infestations are confined to a restricted area (Planer).

COTTON PEST MANAGEMENT

Inexpensive synthetic organic products including the organochlorines were introduced to agriculture after World War II and were effective in controlling all types of insects. With these products cotton producers adhered to a "sterile field" philosophy and applied up to 20 insecticide applications per season. In 1972, 39 million pounds of insecticide were applied to Mississippi cotton (Rajotte et al.). Resistance and environmental concerns ensued, prompting a wider acceptance of integrated methods of control. Adoption of integrated pest management (IPM) in cotton involved the acceptance of economic thresholds as the guiding determinant of whether to apply a pesticide. IPM practices included preservation and use of beneficial insects and other biological control agents, adoption of other cultural (nonchemical) practices of pest control, and the promotion of field scouting to determine pest population densities.

While the adoption of IPM methods is widespread in cotton production, some producers rely upon individual experience and modify extension guidelines to suit their particular situation (Smith et al.). An individual's degree of risk aversion may dictate alternative control methods that nevertheless integrate some or most of extension recommendations (Szmedra et al.). Also, in some instances cotton insecticides are applied by producers on a routine prophylactic calendar schedule despite the apparent superiority of IPM methods (Carlson and Suguiyama).

COTTON INSECT MANAGEMENT SIMULATION

The Cotton Insect Management (CIM) simulation model developed at Mississippi State University (Brown et al.) is employed to investigate the impact on producer returns from the expansion of BWE to the Mississippi Delta. The CIM model is an amalgam of the cotton crop component model COTCROP (Jones et al. 1980), the boll weevil model CIM-BW (Jones et al. 1977), and the *Heliothis* spp. model CIM-HEL (Brown et al.). In COTCROP, crop growth is calculated for plants growing on one meter square of ground area. The model maintains carbohydrate and nitrogen balances for the plants and water and nitrogen balances for the soil. The daily demand for carbohydrate and nitrogen is calculated on the basis of growth rate of the plant. Available nitrogen is determined from plant uptake on the basis of depth of roots and distribution of soil nitrogen. A surplus of either nitrogen or carbohydrate is stored in the crop for later use; a shortage of either causes fruit (bolls or squares) of different ages to be abscised. Water stress also causes abscission of fruit.

The boll weevil is initiated with emergence of over-wintering adults into the cotton field. The state variables in the model consist of vectors of population densities for cohorts of each life stage (egg, larva, pupa, and adult). Development of each stage is a nonlinear function of temperature. Damage to the cotton crop by boll weevil feeding and oviposition is affected by average daily temperature, insect age, and available food sources. Mortality occurs through longevity, insecticide application, and predation.

As the model moves through the season in daily increments, *Heliothis* spp. cohorts age until they make the transition to the next life stage. Stage transitions are dependent on the number of degree days accumulated. Fecundity is a function of temperature and adult age. Mortality can be caused by insecticides, predators, or natural causes. *Heliothis* spp. damage is directly related to fruit age, with the youngest fruit the most susceptible. It is also assumed that *Heliothis* spp. larvae will feed on fruit damaged by boll weevil, but boll weevil will not lay eggs in fruit already damaged by *Heliothis* spp.

The interaction between the cotton crop and insect models occurs through the fruit. The crop damage done by the insect pests is calculated each day and transferred to the crop component model. Also, status of the fruit is updated daily and transferred to the component models of the two insect pests.

The CIM model contains soil descriptions typical of the Mississippi Delta region. Twenty two years of weather data (1962-1983) from the Mississippi Agricultural and Forestry Experiment Station at Stoneville, MS drive the model. The weather data include daily max/min temperature, rainfall, solar radiation, and pan evaporation rate. The model was tested and found to accurately reflect changes in biomass, insect populations, and final end season cotton yield under various parameter initializations and field conditions (Brown et al.). As a case study, both boll weevil and *Heliothis* spp. influxes were assumed to occur at average intensity and normal historical onset as determined by Brown et al. For a detailed evaluation, alternative pest influxes and intensity levels could be investigated. Dates of crop emergence and harvest were set at May 1st and October 1st, typical of the Mississippi Delta region. In actual practice harvesting usually occurs over an extended period of up to 6 weeks depending on the equipment complement. Crop maturity is predicted in the CIM model by percentage of open bolls. In our study, predicted crop maturity was at or near 100 percent open bolls on the October 1st harvest date. Dryland production was assumed. Parameter initializations remained constant throughout the modeling exercise.

