# THE POTENTIAL IMPACT OF COTTON INSECT CONTROL TECHNOLOGY

by

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# The Potential Impact of Cotton Insect Control Technology

The economic and environmental costs of heavy reliance on insecticides to control insect damage of agricultural crops have encouraged the development of numerous technological substitutes for regular insecticide treatments. At the same time social concern for limiting environmental damage has increased the pressure on governmental agencies, such as the Environmental Protection Agency, to restrict the use of environment damaging pesticides and to speed up the use and development of environmentally superior pest control techniques.

Government agencies are faced with two types of problems. First, they must respond to the immediate short run problems of which pesticides to ban and which pesticide control practices to encourage or mandate. Second, to effectively discharge their responsibilities in the longer run, they must assess the prospects of alternative future technologies to determine the appropriate distribution of research funds and to insure that short run decisions mesh with the longer run scheme of pest control in agricultural production.

Previous studies of the economic aspects of pest control have focused either on the problems of making optimal decisions at the farm level or on the problem of estimating aggregate measures of pesticide productivity and substitutability. At the farm level, optimal dosage for a single pesticide application has been investigated by Hilledbrandt, optimal timing for given dosages has been investigated by Carlson and by Headley (1972), and the simultaneous optimization of timing and dosage has been investigated by Hall and Norgaard, Shoemaker, Hueth and Regev, Talpaz and Borosh, and Regev, Gutierrez and Feder. At the aggregate level, Headley (1968) has estimated the productivity of expenditures for agricultural pesticides, Pimentel and Shoemaker have estimated the rate of substitution between land and pesticides and Carlson has estimated the regional productivity of cotton insecticides and rates of substitution between different types of chemical insect controls.

All these studies provide valuable information about the economics of pesticide use and the latter group provide data which can be used directly in making policy decisions. However, the aggregate impacts that can be expected from the pest control techniques that are beginning to be adopted and those that are still being developed has been given little attention.[1/] Since many of these control techniques are already available to farmers and others are expected to be available in the near future, there is a need for information concerning their aggregate economic effects to aid policy-makers in formulating long-run programs.

This paper is an attempt to meet this need. It presents an analysis of the costs, location of production and level of insecticide use with alternative insect control technologies for cotton. A national linear programming model is used to assess the impacts of adoption of technologies currently available and technologies expected to be available within the next ten years. The first part of the paper presents the model design, data sources, data collection procedures and explanation of the technological alternatives evaluated. Then a base evaluation is developed by a static analysis of the impact of adoption of alternative technologies under the assumption that acreage and location of production do not change. This is followed by a dynamic analysis with alternative levels of exports and regional acreage adjustment for both currently available and future technology. Finally, some limitations of the analysis are presented and conclusions set forth.

## The Model

The model is a spatial equilibrium linear programming model which minimizes the cost of producing and transporting eight commodities: corn, sorghum, wheat, oats, barley, rye, soybeans and cotton. The design is derived from that used by Taylor and Swanson. The major modifications included addtion of four soil classes to reflect yield and crop adaptability differences within regions, some changes in the number and composition of regions, and elimination of the land retirement activity (and attendant equalities). In final form the model can be summarized as follow:

Minimize

$$(1) \quad Z = \sum\sum\sum_{ijs} C^{D}_{ij} X^{D}_{ijs} + \sum\sum\sum_{ijs} C^{I}_{ij} X^{I}_{ijs} + \sum\sum\sum_{ikm} t_{ikm} T_{ikm} + \sum\sum\sum_{ikm} tb_{ikm} TB_{ikm}$$

Subject to:

Total cropland restriction

$$(2) \quad \sum_{i} X^{I}_{ijs} + \sum_{i} X^{D}_{ijs} \leq L_{js} \quad (j=1,2...135) \quad (s=1,2...4)$$

Irrigated cropland restriction

$$(3) \quad \sum_{i} X^{I}_{ijs} \leq I_{ijs} \quad (j=1,2...135), \ (s=1,2...4)$$

Cotton acreage lower bound

$$(4) \quad \sum_{s} X^{I}_{ijs} + \sum_{s} X^{D}_{ijs} \geq CAj \quad (j=1,2...135, \ (i=cotton)$$

Cotton lint demand

$$(5) \quad \sum_{j} \sum_{s} Y^{D}_{ijs} X^{D}_{ijs} + \sum_{j} \sum_{s} Y^{I}_{ijs} X^{I}_{ijs} \geq CLD \ (i=cotton)$$

Commodity demand

$$(6) \quad \sum_{s} \sum_{j \epsilon k} Y^{I}_{ijs} X^{I}_{ijs} + \sum_{s} \sum_{j \epsilon k} Y^{D}_{ijs} X^{D}_{ijs} - \sum_{n} TRN_{ikn} + \sum_{m} T_{imk} + \sum_{m} TB_{imk} -$$

$$\sum_{m} T_{ikm} - \sum_{m} TB_{ikm} \geq D_{ik} \quad (i=1,2,...8), \ (k=1,2,...21)$$

Nutrient demand, including:

