RESEARCH BULLETIN 1050 APRIL, 1983

UNIVERSITY OF MISSOURI-COLUMBIA
COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION

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Economic Strategies for Coping with Black Cutworms in Northwest Missouri

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ACKNOWLEDGEMENTS

Helpful comments, criticism, cooperation and counsel from Michael English, Armon Keaster and Mahlon Fairchild of the Department of Entomology at the University of Missouri are gratefully acknowledged as well as assistance from numerous faculty in the Department of Agronomy. We are indebted to Daryll Raitt and Norlin Hein for their thorough review.

Any errors of fact, analysis or interpretation are the responsibility of the authors.

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Economic Strategies for Coping with Black Cutworms in Northwest Missouri

John A. Brady
and
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In 1978, the United States Environmental Protection Agency (EPA) suspended the registration of heptachlor and chlordane, two chlorinated hydrocarbon insecticides widely used for control of black cutworms (BCW) and other soil insects attacking corn. As a result of that suspension of registration, this study was initiated to project economical alternative management strategies to deal with the cutworm problem. Initial possibilities suggested by agronomists and entomologists included 1) changing the cropping system, 2) implementing previously unused or new chemical and biological controls, 3) using no chemicals, but replanting as necessary, and 4) utilizing some combination of the three previous suggestions. Two primary complicating factors make this study difficult. The first is the lack of information concerning the life cycle and habits of the BCW; a problem currently being researched by a number of investigators. The second is that until mid-1978 when chlorpyrifos (LORSBAN[R]) was introduced and registered, no registered chemical treatments as effective as heptachlor were available. Even this new chemical has not performed as well under the varied climatic conditions of continuous annual use as did the reliable heptachlor.

Problem Statement

Implementation of any of the above alternatives would, obviously, have an effect on the economics of a single farm's corn enterprise. This has been specifically shown by Collins and Headley.[1] The thrust of this paper, however, is to examine the total farm economic impact of the cancellation of the registration of heptachlor. From a farm manager's viewpoint the question becomes, "What economically viable strategies remain open for managing black cutworm

[1]Robert A. Collins and J.C. Headley, "Alternative Cutworm Control strategies: The Effect on Missouri Corn Farmers of a Cancellation of the Pesticides Chlordane and Heptachlor," Agricultural Experiment Station, University of Missouri-Columbia, SR 195, November, 1976. (Mimeographed.)

This research was supported by the Missouri Agricultural Experiment Station and is drawn from the senior author's unpublished M.S. thesis.
Brady is a former research assistant and Headley is a professor in the Department of Economics, University of Missouri-Columbia.

outbreaks in the absence of efficacious chlorinated hydrocarbon insecticides?" Entomologists verify the complexity of the question: "Cutworms are among the insects that continue to defy man's efforts at pest management. Although a few cultural practices tend to reduce the intensity of the problem, in some years nothing works."[2] Comparatively severe cutworm outbreaks in 1978 and 1979 heightened interest in a solution to the problem.

Objectives

The overall objective of this report is to provide a framework for 1) evaluating the strategies previously suggested for managing black cutworm outbreaks, and 2) providing farm management guidance for producers and/or their advisers facing the question mentioned above. Such an objective may seem futile to a skeptic avowing that cutworm outbreaks are virtually random occurrences. However, proceeding on the belief that some of the research that has been done is valid and that cutworm outbreaks can be identified and managed, the specific objectives of this paper are as follows:

1) Prepare a model that will evaluate currently available management strategy alternatives for corn production, given the information presently available about the habitat and life cycle of the BCW and the effectiveness of control methods available.
2) Use the model to evaluate the extent of optimality presently occurring on a typical Northwest Missouri farm.
3) Use the model to project the optimum cutworm control strategy for an average Northwest Missouri crop farm with and without livestock enterprises.
4) Examine the effect of having no legal cutworm control chemicals.
5) Attempt an answer to the question: Is an effective cutworm control essential to maintaining corn production in Northwest Missouri?
6) Impute a value for a 100% accurate cutworm scout.

THE GEOGRAPHICAL AREA AND DATA BASE

The Geographical Area

The study area is the northwest quarter of Missouri. This area includes District 1 and District 2, according to Missouri Crop and Livestock Reporting Service's divisions, plus Lafayette and Saline counties (Figure 1). Approximately one-half of the state's corn production for grain occurs in this area.[3,4] Table 1

[2]George W. Thomas et al., "1980 Control Recommendations for Cutworm, Wireworm and Other Corn Soil Insects," UMC Science and Technology Guide (Columbia, MO: University of Missouri-Columbia Extension Division), Guide 4150.

[3]U.S. Dept. of Commerce, Bureau of the Census, *1974 Census of Agriculture*, Volume 1, Part 25, Missouri State and County Data, Book 2, Issued May, 1977.

[4]Missouri Crop and Livestock Reporting Service, comp., *Missouri Farm Facts*, Missouri Department of Agriculture, U.S. Dept. of Agriculture, May 1979, p.23.

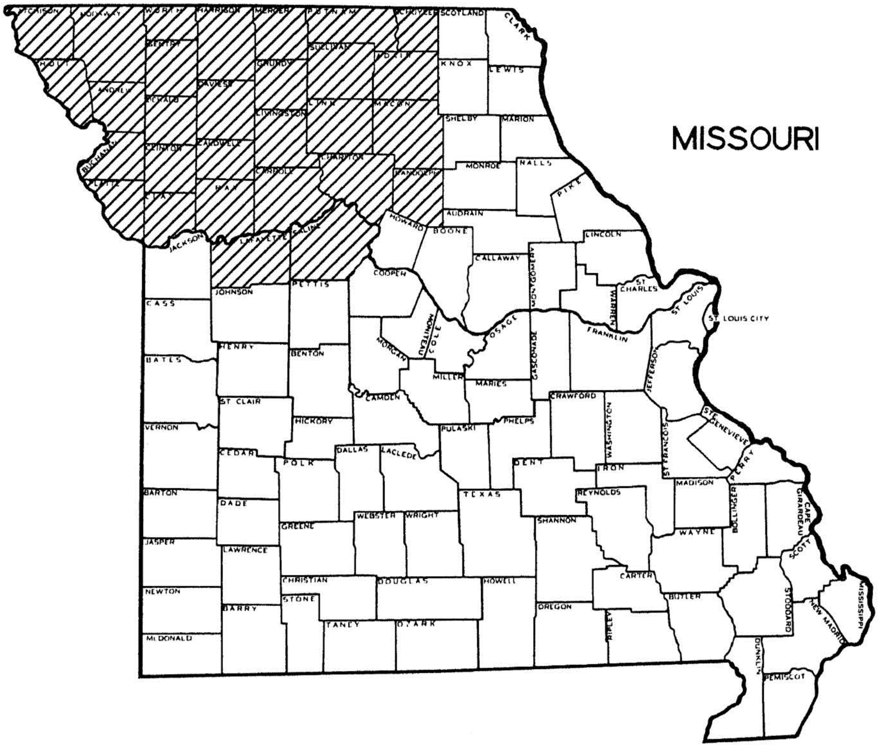

Figure 1
Target Area for Black Cutworm Management Strategies

TABLE 1
Contributions of Northwest Missouri to Total State Acreage in Five Major Crops, 1978