PEST MANAGEMENT STRATEGIES

The central concepts of an IPM program in cotton, including scouting and economic threshold determination, are generally accepted by cotton producers. However, some producers may choose to modify extension guidelines by incorporating past experience, safety first considerations, intuition, and/or reliance on approaches that were successful in the past (Carlson and Suguiyama). Partial or total adoption of extension IPM recommendations may alter the effectiveness of a BWE Program depending upon the extent to which growers modify the suggested guidelines.

To reflect this modifying behavior in a modeling context, a low IPM user is defined as a producer who follows the initial threshold guidelines to apply pesticides for boll weevil and/or *Heliothis* spp., but then follows a pesticide application regime based on a calendar date criterion. In this case, pesticide is applied every ten days after the initial threshold is reached through the remainder of the season. A high IPM user is defined as a producer who allows extension guidelines to control pesticide applications throughout the season. The extension guidelines followed in this study are based on current Mississippi Cooperative Extension Service cotton pest management recommendations (Head).

Chlordimeform, employed for *Heliothis* spp. control, was voluntarily canceled by the manufacturer in 1988 (Osteen and Suguiyama).[1] The insecticide used for *Heliothis* spp. and boll weevil control by the CIM model is a mixture of ethyl (p-nitrophenyl) phenyl phosphonothioate (EPN) and methyl parathion which is reasonably effective on *Heliothis* spp. and provides up to three days of residual action depending upon daily temperature, age, and species of the insect. The mixture is 90 percent effective against boll weevil on the day of control but has no residual effect. EPN's registration has been canceled by the Environmental Protection Agency (EPA) since the development of the CIM model. Though a current limitation of the model, it is assumed that the physical and cost effectiveness of EPN can serve as a proxy for alternative cotton pesticide products currently in use or those undergoing pre-registration testing by the manufacturer or EPA. Specifically, the pyrethroid group of products evidence better control effectiveness for *Heliothis* spp. than EPN but at a greater cost than the canceled product. Methyl parathion remains the chemical of choice for boll weevil control unless both *Heliothis* spp. and boll weevil infestations are detected simultaneously. In that case, pyrethroids are recommended (Reed). The model's use of EPN instead of the pyrethroid group should not alter the relative ranking of pest management regimes, with summary statistics close to what may be expected if pyrethroids were included in the CIM model.

Four pest management strategies were modeled; two to reflect the effectiveness of BWE under high and low IPM adoption; and two to reflect what may occur without BWE under similar IPM adoption levels. In each case, alternative BWE program producer cost shares were subtracted from simulated returns to reflect growers' share of zero, 25, 50, 70, or 100 percent of program costs. The four scenarios modeled were:

1. **High IPM With BWE.** A producer is assumed to followed extension guidelines to apply a pesticide for *Heliothis* spp. when the population reaches or exceeds four larvae per 100 plants. An ongoing eradication program was assumed with producers paying either zero, 25, 50, 70, or 100 percent of the costs of BWE implementation in each of the first three years. BWE is the responsibility of the implementing agencies. The producer pest control decisions center on *Heliothis* spp. populations. A \$6.50 per acre BWE maintenance fee was assumed to be assessed in the fourth year increasing at an annual rate of 5 percent to account for inflation. The maintenance cost in the final year of simulation was \$15.64 per acre. This initial maintenance fee assumed for the Mississippi Delta was based on USDA/APHIS estimates derived from estimated program maintenance costs for the Georgia, Florida, and Alabama expanded BWE region. The fee is lower than that being assessed in the Carolinas because of lessened population and damage pressures of boll weevil in the Delta region, and thus lessened expected maintenance costs. Producers bear 100 percent of this yearly maintenance fee.
2. **Low IPM With BWE.** The grower follows the initial threshold to treat for *Heliothis* spp. but then follows a calendar control regimen, applying a pesticide every ten days until 30 days prior to harvest according to label directions for EPN and methyl parathion. Both chemicals require at least a 30 day period between final season application and harvest to allow for sufficient chemical breakdown so residues conform with allowable limits. Assumptions regarding the BWE program and cost share are the same as the high IPM strategy.
3. **High IPM Without BWE.** A pesticide application was initiated when threshold damage or population levels were reached for the boll weevil and/or *Heliothis* spp. Threshold extension recommendations were followed throughout the season.
4. **Low IPM Without BWE.** Initial control for the boll weevil or *Heliothis* spp. was triggered by extension guidelines but reverted to a calendar regimen with a pesticide application every ten days following the initial application.