Total digestible nutrients

$$(7) \quad \sum_{i} tdn_{in} TRN_{ikn} \geq TDN_{kn} \quad (n=1,2,3), \ (k=1,2...21)$$

Digestible protein

(8) $\sum_i dp_{in} TRN_{ikn} \geq DP_{kn}$ (n=1,2,3), (k=1,2,...,21)

Dry Weight of Feed

(9) $\sum_i TRN_{ikn} W_i = DW_{kn}$ (n=1,2,3), (k=1,...,21)

Pea demand in the pea area of the Northeast

(10) $\sum_s Y_{i,133,s} X_{i,133,s} + \sum_s Y_{i,135,s} X_{i135,s} \leq PD$ (i=peas)

Barge Constraint

(11) $\sum_i TB_{ikm} \leq B_k$ (k=1,2,3,5,9,10), (m=12)

where:

$X_{ijs}$ = acreage of the $i^{th}$ crop in the $j^{th}$ producing region on the $s^{th}$ soil class (Superscript D and I denote dryland and irrigated land).

$C_{ij}$ = short-run variable costs of producing one acre of the $i^{th}$ crop in the $j^{th}$ producing region.

$T_{ikm}$ = quantity of commodity i transported from the $k^{th}$ consuming region to the $m^{th}$ consuming region by rail.

$t_{ikm}$ = cost of transporting one unit of commodity i from the $k^{th}$ consuming region to the $m^{th}$ consuming region by rail.

$Y_{ijs}$ = per-acre yield of the i crop in the $j^{th}$ producing region on the $s^{th}$ soil class.

$L_{js}$ = total cropland of soil class s available in the $j^{th}$ producing region.

$I_{js}$ = total irrigated cropland of soil class s available in the $\Delta^{th}$ producing region.

$CA_j$ = cotton acreage constraint in the $j^{th}$ producing region.

CLD = national cotton lint demand.

$TRN_{ikn}$ = units of commodity i transferred to meet the demand for nutrients in consuming region k for livestock type n.

$tdn_{in}$ = the amount of total digestible nutrients in one unit of commodity i for livestock type n.

$dp_{in}$ = the amount of digestible protein in one unit of commodity i for livestock type n.

$DW_{kn}$ = total dry weight requirement for feed for the $n^{th}$ livestock type in the $k^{th}$ consuming region.

$TDN_{kn}$ = demand for total digestible nutrients by the $n^{th}$ livestock type in the $k^{th}$ consuming region.

$DP_{kn}$ = demand for digestible protein by the $n^{th}$ livestock type in the $k^{th}$ consuming region.

$D_{ik}$ = demand for commodity type i for use as seed, food, export and feed for livestock other than swine, cattle and sheep in the $k^{th}$ consuming region.

D,I = superscripts used to distinguish between dryland and irrigated production activities, respectively.

FD = pea demand in the pea area of Washington and Idaho.

$TB_{ikm}$ = quantity of commodity i transported from the $k^{th}$ consuming region to the $m^{th}$ consuming region by barge. Barge transportation is allowed only to the Delta States (m=12).

$tb_{ikm}$ = cost of transporting one unit of commodity i from the $k^{th}$ consuming region to the $m^{th}$ consuming region by barge.

$B_k$ = total units of commodities that can be transported by barge from the $k^{th}$ consuming region to consuming region 12.

$W_i$ = dry weight content of commodity i.

Insect control strategies are reflected through changes in the variable costs of production, $C_{ij}$, and yields, $Y_{ijs}$. Soil suitability for a particular crop is affected by the presence or absence of entries in the cropland equations. Activities for a region include only crops (1) compatable with the climate of that region and (2) for which cost and yield budgets were available.

The model was validated by running the model using current insect control practices and 1973 prices, yields and demands. Crop production for acreage exogenous to the model was added and the results compared to the corresponding actual 1973 values.

This comparison provides only a rough validation since the situation described by the model is the long run situation implied by 1973 conditions. Due to lags in adjustment this situation is not reflected in the actual 1973 data. Despite this model results were reasonably close to the 1973 situation. In general differences reflected known maladjustments, such as an increase in cotton in Texas (Firch), or results observed by other researchers, such as the movement of sorghum from Nebraska and Kansas into the North Central States as found by Taylor and Swanson. Maladjustments generally reflect the lag in response of farmers to changes in the economics of production.

## The Data

Data on insect control practices and technologies were obtained from entomologists in each of the major cotton producing states. Data were collected either by personal visit or telephone conference and were summarized and returned to each entomologist for review and correction. All data were summarized on a form designed to insure completeness and standardization.

The data provided by each entomologist for his state included (1) prevalence of insect problem, (2) current treatment procedures, (3) insect control technology currently available, (4) insect control technology that is expected to be available within the next 5-10 years that would be applicable to that state, and (5) area of implementation and yields as well as cost and amount of pesticides required for each insect control technology. A complete enumeration of the data collected is presented in (reference to be supplied).

Enterprise budgets used in the model were developed for the 135 producing regions using the Oklahoma State University Farm Enterprise Data System (FEDS) budgets (Garst), Aggregate Production Analysis System (APAS) budgets (Stricklan and Harwell, Pawson, Rude, Worden, Miller, McArthur) and budgets developed by Taylor and Swanson. A 1973 level was used for all prices and costs.