Crop	Acres in Region	Acres in State	Percent in Region	Number of Top 10 Counties in Region
Corn	1,095,200	2,200,000	49.8	7
Milo	214,300	850,000	25.0	0
Hay	1,069,600	3,450,000	31.0	
Soybeans	1,963,900	5,440,000	36.0	4
Wheat	104,500	840,000	12.4	0

Source: Missouri Crop and Livestock Reporting Service, Comp., *Missouri Farm Facts*, Missouri Department of Agriculture, U.S. Dept. of Agriculture, May 1979.

shows the five major crops for the area along with a comparison of Northwest Missouri to the rest of the state.

To maintain simplicity in this study, pastureland and complementary livestock operations, and minor crops have been disregarded in order to maintain a focus on the crops most likely to compete with corn for tillable cropland, along with associated intensive livestock operations that are primary users of concentrate feeds, such as pork, beef, and dairy operations (Table 2).

The Data Base

The 1974 Census of Agriculture estimates the average farm size in the region for farms with over $2500 annual sales is 333 acres. By 1979, the average farm size statewide has increased by 7.45 percent over the 1974 statewide average.[5] Adding this percentage adjustment to the regional figure, the adjusted average size becomes 358 acres. Based on the data obtained, a hypothetical average farm was defined. It consists of 300 acres of tillable cropland of which 100 acres are bottomland and 200 acres are upland. Permanent pasture, wasteland, and low intensity livestock activities are part of a typical farm, but are excluded as mentioned above. An owner-operator is assumed with family help and some hired labor available according to the constraints of the model to be discussed later.

The cropping options open to the farmer are corn silage, corn for grain, milo, wheat, soybeans, and hay. Hay crops consist of alfalfa, grass, and/or mixed hay. The only land use restriction assumed is that alfalfa hay and mixed hay cannot be grown on bottomland due to the internal soil drainage requirements of most legumes. Other crops may be grown on either upland or bottomland. Conventional tillage and other standard cultural practices are assumed. Cash markets are assumed to be available for the grains and soybeans, but the forage crops are assumed to be marketed through the livestock enterprises, although, in some instances, commercial outlets may be available.

[5]Ibid., p.58.

TABLE 2
Contributions of Northwest Missouri to Total State Livestock Production, 1978

Enterprise	No. in Region	No. in State	Percent in Region	Number of Top 10 Counties in Region
Feeder Cattle	225,305	508,378	44	NA
Hogs & Pigs	1,466,500	4,100,000	36	3
Dairy Cows	36,000	276,000	13	NA

Source: Missouri Crop and Livestock Reporting Service, Comp., *Missouri Farm Facts*, Missouri Department of Agriculture, U.S.D.A., May 1979.

The livestock enterprises considered, as mentioned above, are the more intensive farrow-to-finish hogs, feeder cattle, and dairy options. To maintain consistency in the scale of operations relative to the land base of the farm, the maximum consistency in the scale of operations relative to the land base of the farm, the maximum livestock numbers are fifty sow units, fifty dairy cows, and 100 feeder cattle. Later sections explain the specification of each enterprise for the modeling procedure and the nature of the model's selection criteria.

CUTWORM DATA

A difficulty encountered in projecting management strategies for cutworm control is the unpredictable nature of the BCW. The insect's life cycle begins when BCW eggs are deposited on the soil, usually in a moist or shaded spot. Newly-hatched larvae feed on almost any available green plant or plant residues. In a well-prepared corn field, the corn plants are virtually the only green vegetation present. BCW larvae feed either above or slightly below ground level depending on atmospheric conditions and the size of larvae. About four weeks are normally required for the usual six larval instars from egg to adult. A conservative "rule of thumb" estimates that each larva cuts five plants in this interval. The BCW may have several overlapping generations per growing season. The overwintering stage of the BCW is not known with certainty.[6] Some field conditions that have historically been associated with BCW outbreaks are: 1) a previous history of cutworm outbreaks, 2) previous year's crop of soybeans, corn, wheat or long-standing forages, 3) minimum tillage or no-till, 4) medium to heavy population of winter weeds, 5) adjacent permanent vegetation, and 6) poor field drainage or flooding. In 1978, Indiana researchers visited 167 fields classified as "high-risk" BCW fields on the basis of having most or all of the six characteristics listed; none of the fields had cutworms. Various other fields did

[6]George W. Thomas et al., "1980 Control Recommendations for Cutworm, Wireworm, and Other Corn Soil Insects."

have cutworms. The lack of understanding of all the biological and behavioral phenomenon of the BCW is evidenced.[7]

The University of Missouri and other institutions have directed some research toward studying the effectiveness of various chemical control options.[8,9] In this research the effectiveness of a given chemical is measured by showing the percent stand loss incurred. Table 3 shows the most common chemicals currently labeled

TABLE 3

Percent Stand Loss Due to Black Cutworm Damage During the Year Infestation Occurs, By Chemical Treatment

Treatment	Percent of Stand Loss	Total Material Units/Acre[9]	Formulation Time of Application
No Treatment	50[1]	—	—
Lorsban	10[2]	6.5#	15g at planting
Mocap	20[2]	10.0#	10g at planting
Sevin Bait	15[3]	40.0#	5% bait, rescue
Sevin Directed Spray	3.75[4]	2.5#	80 WP, 7-14" band rescue
Lorsban	30[5]	1 qt.	4E, broadcast rescue
Toxaphene	32.5[6]	2⅔ pt.	6E, 7-14" band rescue
Lorsban	10[7]	2 qt.	4E, Pre-plant Incorporated
Furadan	50[8]	10.0#	10g at planting

[1]A 50% stand loss is assumed to be the approximate maximum stand loss that can be tolerated. Many farmers will replant at much lower damage levels.
[2]These values are maximum for moderate BCW infestations according to the UMC Guide 4150.
[3,4,6]Values from plot barrier experiments at Iowa State University Johnson Farm.
[5]Value approximated from band treatment at Iowa State University Johnson Farm.
[7]Unverified approximation. Very limited field studies confirmed with this method.
[8]Furadan is assumed to have no efficacy for BCW control. Included simply for completeness.
[9]Total material per acre is based on 40 inch rows where row width is applicable.

Source: Mahlon Fairchild, principal investigator, "Bionomics and Management of Soil Arthropod Pests," Final Report for EPA Grant #802547, UMC Dept. of Entomology.