For each of the four strategies, all control variables in the simulator (other than those associated with

[1]The EPA allowed chlordimeform to be used on the 1989 cotton crop as the most expeditious way of eliminating the insecticide from dealer and producer stocks. Allowing its use will circumvent the cost of storage and disposal and arguably would be the most environmentally benign method of depleting stocks.

insecticides and BWE), including planting date, row spacing, and cotton variety, were set at the same levels. BWE program costs were available from APHIS officials administering the current BWE program in Georgia, Florida, and Alabama, and the eradication maintenance program in North and South Carolina (USDA; APHIS). It was assumed that the costs of extending the program to the Mississippi Delta would be similar. Maintenance fees were assumed to increase five percent per year after year four to factor in the costs of inflation. The analysis used a cotton spot market price of $0.55 per pound.

High IPM with BWE, Strategy 1, is expected to dominate any of the other strategies at similar producer cost shares. This strategy follows threshold recommendations throughout the season, and thus should result in fewer pesticide applications with associated decreased pesticide costs. Less straightforward, however, are results when differing producer cost shares associated with alternative strategies are compared. For instance, would a producer practicing high IPM without the apparent benefits of a BWE program, Strategy 3, do as well as a producer practicing low IPM with a BWE program, in which he/she contributes 50 percent of the BWE costs? What of a situation in which a high IPM producer in a BWE program region contributes toward defraying 70 percent of program costs, versus a low IPM producer contributing only 25 percent? The share of program costs borne by producers is central to the attractiveness and risk efficiency of BWE program adoption. Though environmental concerns may take precedence at some future date, the outcome of producer referendums in the immediate future will hinge on cost savings and the ultimate profitability of an eradication effort.

Risk efficiency of these alternative strategies was evaluated by employing first and second degree stochastic dominance, FSD and SSD respectively, based on the cumulative density functions of net returns. In addition, summary statistics describing yield in pounds of lint per acre, number of pesticide applications, and cost of control, were calculated. Net present value analysis at alternative discount rates was also employed.

RESULTS

Table 1 provides summary statistics for the four strategies. It is assumed that values for pounds of lint per acre, number of insecticide applications, and cost of control are the same for each level of cost share scenario under a particular strategy. Differences occur in net returns when cost shares are subtracted from gross returns. Yield is highest under a low IPM strategy with BWE, while the lowest yield is realized under a high IPM regime without BWE. It is not surprising that a strategy including BWE would provide the largest yield. Neither is it unusual to find a low IPM adoption strategy providing superior yields compared with a high IPM strategy. The mechanics of the economic threshold concept almost assure this result. Rather than practicing a "sterile field" approach, high IPM deploys an insecticidal application prior to pest populations' reaching damaging levels. Insect pests are allowed to remain in the field longer, causing a yield loss. The value of the yield reduction, however, is below the cost of preventing it. The virtue of IPM is fewer pesticide applications resulting in lower pesticide costs and thus higher net returns.

The high IPM with BWE, Strategy 1, had the fewest number of insecticide applications and lowest application costs (27 percent lower than Strategy 2, low IPM with BWE). Similarly practicing high IPM without BWE, Strategy 3, realized an application cost savings of 28 percent over a low IPM without BWE, Strategy 4.

Risk Efficiency

Table 2 indicates that using Strategy 1.A, high IPM with BWE, and incurring no share of program costs, a producer realized the highest net returns. Under E-V analysis, however, dominance cannot be deter-

Table 1. Summary Statistics for Pest Management Strategies With and Without Boll Weevil Eradication (BWE)

	Means Per Acre		
		Producer Insecticide Control[a]	
Strategy	Yield in Pounds	Number of Applications	Cost in Dollars
1. High IPM With BWE	417.4	5.63	34.97
	(11,074.9)[b]	(0.47)	(14.15)
2. Low IPM With BWE	418.3	7.37	44.53
	(11,181.9)	(1.25)	(37.68)
3. High IPM Without BWE	392.3	6.26	38.45
	(9,655.9)	(0.54)	(16.27)
4. Low IPM Without BWE	399.6	8.21	49.16
	(10,564.1)	(2.62)	(79.25)

[a] Number of applications and cost are for individual producer control of insects and thus insecticide applications by a BWE program are not included in the figures for Strategies 3 and 4.