The land in each region was divided into four classes of decreasing quality corresponding to classes I-IV of the Conservation Needs Inventory (CNI) classification (USDA). Acreage data on a county and crop basis were used to determine the availability of land by class in each producing region. Budget yields were assumed to represent average yield over all four classes. Data on yield differentials by land quality were used to calculate yields for each crop by land class. Model yields were verified by comparing average 1972-74 yields for each state with average model yields calculated using CNI proportions of each crop by soil class. The methods and data used are given in (reference to be supplied).

Product demand for each of the 21 consuming regions was specified as the individual commodity demand for human consumption, exports and miscellaneous livestock plus the total digestible nutrients (TND), digestible protein (DP) and Bulk weight (W) requirement of the cattle, sheep and swine inthe region in 1973. Human consumption is based on region population and average per capita consumption of each commodity. Export demand is based on 1973 net exports by commodity.

## Control Strategies Evaluated

The pest control strategies evaluated include a group that are currently available and a group that entomologists expect will be available to farmers within the next 10 years. Those currently available include:

(1) Scouting program. The objective of the "scouting program" is to treat cotton acreage only when the density and potential threat of insect pest populations justify insecticide treatments. Insect pest populations and natural enemy populations are monitored as well as stage of cotton growth and fruiting. The low cost and high returns from scouting imply that it is likely to be employed regardless of the other technologies adopted. Thus, it is included as a part of all other strategies.

(2) Diapause. Diapause control programs are directed specifically at boll weevils. The aim of diapause control is to substantially reduce over-wintering weevil populations and thus delay the need for insecticide treatments in the following summer. The benefit of delaying weevil treatments as long as possible is that natural enemies important for control of bollworms and budworms are protected and remain active for a longer period of the cotton growing season.

For diapause control, one or two treatments are made before the cotton defoliant is applied to the crop. Then another treatment is made about 2 weeks after the cotton is harvested. When the cotton is harvested, stalks and other parts of the cotton plant are shredded.

(3) Trap Crop. The objective of the trap crop is to concentrate the pest on a small acreage and (or) another crop. The type of trap

crop used varies by location. The cotton trap crop technique involves planting an early cotton to attract boll weevils. About 5 percent (in well distributed strips) of the total cotton acreage of a farm is planted to early cotton about 2 to 3 weeks before the regular crop planting time. The emerging boll weevils are attracted to this early cotton. Then a heavier than normal dosage of insecticide is applied to destroy the boll weevils that congregate on this cotton. Costs, in addition to pesticide and application expenses include: (1) the nuisance cost of having to get the machinery and labor ready to plant cotton 2 to 3 weeks early, and (2) failure of the trap crop in some years (the trap crop fails approximately one in 4 years).

The alfalfa trap crop utilizes 20 feet wide strips of alfalfa covering 6 percent of the acreage. Some insect pests concentrate on the alfalfa, reducing the number of treatments needed on cotton. Costs include maintenance costs for the alfalfa plus the lost yield on the alfalfa acreage.

The sorghum trap crop is planted with four rows of sorghum to each 24 rows of cotton. A sorghum variety attractive to greenbugs is used. Sorghum yields are normally about 85 percent of normal and production costs are increased since the sorghum crop must be planted and harvested in the cotton field.

Technology which is likely to be available within the next 5-10 years (future technology) includes:

(1) Short-season variety. Since damage from bollworms and budworms occurs late in the season, a variety which requires a shorter growing season would provide less time for pest density development and would require fewer insecticide treatments.

(2) Boll weevil resistant variety. Existing varieties with weevil resistance such as "frego bract", are lower yielding than existing commercial varieties. Development of a high yielding resistant variety appears feasible.

(3) Short-season, resistant variety. Combining short-season with resistance would reduce the treatment required for budworm as well as boll weevil.

## Static Analysis

In the analysis conducted, three levels of acreage adjustment to economic conditions were evaluated; no adjustment (static analysis), cotton acreage adjustment limited such that no less than 80 percent of actual 1973 level remains in each region (short-run) and complete adjustment (long-run). The impact of no adjustment was determined via a static analysis in which cotton acreage and location were unchanged from actual 1973 levels. For each insect control technology the production costs, yield and level of insecticide use were calculated under the assumption that the technology under consideration replaced current technology where the analyzed technology is feasible (area of implementation). Outside the area of implementation for each technology it was assumed that scouting would be used in regions where scouting is an available option. In the remaining areas, it is assumed that current pest control methods are continued.