[7]M.L. Fairchild, coord., "Development of Pest Management Strategies for Soil Insects on Corn," p.9, 39.

[8]George W. Thomas et al., "1980 Control Recommendations for Cutworm, Wireworm and Other Corn Soil Insects;" Steven A. Myers, Armon J. Keaster and Fred J. Arnold, "Field Studies Report on Black Cutworms," Dept. of Entomology, University of Missouri-Columbia, 1978. (Mimeographed); Steven A. Myers, Armon J. Keaster, Fred J. Arnold and Judy A Grundler, "Field Studies Report on Black Cutworm," Dept. of Entomology, University of Missouri-Columbia, 1979. (Mimeographed); Steven A. Myers et al., "Missouri Cutworm Damage Survey," Dept. of Entomology, University of Missouri and The Missouri State Crop and Livestock Reporting Service, 1979. (Mimeographed).

[9]Mahlon Fairchild, principal investigator, "Bionomics and Management of Soil Arthropod Pests," Final Report for EPA Grant #802547, UMC Dept. of Entomology.

TABLE 4
Adjusted Stand Loss Due to Black Cutworm[1]
By Chemical Treatment

Treatment	Percent Stand Loss
No Treatment	50
Lorsban 15g at planting	5
Mocap 10g at planting	20
Sevin 5% Bait	15
Sevin Directed Spray	30
Lorsban Broadcast Spray	10
Toxaphene Directed Spray	32.5
Lorsban PPI	10
Furadan	50

[1]Adjusted by author based on consultation with a panel of entomologists at University of Missouri.

Source: Personal Conversations with Mike English, Armon Keaster and Rodney Ward.

for use on corn along with an estimate of stand loss as reported in the research reports. After consultation with UMC entomologists, these stand loss figures were modified to reflect the specialist's assessment of likely field conditions in NW Missouri. These modifications are presented in Table 4 and are basic to this study. The percent stand loss was converted to yield loss by the regression equation,

$$Y = 23.5 + .756X, \text{ where } Y = \% \text{ of normal yield in bushels per acre}$$
$$X = \% \text{ of stand remaining after BCW damage}$$

The authors calculated this equation from data obtained in simulated BCW experiments in five corn belt states.[10] A linear equation was chosen for simplicity and for its fit to the data; however, if more than sixty percent of the stand is lost, the resulting decline in yield is much more severe than shown in this equation. The information in Tables 3 and 4 and the above regression equation was used to determine the resulting yield losses associated with alternative treatments for BCW.

BUDGET AND YIELD DATA

The basic data for crop and livestock budgets came from two sources. The crop budget information was derived from 1978 Missouri Mail-in Record (MIR) data. Chemical and fertilizer expenses were inflated to approximate the price situation of February 1980. Other expenses were inflated to depict the production projections for the 1980 crop season. Insecticide expenses for the

[10]W.B. Showers et al., "Simulated Black Cutworm Damage to Seedling Corn," *Journal of Economic Entomology* 72 (1979): 432-436.

various cutworm treatments on corn reflect February 1980 prices (FOB, Columbia, Mo.). Per acre insecticide expenses were for labeled rates of application.

Livestock budgets were taken from the *Missouri Farm Planning Handbook.* Only three livestock enterprises were selected for this study. Farrow-to-finish hogs, feeder steers, and dairy cows were selected because of their high level of feed grain consumption. It is common practice to market corn via these livestock activities, and corn marketed this way may have a higher or lower implicit value based upon the price level of livestock and dairy products than it would if sold. Two sets of budgets were used for each enterprise and are identical except that one budget used only corn as a concentrate feed and the other budget used milo to replace 75 percent of the corn in the ration. Milo was assumed to substitute for corn at one bushel of milo equals .95 bushels of corn.[11]

Labor requirements for the various enterprises have been taken largely from the *Missouri Farm Planning Handbook* and from Roy N. VanArsdall.[12] These requirements were modified slightly to try to better represent the Northwest Missouri area.

Price data for the various outputs of the farm enterprises came from *Missouri Farm Planning Handbook* and Kansas City milk market order administrator. These are the prices used in the base run of the model and reflect estimates for the period 1979-81. Various ranges of price were used in the sensitivity analysis described later.

The yield coefficients were set according to the best judgment of the author after consulting a variety of sources.[13] These coefficients were presented to and approved by a panel of entomologists knowledgeable about crop production in the Northwest Missouri area. Copies of the budgets and coefficients are available to interested readers on request from the authors.

THE MODEL

A linear programming model was chosen for planning feasible and economically optimal management strategies for the average farm. The objective of the model was to maximize the income over variable costs (IOVC) subject to certain restrictions. A variety of combinations of restrictions was imposed to represent a wide range of potential climatic, financial, resource and management considerations.

The model included 121 buying, selling, hiring, capital borrowing, crop production and livestock activities as options available to the manager. The

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[11]Herman Workman, ed., "Missouri Farm Planning Handbook," Manual 75 (Columbia, MO: University of Missouri, College of Agriculture Extension Division, October 1978).

[12]R.N. Van Arsdall, Labor Requirements, *Machinery Investments and Annual Costs for the Production of Selected Field Crops in Illinois*, AE-4112, Illinois Agr. Exp. Station, Urbana, 1965.

[13]Herman Workman, ed., "Missouri Farm Planning Handbook;" Carroll L. Kirtley and James B. Kliebenstein, *Missouri Farm Business Summary 1978* (Columbia, MO: University of Missouri-Columbia Extension Division).

TABLE 5

Resources Available on the Average Northwest Missouri Farm

Row Identification	Resource Description	Maximum Amount Available in Basic Model
Land 1	Bottomland never affected by cutworms	10 acres
Land 2	Bottomland with BCW infestation every other year average	50 acres
Land 3	Bottomland with BCW infestation one of four years average	40 acres
Land 4	Upland with no BCW	75 acres
Land 5	Upland with BCW every other year average	25 acres
Land 6	Upland with BCW one of four years average	100 acres
Labor 1	Operator and family labor in January, February	272 hours
Labor 2	Operator and family labor in March, April	434 hours
Labor 3	Operator and family labor in May, June	559 hours
Labor 4	Operator and family labor in July, August	489 hours
Labor 5	Operator and family labor in September, October	522 hours
Labor 6	Operator and family labor in November, December	313 hours
Expense	Capital on hand for variable production expenses	$10,000

options are shown in Table 6. Table 5 shows the constraints imposed on the model in the form of land, labor and capital restrictions.