[b] Variances are in parentheses.

Table 2. Net Returns for Pest Management Strategies With and Without Boll Weevil Eradication (BWE) under Differing Producer Cost Shares for Eradification

Strategy	Cost Share	Net Returns			
		Mean	Variance	Minimum[a]	Maximum
	Percent	dollars per acre			
1 High IPM With BWE					
A	0	232.57	4,037.37	156.60	464.45
B	25	223.32	4,123.84	148.30	457.28
C	50	221.44	4,097.90	148.30	457.28
D	70	219.95	4,100.85	148.30	457.28
E	100	217.70	4,144.74	148.30	457.28
2 Low IPM With BWE					
A	0	225.65	3,943.32	151.22	454.61
B	25	216.39	4,036.51	139.92	447.44
C	50	214.52	4,030.91	139.92	447.44
D	70	213.02	4,050.13	139.92	447.44
E	100	210.77	4,118.42	139.92	447.44
3 High IPM Without BWE	N/A	214.21	3,441.48	142.83	443.34
4 Low IPM Without BWE	N/A	210.35	3,789.63	129.39	433.05

[a] Program costs differ for alternative cost shares only during the first four years of BWE implementation. Maintenance costs are the same for years five through 22. Minimum and maximum values occurred in years ten and seven, respectively.

mined between BWE with no cost share, Strategy 1.A, and no BWE under high IPM, Strategy 3. Similar results occur under low IPM, where both Strategy 2.A and Strategy 4 are E-V efficient. Under Rawlsian criteria (Wetzstein et al.), however, low or high IPM with BWE under any cost share dominates IPM without BWE. Thus, in general, BWE tends to prevent very low returns. Uniformly higher net returns result when following high IPM, Strategy 1, versus low IPM, Strategy 2, for each comparable cost share. In terms of E-V analysis for each comparable cost share, both high and low IPM are risk efficient. This results from the lower absolute variance associated with low IPM.

Table 3 reports the results of the risk efficient analysis using stochastic dominance techniques. The results reduce the E-V efficient sets and reflect the conclusions reached above. Practicing high IPM was the most risk efficient strategy under any cost share. Practicing low IPM proved superior when farmers incurred no costs for BWE compared with high IPM practitioners bearing the costs of program implementation. The difference in participation costs caused low IPM with BWE and no cost share, Strategy 2.A, to be FSD or SSD over each high IPM cost share, Strategies 1.B, 1.C, 1.D, and 1.E, as well as high IPM without BWE, Strategy 3. This result reinforces the original hypothesis concerning both the importance of a BWE program in enhancing cotton producers' profitability as well as the level of producers' program cost sharing. Low IPM with BWE, strategies 2.A, 2.B, 2.C, and 2.D, dominates high IPM without BWE, Strategy 3, up to and including a 70 percent cost share. This indicates that even with low IPM participation, BWE is dominant. Thus, participation in a BWE program offers the potential for a greater positive impact on returns compared to increasing the level of individual pro-

Table 3. Stochastic Dominance Results[a]

Strategy	Strategy						
	3	2.A	2.B	2.C	2.D	2.E	4
1.A	1	1	1	1	1	1	1
1.B	1	-2	1	1	1	1	1
1.C	2	-1	1	1	1	1	2
1.D	2	-1	2	1	1	1	2
1.E	2	-1	0	2	2	1	2
3	-	-1	-2	-2	-2	2	2

[a] A, B, C, D, and E indicate zero, 25, 50, 70, and 100 percent share of BWE costs by the producers. Strategies 1, 2, 3, and 4 are high IPM with BWE, low IPM with BWE, high IPM without BWE, and low IPM without BWE, respectively.

Code: 1 = row dominates column by FSD,
2 = row dominates column by SSD,
-1 = column dominates row by FSD,
-2 = column dominates row by SSD,
0 = no dominance.

er's use of IPM. In terms of enhancing producer rns, it is more important that a cotton producer in a region in which BWE has been carried out n that he/she practice a high level of IPM.

he potential profitability of a BWE program for ississippi Delta cotton producers is further clarid by comparing high IPM with BWE and 100 rcent cost share, Strategy 1.E, versus high IPM ithout BWE, Strategy 3. Incurring total program sts over the life of the eradication and maintenance fort while practicing high IPM, Strategy 1.E, roved SSD over no BWE under high IPM compli-nce, Strategy 3. BWE is a SSD risk efficient strat-gy for Mississippi Delta cotton producers even if here is no governmental agency subsidy where total rogram costs are borne by producers.