The results of the static analysis are summarized in table 1. Savings in insect control costs reflect the change in insecticide, insecticide application and other costs connected with adoption of a particular technology. Other costs include such items as added operating costs connected with employment of a cotton trap crop. Change in value of production reflects the increase or decrease in cotton production resulting from expected

Table 1 Effect of Nationwide Implementation of Cotton Insect Control Technologies on Insect Control Costs and Insecticide Use--Static Analysis

| Insect control Alternative | Area of implementation | Savings of insect control costs a/ | Change in value of production | Net benefits | Insecticide use a/ | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Chlorinated Hydrocarbons | Organophosphates | Carbamates | Total |
| Current Technology: | Million acres | Million dollars | | | Percent of current use | | | |
| Scouting | 10.6 | 26 | +27 | 53 | 82 | 72 | 45 | 77 |
| Diapause scouting | 6.0 | 42 | +29 | 71 | 64 | 64 | 54 | 64 |
| Trap crop scouting | 5.2 | 46 | +26 | 72 | 67 | 58 | 1.32 | 65 |
| Most economical | 13.1 | 81 | +27 | 108 | 61 | 54 | .98 | 59 |
| Least pesticide feasible | 13.1 | 68 | +27 | 95 | 58 | 50 | 44 | 55 |
| Future Technology | | | | | | | | |
| Short season variety scouting | 8.6 | 115 | -86 | 29 | 45 | 39 | 13 | 42 |
| Resistant variety scouting | 7.9 | 118 | -5.0 | 113 | 43 | 37 | 12 | 40 |
| Resistant short-season variety, scouting | 8.6 | 150 | -55 | 95 | 31 | 30 | 9 | 30 |
| Most economical | 13.1 | 136 | +23 | 159 | 41 | 40 | 88 | 42 |
| Least pesticide feasible | 13.1 | 133 | - 7 | 126 | 33 | 28 | 2 | 31 |

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a/ Using current insect control practices and cotton acreages, it was estimated that insect control costs were currently $253 million and use of clorinated hydrocarbons, organophosphates and carbamates was 103 and 4 million pounds, respectively.

yield changes. Cotton was valued at $0.45 per pound. The level of insecticide use is the amount of insecticide used as a proportion of the amount required with technology currently in use.

Two of the insect control alternatives evaluated are combinations of the specific technologies described earlier. The alternative entitled "most economical" involves use of that technology in each region which has the lowest pest control costs among those available in the time period specified. Both insect control costs and yield losses are considered in determining pest control costs. This alternative reflects use of the pest control strategy in each region that farmers in that region could be expected to choose from those that are feasible, if the choice is determined solely by economic factors.

The "least insecticide feasible" alternative involves use of that technology in each region which requires the least insecticide among those control methods that are both technologically and economically feasible. An option is considered economically feasible if the combined costs of insect control and yield loss is not more than 15 percent greater than current insect control costs. While adoption of the configuration of technologies implied by this alternative is likely administratively unenforceable, the alternative does indicate a realistic upper bound for the environmental gain that could be achieved with the technologies evaluated and can be used as a standard for evaluating other alternatives.

The least insecticide feasible and most economical options are defined for both currently available technology and technology expected to be available within the next 5-10 years. For the latter time period all the currently available technology is also considered feasible.

## Dynamic Analysis

The linear programming model was used to evaluate current and future insect control alternatives with both limited and unlimited shifts in regional cotton acreage. The limited acreage shift is a necessary restriction for the short run analysis since only partial adjustment to the technical and economic environment is possible. Lack of complete adjustment could be caused by lack of sufficient time for individuals to react or by barriers to adjustment such as historically provided by the government cotton acreage control program. This regulation and the threat of its return when it is relaxed, limits the rate at which cotton will shift out of noncompetitive areas. Fixed factors of production and normal resistance to change also contribute to slow adjustment. The results of the short run analysis are summarized in table 2. The long run analysis assumes complete adjustment to optimum resource allocation and thus acreage shifts are not limited. The results of the long run analyses are summarized in tables 3 through 5.

Since the dynamic analyses involve more adjustment to the economic environment than farmers had achieved in 1973, a "current practice" analysis was conducted. This analysis forced each region to use the same insect control strategies that were used in 1973 but allowed regional shifts in production. The results reflect the impact of allowing the location of production to change with no changes in technology. This is particularly important for cotton since the allotment program has tended to maintain historical production patterns over time.

## The Results

The static analysis indicates that significant insect control cost and insecticide use reduction could be achieved through adoption of currently available technology. Adoption of scouting alone would reduce total

Table 2 Effect of nationwide Implementation of Cotton Insect Control Technologies on Insect Control Costs and Insecticide Use-Short Run

| Insect control alternatives | Savings in insect control costs | Total Production costs a/ | Insectidice Use | | | |
|---|---|---|---|---|---|---|
| | | | Hydrocarbons | Organo-phosphates | Carbamates | Total |
| | Million dollars | | Percent of Current Use | | | |
| Current Technology: | | | | | | |
| Current practice | 64 | 8,288 | 74 | 67 | 48 | 71 |
| Scouting b/ | 75 | 8,282 | 64 | 54 | 23 | 59 |
| Diapause scouting | 82 | 8,265 | 46 | 48 | 28 | 47 |
| Trap-crop scouting b/ | 85 | 8,258 | 54 | 45 | 100 | 52 |
| Most economical b/ | 138 | 8,220 | 48 | 41 | 100 | 46 |
| Future Technology: | | | | | | |
| Short season scouting | 124 | 8,252 | 34 | 34 | 8 | 33 |
| Resistant scouting | 136 | 8,220 | 35 | 30 | 8 | 33 |
| Resistant short-season scouting | 159 | 8,207 | 25 | 24 | 5 | 24 |
| Most economical b/ | 175 | 8,182 | 35 | 31 | 78 | 34 |

a/ For all crops.

b/ While preparing this manuscript it was discovered that inaccurate cost data for cotton were used for one producing region. An analysis of the range of impacts indicates that the order and basic magnitudes of the results would not be changed.