Land resources were divided into bottomland and upland categories and each category was further divided into three categories reflecting 1) no BCW problems, 2) BCW infestation every other year on the average and, 3) BCW

TABLE 6

Real Farm Activities for an Average Northwest Missouri Farm

Activity Name	Description	Unit of Activity
Beans 1-6	Soybeans grown on land categories 1-6	1 acre
Wheat 1-6	Wheat grown on land categories 1-6	1 acre
Milo 1-6	Grain sorghum grown on land categories 1-6	1 acre
Grass 1-6	Grass hay grown on land categories 1-6	1 acre
Alfal 4-6	Alfalfa grown on land categories 4-6	1 acre
Mixha 4-6	Mixed hay grown on land categories 4-6	1 acre
Silag 1,4	Corn silage grown on land 1 or 4	1 acre
Corn 11-16, 21-26, 31-36, 42-43, 45-46, 52-53, 55-56, 62-63, 65-66, 72-73, 75-76, 81-86, 91-96, 102-103, 105-106	Corn for grain activities[1]	1 acre
Feeder 1	Feeder cattle activity using corn	1 steer
Feeder 2	Feeder cattle activity using part milo, part corn	1 steer
Hogs 1	Farrow to finish hog activity using corn	1 sow
Hogs 2	Farrow to finish hog activity using milo and corn	1 sow
Dairy	Dairy activity using corn	1 cow
Dairy 2	Dairy activity using milo and corn	1 cow
Hogsel	Hog selling at 48 cents	1 lb.

TABLE 6 - (Continued)

Activity Name	Description	Unit of Activity
Beefsl	Finished cattle selling at 62 cents	1 lb.
Beefby	Buying feeder cattle at 70 cents	1 lb.
Lbhir 1-6	Labor hiring activities for periods 1-6 at $3.25	1 hour
Corsel	Corn selling at $2.60	1 bushel
Corbuy	Corn buying at $2.65	1 bushel
Soysel	Soybean selling at $6.50	1 bushel
Sorsel	Grain sorghum selling at $2.20	1 bushel
Sorbuy	Grain sorghum buying at $2.25	1 bushel
Whtsel	Wheat selling at $3.50	1 bushel
Alfsel	Alfalfa selling at $60.00	1 ton
Alfbuy	Alfalfa buying at $65.00	1 ton
Ensbuy	Corn silage buying at $19.00	1 ton
Grasel	Grass hay selling at $45.00	1 ton
Grasby	Grass hay buying at $46.00	1 ton
Mixsel	Mixed hay selling at $50.00	1 ton
Mixbuy	Mixed hay buying at $51.00	1 ton
Milksl	Milk selling at $12.50	1 cwt.
Borrow	Operating capital borrowing	1 dollar

[1]The first number(s) 1-10 specify the cutworm treatment, the second (or third) number 1-6 specifies the land category involved. Treatments 4-7, and 10 are rescue treatments. When grown on Land 1 or 4 no control is needed; thus 41, 51, 61, 71, 101 are equivalent to activity 11, and 44, 54, 64, 74, 104 are equivalent to activity 14. Corn treatments: 1 = no chemical or other control, 2 = Lorsban 15g at planting, 3 = Mocap 10g at planting, 4 = 5% Sevin bait rescue, 5 = Sevin sprayable rescue, 6 = Lorsban 4EC rescue, 7 = Toxaphene 6E rescue, 8 = Lorsban 4EC pre-plant incorporated, 9 = Furadan 10g at planting, 10 = replanting.

infestation one year in four on the average. This gives six different land categories (see Table 5).

Family labor resources were divided into six categories each covering two calendar months. The farmer was given the opportunity to hire labor to augment the family supply.

The initial operating capital constraint was set at $10,000 with opportunities to borrow operating funds. As a part of the analysis, the interest rate was varied to determine the sensitivity of the solutions to the cost of credit.

Optimization Results

In total, 23 different farm plans were generated using different resource restrictions. Nine of those plans were selected for presentation in Table 7.

Plan 1 imposed three restrictions. Dairy cows and sows were restricted to 50 units each and a minimum of 74 acres of corn was required. Corn is grown only on land free of cutworms, that is land category 1 (bottomland) and land category 4 (upland). Soybeans occupied the balance of the land. Milo was fed in the livestock rations as a partial corn substitute and was purchased at $2.25 per bushel. Plan 2 is identical except that milo could not be fed. The change in IOVC is the result of the price differential between milo and corn purchased.

The dairy option was used in Plans 1 and 2 for illustration. Because of high capital and labor requirements and lack of a market base, only a few farms in the area use this option. It is clear that a dairy enterprise will increase IOVC in situations set up for it.

Plan 3 illustrates a *realistic* optimum resource use on an average farm in Northwest Missouri. This plan includes 50 sows and a cropping system of continuous soybeans. The $59,018 IOVC is a return to land, management, family labor and fixed capital as illustrated in Table 8. Since Plan 3 is an optimum, subsequent plans provide lower IOVC. For reasons such as disease control, control of pests other than BCW, erosion control, risk aversion, capital rationing, or management preferences, some departure from the optimum may be required. It should be noted that dropping the dairy enterprise reduced the amount of operating capital that had to be borrowed and, although not shown in Table 7, labor requirements were also reduced.

Plan 4 is similar to Plan 3 except that soybeans were restricted to 150 acres or half of the tillable land. The results were that 49 acres of corn was grown and 98 acres of milo was grown on the upland with BCW problems one year in four. Income over variable cost was reduced by $3292 or about $22 per acre of soybeans removed from the plan. Borrowed capital needed also increased due to the additional capital needed to grow corn and milo. It should also be noted that the shadow prices for land were also reduced because of the restrictions. Corn was grown on land requiring no chemical treatment for BCW.

To provide a benchmark, Plan 5 is a simulation of the present land use in the area. Based on aggregated data, the average farm would have 74 acres of corn, 7 acres of wheat, 14 acres of milo and 72 acres of hay arbitrarily divided into 40

TABLE 7

Selected Farm Plans for An Average Northwest Missouri Farm With Black Cutworm Problems

Plan No.	Farm Plan Restrictions	Income Over Variable Cost ($)	Operating Capital Borrowed* ($)	Land and Infestation Level**	Corn Acres	Corn BCW Treatment	Soybeans (acres)	Alfalfa (acres)	Milo (acres)	Wheat (acres)	Grass and Mixed Hay (acres)	Land*** Shadow Price ($/A)	Livestock Type and No. of Head
1	Dairy Cows 50	91,121	79,961	Bottom 0	10	None						132	Sows 50
	Sows 50			Upland 0	64	None	7					88	Dairy 50
	Corn Acres 74			Bottom .5			50					126	
	Option to			Bottom .25			40					126	
	Feed Milo			Upland .5			25					88	
				Upland .25			100					88	
2	Dairy Cows 50	87,956	79,961	Bottom 0	10	None						133	Sows 50
	Sows 50			Upland 0	64	None	7					88	Dairy 50
	Corn Acres 74			Bottom .5			50					126	
	No Milo Fed			Bottom .25			40					126	
				Upland .5			25					88	
				Upland .25			100					88	
3	Sows 50	59,018	42,981	Bottom 0			10					136	Sows 50
	Dairy = 0			Bottom .5			50					136	
				Bottom .25			40					136	
				Upland 0			73					98	
				Upland .5			25					98	
				Upland .25			100					97	