Net Present Value

Table 4 presents the net present value of an income stream for the 22 year simulation period. The benefit stream is the result of subtracting net returns, reflecting a pest management regime including BWE, from a regime without BWE for each simulated year. For example, returns from low IPM with BWE and a 50 percent cost share, Strategy 2.C, were subtracted from returns realized from low IPM without BWE, Strategy 4, for each year. These benefits were summed over the 22 year period and discounted at four nominal interest rates assumed to reflect a time value of money into the near future.[2]

The present value of the BWE program at a 10 percent discount rate is economically more attractive when high IPM strategies are being followed. Producers using high IPM and bearing 100 percent of eradication and maintenance costs, Strategy 1.E, would realize a positive net present value at that interest rate without any governmental agency subsidy. From a strict cost/benefit standpoint, investment in a BWE program is a sound, profit generating action. Under low IPM, discounted cash flow becomes negative at 70 percent cost share at a discount rate of 7.14 percent. This finding implies that low IPM users should be particularly concerned about level of cost defrayment agreed upon prior to BWE implementation. The original North Carolina program specified a 50 percent cost share level. More recently, the Georgia, Florida, and Alabama program has allocated 70 percent of costs to be paid by growers in the eradication region. A low IPM user would probably experience a negative discounted cash flow at that level of grower financing at an implied interest rate of 7.14 percent or more. Evaluation of both the summary statistics and discounted cash flow returns argue for high IPM adoption in a region where BWE is being implemented.

Table 4. Net Present Value Results for Four Discount Rates Over a 22 Year Period

	Net Present Value			
	Discount Rates			
Strategy[a]	7%	10%	12.5%	15%
	--------dollars per acre--------			
1.A	177.69	140.37	117.69	100.27
1.B	93.02	74.98	63.83	55.15
1.C	65.47	50.14	40.98	34.09
1.D	46.47	33.29	25.54	19.82
1.E	10.37	0.46	-4.72	-8.04
2.A	144.13	113.08	84.05	80.57
2.B	53.53	41.15	33.96	28.68
2.C	24.05	13.83	8.26	4.46
2.D	0.47	-8.04	-12.31	-14.92
2.E	-34.91	-40.83	-43.15	-43.99

[a] A, B, C, D, and E indicate zero, 25, 50, 70, and 100 percent share of BWE costs by producers. Strategies 1 and 2 are high IPM with BWE and low IPM with BWE, respectively.

CONCLUSIONS

Results from the simulation model indicated BWE to be a cost effective and risk efficient program under various alternative cost shares and IPM adoption levels. Practicing high IPM under an eradication program provided generally superior results compared to low IPM. Discounted cash flow analysis indicated that an eradication program coupled with high IPM at most cost share levels and discount rates analyzed, resulted in positive cash flow for all but the highest interest rates. On the other hand, low IPM and BWE experienced negative cash flow at a 70 percent producer share and 7.14 percent discount rate. Stochastic dominance results, in general, corroborate other findings in indicating the attractiveness of following a high IPM regime regardless of the cost sharing scheme.

Obviously the lower the cost share levels, the more economically attractive a BWE program appears to

[2] Analyzing the projected income stream over an abbreviated planning horizon of perhaps 10 or 12 years may be valid if one is concerned with recouping the benefits associated with the initial project investment in capital equipment to implement the BWE program. Using a shorter horizon would diminish the financial attractiveness of participation in a BWE program. For an individual producer, however, share of capital equipment outlays has been included in the cost-sharing scheme. Therefore, an extended horizon was chosen to reflect the long term benefits to cotton producers of a region-wide BWE program.

the cotton grower. However, the results indicate a BWE program to be economically attractive at virtually any cost share provided high IPM is followed. Specifically, the analysis indicated that a positive cash flow results when producers finance 100 percent of program costs. In general, producers utilizing BWE can expect higher net returns than from a comparable strategy without eradication in effect, due to fewer insect control applications and thus less control costs.

An objective of this study was to present a method to evaluate a BWE program for different levels of IPM and producer cost sharing. The results of this study indicate that BWE is a significant step towards improving the cotton producer's financial situation as well as limiting the number of pesticide control actions. Increased returns and decreased environmental degradation are key issues in considering BWE, and this study presents a method to assess the BWE program in this context.