Table 3 Effect of Nationwide Implementation of Cotton Insect Control Technologies on Insect Control Costs and Insecticide Use--Long Run

| Insect Control alternatives | Savings in insect control costs | Total production costs[a] | Insecticide Use |  |  |  |
|---|---|---|---|---|---|---|
|  |  |  | Chlorinated Hydrocarbons | Organo-phosphates | Carbam-ates | Total |
|  | Million dollars |  | Percent of Current Use |  |  |  |
| Current Technology: |  |  |  |  |  |  |
| Current practice | 161 | 7,988 | 35 | 33 | 3 | 33 |
| Scouting | 132 | 8,008 | 33 | 37 | 5 | 34 |
| Diapause scouting | 141 | 7,991 | 23 | 31 | 5 | 26 |
| Trap-crop scouting | 148 | 7,987 | 26 | 30 | 13 | 27 |
| Most economical | 179 | 7,944 | 24 | 13 | 13 | 26 |
| Future Technology: |  |  |  |  |  |  |
| Short-season scouting | 149 | 7,996 | 25 | 29 | 1 | 26 |
| Resistant scouting | 155 | 7,954 | 22 | 24 | 1 | 23 |
| Resistant short-season scouting | 168 | 7,964 | 19 | 24 | 1 | 21 |
| Most economical[b] | 188 | 7,928 | 20 | 27 | 5 | 22 |

[a] For all crops.

[b] While preparing this manuscript is was discovered that inaccurate cost data for cotton were used for one producing region. An analysis of the range of impacts indicates that the order and basic magnitudes of the results would not be changed.

Table 4 Distribution of Cotton Production with Future Insect Control Strategies--Long Run

| Region | Insect Control Strategy | | | | |
|---|---|---|---|---|---|
| | Short-Season Scouting | Resistant Scouting | Resistant Short-Season Scouting | Most Economical (Future) | Actual 1973 Acreage |
| | - - - - - - - - - - - - - - - Thousand Acres- - - - - - - - - - - - - - - | | | | |
| Iowa/Missouri | 0 | 0 | 0 | 0 | 214 |
| Va./W.Va./N.C. | 30 | 30 | 30 | 30 | 189 |
| Ky./Tenn. | 68 | 68 | 68 | 68 | 461 |
| Ala./Ga./S.C. | 202 | 0 | 202 | 202 | 1,241 |
| Florida | 0 | 0 | 0 | 0 | 13 |
| Ark./La./Miss. | 3,310 | 3,381 | 3,401 | 3,725 | 2,945 |
| Texas/Okla. | 9,049 | 8,752 | 9,014 | 8,010 | 5,979 |
| Ariz./N.M. | 107 | 28 | 72 | 71 | 460 |
| Calif. | 48 | 48 | 48 | 48 | 950 |
| Total | 12,814 | 12,307 | 12,835 | 12,154 | 12,479 |

Table 5 Distribution of Cotton Production with Current Insect Control Strategies--Long Run

| Consuming Regions | Insect Control Strategy | | | | | |
|---|---|---|---|---|---|---|
| | Current Practice | Scouting | Diapause Scouting | Trap-Crop Scouting | Most Economical (Current) | Actual 1973 Acreage |
| | - - - - - - - - - - - - - - - -Thousand Acres- - - - - - - - - - - - - - - - | | | | | |
| Iowa/Missouri | 0 | 0 | 0 | 0 | 0 | 241 |
| Va./W.Va./N.C. | 30 | 30 | 30 | 30 | 30 | 189 |
| Ky./Tenn. | 68 | 68 | 68 | 68 | 68 | 461 |
| Ala./Ga./S.C. | 0 | 0 | 0 | 42 | 42 | 1,241 |
| Florida | 0 | 0 | 0 | 0 | 0 | 13 |
| Ark./La./Miss. | 2,281 | 2,665 | 2,794 | 2,841 | 2,998 | 2,945 |
| Texas/Okla. | 9,753 | 9,462 | 9,087 | 9,080 | 8,895 | 5,979 |
| Ariz./N.M. | 102 | 107 | 107 | 107 | 107 | 460 |
| Calif. | 48 | 48 | 48 | 48 | 48 | 950 |
| Total | 12,136 | 12,136 | 12,380 | 12,216 | 12,187 | 12,479 |

insecticide use by 21 percent and net insect control costs by $53 million. Combining diapause or trap crop with scouting increases cost savings 50 percent and further reduces insecticide use. Use of the trap crop increased use of carbamate but the small total carbamate use level makes this relatively unimportant in terms of total insecticide use.