TABLE 7 (Cont'd)

Plan No.	Farm Plan Restrictions	Income Over Variable Cost ($)	Operating Capital Borrowed* ($)	Land and Infestation Level**	Corn Acres	Corn BCW Treatment	Soybeans (acres)	Alfalfa (acres)	Milo (acres)	Wheat (acres)	Grass and Mixed Hay (acres)	Land*** Shadow Price ($/A)	Livestock Type and No. of Head
4	Sows 50	55,726	46,392	Bottom 0	10	None						114	Sows 50
	Soybean			Upland 0	39	None	33					70	
	Acres 150			Upland .25			1		98			70	
	Dairy = 0			Bottom .5			50					108	
				Bottom .25			40					108	
				Upland .5			25					70	
5	Area	53,992	46,124	Bottom 0	10	None						137	Sows 50
	Simulation			Upland 0	64	None	9					93	
	Sows 50			Upland .25			7	40	14	7	32	93	
	Dairy 0			Bottom .5			50					131	
				Bottom .25			40					131	
				Upland .5			25					93	
6	Sows = 0	34,978	14,487	Bottom 0			10					139	
	Dairy = 0			Bottom .5			50					139	
				Bottom .25			40					139	
				Upland 0			75					131	
				Upland .5			25					131	
				Upland .25			100					131	
7	Feeder	32,043	21,927	Bottom 0	10	None						145	Feeders 50
	Cattle 50			Upland 0	64	None	8					101	
	Dairy = 0			Bottom .5			50					139	
	Sows = 0			Bottom .25			40					139	
	Corn Acres 74			Upland .5			25					101	
				Upland .25			100					101	

TABLE 7 (Cont'd)

Plan No.	Farm Plan Restrictions	Income Over Variable Cost ($)	Operating Capital Borrowed* ($)	Land and Infestation Level**	Corn Acres	Corn BCW Treatment	Soybeans (acres)	Alfalfa (acres)	Milo (acres)	Wheat (acres)	Grass and Mixed Hay (acres)	Land*** Shadow Price ($/A)	Livestock Type and No. of Head
8	Corn Acres 150	29,151	23,369	Bottom 0	10	None						151	
	Milo Acres 75			Bottom .5	25	Lorsban Rescue	25					139	
	Sows = 0			Bottom .25	40	Lorsban Rescue						144	
	Dairy = 0			Upland 0	75	None						107	
				Upland .5			25					101	
				Upland .25			25		75			101	
9	Corn Acres 265	27,491	26,740	Bottom 0	10	None						151	
	Sows = 0			Bottom .5	25	Lorsban Rescue						140	
	Dairy = 0			Bottom .25	40	Lorsban Rescue						144	
				Upland 0	75	None						107	
				Upland .5			25					101	
				Upland .25	90	Lorsban Rescue	10					101	

* Capital assumed to be borrowed for 6 month loan periods at an interest rate of 12 percent.

** The numbers following the land location indicate the fraction of years when cutworms are expected to be a problem.

*** Shadow prices show the amount income over variable cost would increase per acre increase of land in that location and with that fraction of years when cutworm problems are expected.

TABLE 8
An Example for Converting Income Over Variable Costs to Net Returns

Income Over Variable Cost		$ 59018
Real estate taxes, interest and depreciation on buildings and improvements; $75/A.	$22500	
Interest and depreciation on machine investment; $24/A.	$ 7200	
Family Labor $3 x 2588 hr.	$ 7764	
Total Fixed Costs	$37464	$-37464
Return to Management and Owner's Equity in Land, Buildings, and Equipment (net return)		$ 21554

acres of alfalfa, 20 acres of grass hay and 12 acres of mixed hay with the remaining 140-150 acres in soybeans. Livestock consisted of 50 sows. The hay was assumed to be sold since there was no forage using livestock options in the plan. This plan generated $53,992 of IOVC, about 10% less than Plan 3 which had an identical hog enterprise. The $5026 reduction in IOVC is about $30.00 per acre for each acre of soybeans displaced in moving from Plan 3 to Plan 5.

If the farm was organized as a strictly cash grain farm such as Plan 6, all tillable land goes to soybeans, but IOVC drops to $34,978 and the credit needs are reduced. The difference in IOVC in Plan 5 and Plan 6 is due to loss of income from the hogs; all of which could not be offset by the increase in the acreage of the more profitable soybeans. If one compares Plan 6 and Plan 3, where the only difference is the hog enterprise, IOVC was reduced by $24,040 or $480 per sow.

Plan 7 indicates that feeder cattle are not profitable given the feed prices and the negative buy-sell margins of the budgets of 18 cents per lb. The inclusion of 74 acres of corn also helped to reduce IOVC compared to the cash grain organization of Plan 6.

When a cash grain organization was specified requiring at least 150 acres of corn and at least 75 acres of milo as in Plan 8, IOVC was further reduced to $29,151. Corn was grown on the three bottomland categories and on the upland with no BCW problems. The 10 acres of corn on land category 1 had no chemical treatment. Corn on land categories 2 and 3 (bottom land with BCW every other year and one year in four respectively) was treated with Lorsban 4EC as a rescue treatment for BCW and the 75 acres of corn on land category 4 (upland with no BCW problems) had no chemical treatment for BCW. The milo was grown on land category 6, which was the upland susceptible to BCW one year in four. Soybeans completed the cropping system.

Finally, in Plan 9 corn was required on at least 265 acres with no livestock. Again as in Plan 8, the corn was put on the land categories 1-4 (bottom land and upland with no BCW problems) and upland which was in milo and soybeans in Plan 8 was placed in corn. All of the land in categories 2, 3 and 6 which is BCW susceptible was given Lorsban 4EC as a rescue treatment. The result of replacing 75 acres of milo and 40 acres of soybeans with corn was a reduction in IOVC of $1660 or about $14.40 per acre of corn added.

Inferences from Optimization Results

The primary inference than can be drawn from the results is that continuous cropping of soybeans and a profitable livestock operation of hogs or dairy are the best generators of income for a Northwest Missouri farm. It is also clear that unless a wide buying price over selling price differential exists for corn as feed, even agronomically optimal corn enterprises cost the producer in terms of lost potential income.[14] To the extent that milo can replace corn in the cropping system and in the livestock rations, losses of IOVC will probably be reduced. From a cutworm management standpoint, corn should be avoided except in limited optimum circumstances, and even then the motive for corn production must be one other than profit, such as for pest management erosion control or owner preference. In cases where no livestock are considered, such as cash grain farms, the percentage income penalties for forcing corn into the model were greater, although the absolute penalties are much the same under either livestock or cash grain systems.