References

Brandon, H. "Boll Weevil Control Effort Scrutinized." *Delta Farm Press.* 4 Nov. 1988.

Brown, L.G., R.W. McClendon, and J.W. Jones. "Cotton and Insect Management Simulation Model." In Cotton Insect Management With Special Reference to the Boll Weevil. R.L. Ridgway, E.P. Lloyd, and W.H. Cross, eds. Washington, D.C.: USDA ARS Agricultural Handbook No. 589, Nov. 1983.

Carlson, G.A., and L. Suguiyama. "Economic Evaluation of Area-Wide Cotton Insect Management: Boll Weevils in the Southeastern United States." North Carolina State University Agricultural Research Service, Bulletin 473, June 1985.

Carlson, G.A., G. Sappie, and M. Hammig. "Economic Returns to Boll Weevil Eradication." Washington, D.C.: ERS, AER No. 621, Sept. 1989.

Head, R.B. "Cotton Insect Control Guide, 1988." Mississippi State University Cooperative Extension Service, Publication 343.

Jones, J.W., L.G. Brown, and J.D. Hesketh. "COTCROP: A Computer Simulation Model for Cotton Growth and Yield." *In Predicting Photosynthesis for Ecosystem Models,* Vol. 2, pp. 209-241. Boca Baton, FL.: CRC Press, 1989.

Jones, J.W., H.D. Bowen, R.E. Stinner, J.R. Bradley Jr., and J.S. Bacheler. "Simulation of Boll Weevil Population as Influenced by Weather, Crop Status, and Management Practices." *Transactions of the ASAE.* 20 (1977):121-125, 131.

McPherson, W.W., and M.R. Langham. "Commercial Agriculture in Historical Perspective." *Am. J. Agr. Econ.,* 63(1981):894-901.

Osteen, C., and L. Suguiayama. "Losing Chlordimeform Use In Cotton Production." Washington, D.C.: USDA ERS AER No. 587., May 1988.

Planer, F. USDA APHIS. Boll Weevil Eradication Program Head, Expanded BWE region. Personal communication, Dec. 1988.

Rajotte, E.G., R.F. Kasmierczak, G.W. Norton, M.T. Lambur, and W.A. Allen. "The National Evaluation of Extension's Integrated Pest Management (IPM) Program." Mississippi Cotton IPM Impact Study; Appendix 7 Virginia Cooperative Extensive Service, VCES Pub. 491-018, July 1987.

Reed, J. Department of Entomology, Mississippi State University, Stoneville, MS. Personal communication, Dec. 1988.

Simpson, E.H. III, and D.W. Parvin, Jr. "Impact of Alternative Cotton Insect Management Strategies on Producer Income in Mississippi." *In Cotton Insect Management with Special Reference to the Boll Weevil.* R.L. Ridgway, E.P. Lloyd, and W.H. Cross, eds. USDA ARA, Agricultural Handbook 589, Nov. 1983.

Smith, S., M.E. Wetzstein, and G. Douce. "Evaluation of Various Pest Management Characteristics." *So. J. Agr. Econ.,* 19(1987):93-101.

Szmedra, P.I., R.W. McClendon, and M.E. Wetzstein. "Risk Efficiency of Pest Management Strategies: A Simulation Case Study." *Transactions of the ASAE.* 31.6(1988):1642-1648.

Taylor, C.R., G.A. Carlson, F.T. Cooke Jr., K.H. Reichelderfer, and I.R. Starbird. "Aggregate Economic Effects of Alternative Boll Weevil Management Strategies." *Agr. Econ. Res.* 35.2(1983):19-28.

U.S. Department of Agriculture. "Program Definitions and Public Costs, Beltwide Boll Weevil/Cotton Insect Management Programs." Overall Evaluation Appendix D. Washington, D.C.: NRED ESS, ERS Staff Report No. AGES810504, May 1981.

U.S. Department of Agriculture, Animal and Plant Health Inspection Service (APHIS), Regional Budget Analyst, Gulfport, MS, prsonal communication, November 1988.

Wetzstein, M.E., P.I. Szemdra, R.W. McClendon, D.M. Edwards. "Efficiency Criteria and Risk Aversion: An Empirical Evaluation." *So. J. Agr. Econ.*, 20(1988):171-178.