Use of the most economical insect control strategy in each region resulted in lower insect control costs and insecticide use levels than use of any one of the individual technologies. This results from the inadaptability of each technology to certain areas as well as regional differences in the costs and effectiveness of individual technologies.

The question that the most economical analysis raises is; why are farmers not adopting technology that would increase profitability? There appear to be several contributing factors. The new technologies are more complex than regular treatment. "Scouting" itself requires knowledgeable specialists to advise growers. Regular insecticide treatment provides the grower with a form of crop insurance. Investing in a specialist to advise when not to treat is viewed as somewhat of a gamble. Insecticide company representatives have long been an important source of technical advice to farmers. These "free advisors" can be expected to be reluctant to adopt new technologies requiring less insecticide. Some technologies, such as diapause control of the boll weevil, require region wide adoption to be effective. In most areas no one has assumed the responsibility for assuring regional participation. Trap crops are a nuisance to plant and harvest since they involve small acreages widely dispersed and frequently planted before the regular season. The combined effect of these factors is to slow the rate of adoption of the new technologies. Considerable time is required, first to learn about a particular technology, and then to get it properly integrated into the total farm operation.

Insect control costs and insecticide use could be significantly reduced with current technology by allowing greater regional shifts in cotton production. Even if current insect control practices were continued, nationwide insect control costs could be reduced by $64 million with limited acreage shifts (table 2) and by $161 million with unlimited shifts.

These savings would result in greater regional concentration of cotton production and the virtual elimination of cotton from certain areas. Cotton production would shift from the southeast and lower midwest to the south and southwest. The greatest negative impact would be felt in Alabama, Georgia and South Carolina. The major beneficiaries would be Texas and Oklahoma.

The value of future technology that is expected to be available within the next 5-10 years depends on the degree of regional production shift that is allowed. With the current location of production a net benefit of approximately $50 million could be achieved if farmers used the most economical technology for their region (table 1). Also, insecticide use would be reduced by over 30 percent. The negative yield impact of the short season variety makes it a less attractive new technology than a resistant variety which is expected to have modest yield impacts. Short season and resistant variety technologies would have similar environmental impacts.

With limited location adjustment the value of future technology drops to a maximum of $38 million (table 2). The reduction in insecticide use over that achievable with current technology is similar to that found with no acreage shift except that it is at a lower level.

Complete spatial equilibrium in production would reduce the savings generated by future technology to $16 million and insecticide use would be only slightly below that achievable with current technology. The gains from future technology are less with unlimited acreage shifts because this technology provides the greatest costs saving for those areas where cotton currently has the least competitive advantage. For example, resistance (with scouting) reduced insect control costs by nearly $30 per acre in southern Georgia but reduced costs in most of Texas by less than $6.

The interaction between the level of cost savings and location of production implies an important potential impact for future cotton allotment programs. The historically based cotton allotment program must bear some of the blame for the current locational disequilibrium in the production of cotton. A future cotton program which tends to limit location adjustments will increase the total societal benefits of the new cotton technology but will also result in higher crop production costs and a higher level of insecticide use than could be achieved with both location adjustment and the new technology. The Southeast will benefit most from a policy involving little location adjustment and high research expenditures. Texas and Oklahoma will benefit most from programs that encourage production location adjustment.

The generally lower costs and comparable insecticide use levels achieved with the most economical insect control alternatives indicate that no single technology is best throughout the nation. The best combination of methods varies from region to region. This implies that although regulations forcing the use of particular insect control technologies could achieve significant cost and environmental gain, a program designed to encourage farmers to adopt the most economical technique for their farm has the potential of even greater gain. In addition a program which takes advantage of the natural economic gain that framers could achieve should be administratively superior to a program designed to force universal adoption of a particular technology.

### Alternate Export Levels

To assess the impact of export demand changes, three levels of food-feed grain exports were analyzed:

1. Low - 50 percent below 1973 levels, which approximately equals 1971 quantities for many crops.
2. Medium - The level experienced during 1973.
3. High - 50 percent above the 1973 levels - which assumes that effective demand of developing countries will continue to expand.

The increased competition for land brought about by exports generally increased both insecticide use and production costs (table 6). The magnitude of this increase appears to be 3 percent or less in moving from approximately 1971 (low) export levels to 1973 (medium) export levels. However, a further increase of approximately the same magnitude would increase insecticide use 7 to 12 percent and insect control costs 13 to 21 percent with current technology.

Increases in exports had little impact on the location of production except a significant increase in the Delta States (Arkansas, Louisiana and Mississippi) and a corresponding decrease in Texas and Oklahoma. The higher yields in the Delta States and greater competition of other crops in Texas and Oklahoma appear to be the major causes of this shift.