In the next section, the sensitivity of the optima to changes in price, yield, and biological factors will be examined. The degree of sensitivity will tell something about the validity of the inferences of the optimizing procedures.

Sensitivity Analysis

In a model of this size, endless changes and adjustments could be made to reflect varying financial situations, management preferences, or resource bases. Three general areas will be examined here: 1) price sensitivity, 2) land category sensitivity, and 3) sensitivity to biological factors. An analysis of items 1 and 2 is included to establish the effect (or more accurately, the lack of effect) of these two factors upon the optimum farm plans suggested. Item 3 is the most relevant portion of this section on sensitivity analysis and is discussed last as a culmination of the thrust of both this section and the chapter as a whole.

Price Sensitivity: Tables 9-11 show the results of changing prices and price ratios for the three commodities of prime economic import in Northwest

[14]One reviewer has pointed out that the 5 cent margin between the farm price of corn and the price farmers pay for corn is too narrow. It is clear that a wider margin would favor home grown corn. The sensitivity could not be checked for inclusion in this report.

Missouri. Farm Plan 3, discussed previously as the optimum, is used as the "baseline" plan in these tables. Recall that this plan generates $59,018 of IOVC by continuous cropping of soybeans and raising hogs.

Corn prices are varied from $1.80-$3.20, a rather broad range while holding soybean price at $6.50 per bushel (Table 9). Note also that the effective corn-soybean price ratio ranges from 1:3.6 to 1:2.0, a fairly wide range around the typical 1:2.5 ratio. At a corn price of $1.80, feeder cattle enter the model at nearly 1500 head, a number resulting from the linearity assumption mentioned earlier. This does indicate that the enterprise is profitable at a corn price of $1.80 per bushel. Increasing corn price to $1.90 per bushel lowers the profitability of feeder cattle and only 68 are fed. At the $2.00 price the profit in the cattle feeding is gone; at $2.40 the hog enterprise switches from the strictly corn ration to the corn-milo ration. The optimum farm plan, Plan 3, is selected from $2.40-$2.79 at which point ten acres of the highest yielding corn on bottom land with no BCW problem enters the solution. The shadow price of soybeans at this point ($5.89/acre) suggests that less than a bushel increase in soybean yield over the thirty-three assumed would make soybeans the most profitable crop. At the corn price of 3.00, a substantial amount of corn acreage enters. BCW treatment is the 96% effective Lorsban rescue treatment. At a price of $3.20 per bushel, the model suggests growing corn on all land types using the Lorsban rescue treatment.

Soybean prices were decreased from $6.50 while all other prices remained at the baseline level (Table 10). No need for increasing soybean price is evident because it is simple arithmetic to calculate the effect on increased IOVC. The ideal corn situation, corn on bottom land with no BCW shows up problems when the price of soybeans drops to $6.00. Fifteen acres of corn on bottom land with BCW problems one year in four enters at $5.75 and by the time price drops to $5.50 soybeans disappear in favor of corn with Lorsban rescue treatments and milo. This confirms earlier indications that milo is a reasonable choice when any but the most favorable corn growing conditions prevail.

The corn-bean price ratio should be given attention. The likelihood of price ratios changing to favor corn production is not great. Ordinarily both corn and soybean prices will move together closely enough to maintain a fairly narrow range of price ratios around the 1:2.5 average.

Pork prices were varied downward from the initial $0.48 per pound figure with other prices at baseline level (Table 11). The most striking result of this series is the substantial decrease in IOVC. Hogs drop out of the picture conclusively at $0.33 per pound. Purchased feed is economically preferred to the on-farm produced feed at all pork price levels.

No table of interest rate changes is shown. The model, however, was insensitive to changes in interest rate over the range from 0-20 percent. The only change occurring was an increase or decrease in IOVC depending on the dollar amount of interest paid.

TABLE 9

Effects of Increasing Corn Price on the Farm Plan for an Average Northwest Missouri Farm

Corn Price ($/bu)	IOVC[1] ($)	Borrowed Capital ($)	Corn/Bean Price Ratio	Activities Added[2] Name	Activities Added[2] Land and Infestation Level	BCW Treatment	Activities Deleted[2] Name and Number	Activities Deleted[2] Land and Infestation Level	Marginal Cost of Corn[4] ($/ac)	Marginal Cost of Soybeans[5] ($/ac)
1.80	67818	184464	1:3.6	Feeders 1					97.13	
2.00	62907	42981	1:3.3				Feeders 1	74.10		
2.20	60907	42981	1:3.1						54.10	
2.40	59518	42981	1:2.7	Hogs 2[3]			Hogs 1		34.10	
2.60	59018	42981	1:2.5						14.10	
2.80	58577	43463	1:2.3	Corn(10A)	Bottom 0	None	Soybeans	Bottom 0		5.89
				(Corn 40A)	Bottom .25	Lorsban Rescue	Soybeans	Bottom .25		
3.00	59630	51377	1:2.2	Corn(73A)	Upland 0	None	Soybeans	Upland 0		18.87
				Corn(25A)	Upland .5	Lorsban Rescue	Soybeans	Upland .5		
				Corn(50A)	Bottom .5	Lorsban Rescue	Soybeans	Bottom .5		
3.20	63873	57169	1:2.0	Corn(100A)	Upland .25	Lorsban Rescue	Soybeans	Upland .25		38.87

[1]Income over variable cost.

[2]The baseline farm plan, Plan 3, is at corn price of $2.60 and consists of 50 sow units using a 3:1 milo/corn ration and cropping continuous soybeans on all land, activities added or deleted show the change from the baseline at a given cow price.

[3]Hogs 2 is the name of the activity that uses 3:1 milo/corn ration. Hogs 1 is the hog activity that uses only corn.

[4]The marginal cost of corn is the amount IOVC would decrease if one acre of corn on bottom land with no BCW problems was forced into the plan.

[5]The marginal cost of soybeans is the amount IOVC would decrease if one acre of soybeans on bottom land with no BCW problems was forced into the plan.