## Shortcomings of the Analysis

Major shifts in the location of production result in interregional, and thus, interfarm impacts which are not accounted for in the analysis. Farmers in those areas where cotton acreage is increased should be better off since they have an additional crop alternative. They would not buy added durable assets to increase cotton production unless the projected added income would

Table 6 Insect Control Costs, Insecticide Use and Production Costs with Alternate Export Levels, the Short Run

| Insect control alternative and export level | Insect control costs | | Total production costs | Insecticide use | |
|---|---|---|---|---|---|
| | Cotton | Corn | | Cotton | Corn |
| | - - - - - -Million dollars- - - - - - | | | - -Million pounds- - | |
| Scouting | | | | | |
| Low Exports | 166 | 81 | 6,556 | 101 | 21 |
| Medium Exports | 171 | 109 | 8,282 | 104 | 29 |
| High Exports | 206 | 174 | 10,836 | 115 | 53 |
| Most Economical (Current) | | | | | |
| Low Exports | 133 | 81 | 6,503 | 81 | 21 |
| Medium Exports | 135 | 108 | 8,220 | 81 | 29 |
| High Exports | 152 | 172 | 10,824 | 87 | 53 |
| Resistant/Scouting | | | | | |
| Low Exports | 113 | 81 | 6,513 | 63 | 21 |
| Medium Exports | 117 | 111 | 8,220 | 57 | 29 |
| High Exports | 133 | 172 | 10,817 | 71 | 53 |
| Resistant/Short Season Scouting | | | | | |
| Low Exports | 96 | 96 | 6,427 | 43 | 21 |
| Medium Exports | 95 | 110 | 8,207 | 42 | 29 |
| High Exports | 99 | 176 | 10,812 | 47 | 54 |

be great enough to pay for those assets. However, farmers in regions of declining cotton acreage will experience capital losses on cotton related durable assets. In an effort to minimize capital losses farmers in declining areas will continue to produce cotton as long as a significant proportion of the cotton related durable assets are functional.

Alternatives to cotton in declining areas will obviously be less profitable, otherwise farmers would have substitutedthem for cotton earlier. Thus, farm incomes in declining areas will fall. The magnitude of the fall will depend on the profitability of alternate crops but will likely be significant in certain areas. The lower level of income in declining regions where cotton is important can also be expected to have a negative impact on local agriculturally based farm communities.

In addition to the limitations imposed by the assumptions of linear programming, models such as the one used in this analysis may be very sensitive to minor differences in budgeted costs and yields. Developing a uniform, consistent set of budgets is a monumental task with no objective certainty that a completely accurate set of data has been constructed. This shortcoming of large linear programming models is frequently understated by those reporting the results generated by a model in which they have invested considerable time and effort.

The dynamic nature of agriculture and the high level of durable assets used in production implies that the agricultural system is never in equilibrium. This hampers validation of an equilibrium model since no historical time period can provide a completely accurate comparison.

## Justifiable Research Outlays

To the degree that reduced production costs represent benefit to society, the data in tables 1 to 3 imply a level of research expenditure that could be made to develop the resistant and short season technologies. Depending on the level of regional production shifts allowed, the net savings would range from $16 million (table 3) to $51 million (table 1) if the most economical alternatives were used in each region. The amount that could be spent per year would be influenced by the term required for development, the duration of the technology and the discount rate. Surveyed entomologists indicated that five to ten years would be required for development. The period for which the technology will be viable is uncertain. Widespread use of boll weevil resistant cotton technology is likely to result in the development of weevil strains immune to the resistance in cotton. Similarly, strains with more resistance to natural enemies, that will over winter more hardily and mature more rapidly, could ultimately reduce yields on short season varieties. The time period required for these developments is unknown. Also, the increased genetic pool generated in the development of resistant varieties should contribute to development of additional new varieties.

Table 7 indicates the maximum amount of money per million dollars of cost saving that could be profitably spent on research and development each year until the future technology is developed depending on the time to development and the duration over which the technology is effective. A $16 million savings in annual production costs, which is approximately the minimum savings that could be expected from the future technology (table 3), would justify yearly research expenditures of 8.8 to 16.8 million dollars per year for 10 years depending on the durability of the technology. If the technology could be developed in five years, considerably more could be spent in each of these five years. Continuation of policies which limit regional production shifts will at least double the level of research expenditures that could be made. Even in the absence of such policies the normal lag in adjustment in the location of production implies benefits in excess of the 8.8 to 16.8 million dollars. Benefits would also be higher in the likely case that increased insect resistance raised damage levels under current technology in future years.

This analysis excludes the benefits to society of the reduced environmental damage from pesticides that will result from the new technology. The value of these environmental benefits could easily exceed the cost saving benefits. However, estimation of the value of these benefits is extremely difficult and controversial. This analysis includes only those economically definable benefits that will be actually achieved by society through lower producer costs and the resultant lower product prices.

Table 7 Annual Research Funds Supportable Per Million in Annual Cost of Production Savings with Future Technology [a/]

| Duration of Technology (Years) | Years to implementation of new technology [b/] | |
|---|---|---|
| | 5 | 10 |
| | - - - - - - -Million dollars- - - - - - - - | |
| 10 | 1.30 | 0.55 |
| 15 | 1.75 | 0.80 |
| 20 | 2.10 | 0.95 |
| 25 | 2.40 | 1.05 |

[a/] When expensitures are made at the beginning of the year and cost savings are received at the end of the year using a 5 percent social rate of return (discount).

[b/] Includes time required for development and adoption.