TABLE 10

Effects of Decreasing Soybean Prices on the Farm Plan for an Average Northwest Missouri Farm

Soybean Price ($/bu)	IOVC[1] ($)	Corn/ Bean Price Ratio	Activities Added[2] Name	Activities Added[2] Land And Infestation Level	BCW Treatment	Activities Deleted[2] Name	Activities Deleted[2] Land And Infestation Level	Marginal Cost of Corn[3] ($/ac)	Marginal Cost of Soybeans[4] ($/ac)
6.50	59018	1:2.5						14.10	
6.25	56704	1:2.4						5.35	
6.00	54424	1:2.3	Corn (10A)	Bottom 0	None	Soybeans	Bottom 0		3.39
5.75	52299	1:2.2	Corn (15A)	Bottom .25	Lorsban Rescue	Soybeans	Bottom .25	7.20	
5.50	51314	1:2.1	Milo (25A)	Upland .5	N/A	Soybeans	Upland .5		
			Milo (100A)	Upland .25	N/A	Soybeans	Upland .25		
			Corn (73A)	Upland 0	None	Soybeans	Upland 0		13.87
			Corn (50A)	Bottom .5	Lorsban Rescue	Soybeans	Bottom .5		
			Corn (40A)	Bottom .25	Lorsban Rescue	Soybeans	Bottom .25		
5.25	51314	1:2.0							

[1]Income over variable costs.

[2]The baseline farm plan, Plan 3, is at a soybean price of $6.50 and consists of 50 sow units using a 3:1 milo-corn grain ration and cropping continuous soybeans. Activities added or deleted show the change from baseline at a given soybean price.

[3]The marginal cost of corn is the amount IOVC would decrease if one acre of corn on bottom land with no BCW problems was forced into the plan.

[4]The marginal cost of soybeans is the amount IOVC would decrease if one acre of soybeans on bottomland with no BCW problems was forced into the plan.

TABLE 11

Effects of Decreasing Hog Prices on the Farm Plan for An Average Northwest Missouri Farm

Price	IOVC[4]	Activities Added[1]	Activities Deleted[1]	Marginal Cost of Corn ($/ac)	Marginal Cost of Milo ($/ac)
48 cents	$59018			$14.10	$32.16
46 cents	$55718			$14.10	$32.16
44 cents	$52418			$14.10	$32.16
42 cents	$49118			$14.10	$32.16
40 cents	$45818			$14.10	$32.16
38 cents	$42518			$14.10	$32.16
36 cents	$39218			$14.10	$32.16
34 cents	$36055			$14.06	$32.16
33 cents	$34978		Hogs 2[5] 1	$17.44	$32.16

[1]These are production activities which enter or leave Farm Plan 3, the baseline model, which earned $59018 in IOVC.
[2]This is the dollar amount that IOVC would be decreased if one acre of Corn 11 was forced into the plan to provide livestock feed.
[3]This is the dollar amount that IOVC would be decreased if one acre of Milo 1 was forced into the farm plan to feed livestock.
[4]Income over variable cost.
[5]The number 2 indicates a livestock activity using milo and corn in a 3:1 ratio.

Land Category Sensitivity: Because the assignments of land to the cutworm damage categories was largely arbitrary and will certainly vary from farm to farm, a sensitivity analysis is appropriate in determining the effect of shifts in the acreage assigned to each land category. In order to force corn or other crops to enter the model, thereby providing insightful results, soybean acreage was restricted to 150 acres; thus, Farm Plan 4 becomes the new baseline plan for this section of the analysis. Recall that in Plan 4, milo used ninety-eight acres of upland with BCW problems one year in four, corn used all ten acres of bottom land with no BCW problems and thirty-nine acres of upland with no BCW problems. This basic situation prevailed over a broad range of land acreage assignment.

The sensitivity analysis indicated that ± 50 percent variation in assigning land to the worst or best categories according to BCW damage resulted in the BCW susceptible bottom land and some of the unsusceptible upland being used for soybeans, all of the unsusceptible bottom land and some of the unsusceptible upland being used to maintain 45 to 55 acres of corn, and nearly all the two least susceptible categories of upland being used for milo production. As the case was pressed toward the limit of all worst case land, all 100 acres of bottom land, plus fifty acres of upland with the worst BCW problems, was used for soybeans with the remaining upland in milo. When all land was shifted to the most desirable categories, corn acreage increased to 100 acres, all on bottom land; the soybean activity filled its 150 acre allotment from upland and milo continued in production on about forty-eight acres of upland *even though BCW was not a threat.* This persistence of milo in the plan, even under favorable upland conditions for corn production, underscores previous evidence that milo is an economically viable alternative.

Biological Sensitivity: An infinite variety of biological factors can act and interact on the farm. It is impossible to account for many of these variables in a model of this nature. An attempt was made, however, to examine possible effects of such things as: 1) additional stand reduction due to poor germination, soil crusting, other insect or disease pests, mechanical problems, varying management levels, etc., 2) drought effects, hybrid type, or population, 3) weed problems in BCW reduced stands, and 4) late detection of BCW, poor chemical performance, or delayed field entry. A new baseline model (not shown in Table 7) forcing the inclusion of 150 acres of corn, limiting hogs to fifty sow units, and maintaining other coefficients at original levels was the baseline for testing these biological variables. This new baseline was necessary to illustrate effectively the results of biological variability in a situation where corn is produced as is the case in Northwest Missouri. Even though continuous soybeans have been demonstrated to be optimum, corn production will very likely continue in the area.

Additional stand reduction besides that caused by BCW is entirely possible due to various climatic, soil, pest, or mechanical reasons. Two levels of additional stand loss, ten percent and twenty percent, were considered. These stand losses were converted to yield losses by the formula presented earlier. The yield loss estimate thus obtained could represent such things as soil compaction problems, management level, and damage inflicted by non-fatal insects (such as earworm and rootworm) that reduce yields, as well as actual stand reducing factors. It is impossible to predict all possibilities; thus only two levels of damage are included to point out possible trends.

Table 12 illustrates the effect of these increased stand or yield loss situations. A measurable amount of decrease in IOVC occurs, as would be expected, simply due to having less corn to sell. An interesting development is that as stand loss increases, bottomland categories are taken out of production in favor of upland and less expensive, less efficacious insecticide treatments (Toxaphene) show up in the farm plan. This indicates that because of the small yield advantage given to bottomland soybeans over upland soybeans (4 bu.) and the subsequent income generating ability, high expense corn production enterprises are less preferred to either lower expense corn activities or the more certain yield situations of land not subject to BCW problems or the more efficacious rescue treatments where relatively lower expense and more certain yield levels are combined. This trend says that the higher the cost of corn production the more imperative it becomes

TABLE 12

The Effects of Increased Stand Loss Above that Inflicted by Black Cutworms for an Average Northwest Missouri Farm

	IOVC[1]	Borrowed Capital	Corn Activities Farm Plan[2]	Acres
Baseline model[3]	$55127	$50,077	Corn 11	10.0
			Corn 14	73.5
			Corn 62	26.5
			Corn 63	40.0
10% increased stand loss	$52685	$49,772	Corn 11	10.0
			Corn 14	73.5
			Corn 66	26.5
			Corn 73	40.0
20% increased stand loss	$49974	$49,546	Corn 11	10.0
			Corn 14	73.5
			Corn 66	66.5

[1]Income over variable costs.
[2]The first descriptive number denotes insecticide treatment; 1 = no treatment, 3 = Mocap at planting, 6 = Lorsban 4EC rescue, 7 = Toxaphene rescue. The second number denotes land type and regularity of cutworm infestations; 1 = bottom land, cutworms every four years, 4 = upland, no cutworms, 5 = upland, cutworms every other year, 6 = upland, cutworms every four years.
[3]The baseline model requires 150 acres of corn production and limits pork production to 50 sow units. Soybeans are selected by the model to fill the remaining 150 acres.

that all production factors work properly. An implication is that higher degrees of risk are associated with higher production costs because the manager is more financially vulnerable to any uncontrollable factors such as weather or insects.