## Conclusions

Insect control costs and level of insecticide use on cotton could be reduced by as much as 30 and 40 percent, respectively, through adoption of currently available technology. Elimination of all actual and implied constraints on the location of production would cause a shift in cotton production from the Southeast to the South and Southwest and would further reduce production costs and insecticide use.

Short season and resistant variety technologies that entomologists expect will be available within the next 5-10 years would significantly reduce production costs and insecticide use, regardless of the location of production, but would have the greatest impact if regional shifts are limited. Resistance would have a greater impact than short season.

Regardless of the level of technology, no single technology is best for the entire country and use of the most economical alternative in each region will result in lower production costs and environmental damage than mandatory adoption of any particular technology. This implies greater social gain from use of funds on educational efforts to encourage use of locally optimal technology than on policing efforts to insure adoption of a particular technology. It also supports the decisions to invest in the integrated pest management programs currently underway.

The cost savings estimated for the short season and resistant variety technologies imply a direct social and economic gain which would justify research expenditures for technology development. Assuming that the technology could be developed in 10 years, as indicated by the entomologists surveyed, annual research expenditure of 8.8 to 16.8 million dollars (1973 prices) could be justified on the basis of cost saving alone. This does not include the value of the reduced environmental damage that would also result from the technology.

The differing regional impacts of the policy variables investigated can be expected to divide the agricultural community with respect to specific legislative proposals. An analysis of the negative impacts of regional shifts in cotton production is needed before firm policy recommendations can be made.

## Footnotes

1. Making use of data collected as part of this study Taylor and Lacewell have contracted eradication with two loosely defined alternatives representing currently available pest control strategies and those expected to be available in 5-10 years.

# REFERENCES

1. Carlson, G.A., "A Decision Theorectic Approach to Crop Disease Prediction and Control." American Journal of Agricultural Economics 52 (1970): 216-223.

2. Carlson, G.A., "Long-Run Productivity of Pesticides." American Journal of Agricultural Economics 59 (1977): 543-548.

3. Firch, R.S., "Adjustments in a Slowly Declining U.S. Cotton Industry." American Journal of Agricultural Economics 55 (1973): 892-902.

4. Hall, D.C. and R.B. Norgaard, "On the Timing and Application of Pesticides." American Journal of Agricultural Economics 55 (1973): 198-201.

5. Headley, J.C., "Estimating the Productivity of Agricultural Pesticides." American Journal of Agricultural Economics 50 (1968): 13-23.

6. Headley, J.C., "Defining the Economic Threshold." in Pest Control Strategies for the Future, pp. 100-108, National Academy of Science, 1972.

7. Hueth, D. and U. Regev, "Optimal Agricultural Pest Management with Increasing Pest Resistance." American Journal of Agricultural Economics 56 (1974): 543-552.

8. McArthur, W.C., Selected U.S. Crop Budgets: Yields, Inputs, and Variable Costs, Vol. I, Southeast Region. U.S. Dept. of Agriculture ERS 457, 1971.

9. Miller, T.A., Selected U.S. Crop Budgets: Yields, Inputs, and Variable Costs, Vol III, Great Plains Region. U.S. Dept. of Agriculture ERS 459, 1971.

10. Pawson, W.W., Selected U.S. Crop Budgets: Yields, Inputs, and Variable Costs, Vol. VI, Southwest Region. U.S. Dept. of Agriculture ERS 514, 1973.

11. Pimentel, D. and C.A. Shoemaker, "An Economic and Land Use Model for Reducing Insecticides on Cotton and Corn." Environmental Entomology 3 (1974): 10-20.

12. 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 58 (1976): 186-197.

13. Rode, L.C., Selected U.S. Crop Budgets: Yields, Inputs, and Variable Costs, Vol. IV, Northwest Region. U.S. Dept. of Agriculture ERS 460, 1971.

14. Shoemaker, Christine, "Optimization of Agricultural Pest Management III: Results and Extensions of a Model." Math. Biosci. 18 (1973): 1-23.

15. Stricklan, P.L. and R.L.Harwell, Selected U.S. Crop Budgets: Yields, Inputs, and Variable Costs, Vol. V, South Central Region. U.S. Dept. of Agriculture, ERS 461, 1971.

16. Talpaz, Hovav and Itshak Borosh, "Strategy for Pesticide Use: Frequency and Applications." American Journal of Agricultural Economics 56 (1974): 769-775.

17. Taylor, C. Robert and Ronald D. Lacewell, "Boll weevil Control Strategies: Regional Benefits and Costs" Southern Journal of Agricultural Economics Vol. IX no. 1, July 1977.

18. Taylor, C. Robert and Earl R. Swanson, The Economic Impact of Selected Nitrogen Restriction on Agriculture in Illinois and 20 other Regions of the United States, Dept. of Agr. Econ., U. of Ill, AERR 133 1975.

19. U.S. Department of Agriculture, Unpublished data, 1967 Soil Conservation Needs Inventory, Soil Conservation Service, 1967.

20. Worden, G. et. al., Selected U.S. Crop Budgets: Yields, Inputs, and Variable Costs, Vol. II, North Central Region. U.S. Dept. of Agriculture ERS 458, 1971.