Drought, even though mild, is another factor than can adversely affect corn production. This is essentially similar to the variables just discussed with the exception that all crop enterprises are affected, not just the corn enterprises. The difficulty of quantifying yields in response to hypothetical drought conditions is evident.

For purposes of this study, the yield coefficients were revised judgmentally to correspond to two drought situations. The first is a mild to moderate drought condition, the second a moderate to severe condition. Researchers have demonstrated many times that reducing corn populations under drought conditions can contribute to increased yield depending on type of hybrids grown. This phenomenon was allowed for by using less severe yield decreases on the corn activities hit hardest by BCW. The validity of such an approach rests upon whether or not cutworms will more or less randomly work a field or if they concentrate in specific areas. The random theory is assumed here, but is left open to modification by future research.

Table 13 shows the drastic effect on IOVC caused by the drought assumptions. In the drought situation specified here the trend is toward Toxaphene rescue treatments and to a limited degree Mocap granules at planting. This trend is due to the lower expense factors stated above relating to Toxaphene use plus the fact that yield coefficients have not been penalized as severely as some other treatments. It is also of interest to note that the entirely nontreated corn activities don't enter the drought solutions. This suggests that the low efficacy treatments strike a balance between the cost of treatment with resulting moderately thin stands as opposed to the cost of heavy stand thinning associated with no treatment. An interesting implication of this result is that even in a drought year a low cost chemical treatment has economic attraction. The livestock enterprises become more attractive in a drought situation as a means of maintaining some income. The primary point of this drought simulation, however, is that the assumed positive effect of reduced plant populations due to BCW damage does not nearly offset overall income penalties caused by drought. From an agronomic viewpoint, milo would probably become substantially more attractive than corn in a drought situation, even though it does not displace soybeans on the 150 acres left open to model selection.

A common difficulty arising in thin stands of corn is that the lack of ground shading allows weed competition. Here again, quantification of the damage is virtually impossible. An attempt was made to quantify the situation by discretely using the yield coefficients for stand loss discussed earlier. If the original stand loss due to BCW was between 0-10%, the ten percent additional stand loss factor was included. If the original stand loss exceeded ten percent, the twenty percent additional loss factor was included to represent greater weed competition and reduced yields. Yields on bottom and upland with no BCW were obviously not reduced. The results of this run suggested that IOVC was reduced about $1200 due to weeds. Corn treated with the preferred Lorsban rescue treatment was grown on all of the available bottom and upland with BCW problems one year in four. Since weed pressure is the only new variable introduced and 66.5 acres are affected, a per acre charge for weed induced yield loss indirectly due to BCW is about $18.14. This implicit cost added to the already explicit cost of growing corn on land suited for soybeans further detracts from the economic viability of growing corn under cutworm pressure situations.

In previous portions of this section, the desirability of rescue treatments over planting time or preplant treatments has been demonstrated. This situation raises questions concerning late detection of cutworm infestations, poor rescue chemical performance, or delayed ground or aerial application of chemicals. Cutworm damage, in many instances, can double in a twenty-four hour period. To test for some of these possibilities the ten and twenty percent calculations were again used. This situation was projected at two levels; the first level assumes that all rescue treatments are discounted an additional ten percent stand loss

TABLE 13

The Effects of Simulated Drought Conditions on Income over Variable Cost for an Average Northwest Missouri Farm

	IOVC[1]	Corn Activities Farm Plan[2]	Acres
Baseline	$55127	Corn 11	10
		Corn 14	73
		Corn 62	26.5
		Corn 63	40
Moderate Drought	$41508	Corn 34	25
		Corn 35	25
		Corn 76	100
Severe Drought	$28648	Corn 34	25
		Corn 75	25
		Corn 76	100

[1]Income over variable costs.

[2]The first descriptive number denotes insecticide treatment; 1 = no treatment, 3 = Mocap at planting, 6 = Lorsban 4EC rescue, 7 = Toxaphene rescue. The second number denotes land type and regularity of cutworm infestations; 1 = bottom land, no cutworms, 2 = bottom land, cutworms every other year, 3 = bottomland, cutworms every four years, 4 = upland, no cutworms, 5 = upland, cutworms every other year, 6 = upland, cutworms every four years.

[3]The baseline model requires 150 acres of corn production and limits pork production to 50 sow units. Soybeans are selected by the model to fill the remaining 150 acres.

equivalent and the second assumes an additional twenty percent stand loss equivalent. The model's solution at either level was exactly the same; Lorsban at planting time was then the preferred method of control. The lost IOVC due to this propylactic sort of treatment as opposed to the rescue treatment as needed is $55127 - $54727 = $400, or $2.66 per acre of corn grown. For many farm managers this may appear to be a low premium to pay for "insurance" against potential cutworm losses induced by various human, chemical, or mechanical failures inherent in the rescue treatment approach. One inference that may be logically derived from these solutions is that even a completely accurate field scout (no human error) is worth something less than $2.66 per acre when chemical or mechanical delays are accounted for.

Inferences From Sensitivity Analysis

The information gleaned from testing the sensitivity of the model lends a high degree of credibility to the optimum solutions presented previously. Soybeans and hog production are evidently profitable enough enterprises that major cost or price changes relative to the other enterprise activities, or high subjective priorities are necessary to cause the farm manager to turn away from these two.

One conclusion regarding the subject of this paper is that a corn enterprise is not an economic competitor with soybeans or milo if cutworms or climatic conditions will not allow at least 100 bushel per acre yields. The eighty bushel or lower yields representing upland appear to be alternatives when corn is forced into the model because of the lower costs of production used in upland budgets. If the level of management on the farm is not high, or if other adverse conditions arise which effectively create a situation where bottomland type costs are incurred to gain upland type yields, corn production is clearly an economic noncompetitor when compared to soybeans or even milo, both of which are perhaps more limited in terms of absolute maximum *potential*, but are far more stable in an unpredictable environment.

Certain subjective factors could modify this conclusion. Many have been mentioned: for example, owner or manager preferences, pest management, production costs, commodity prices, location and availability of markets, fixed capital equipment and facilities, etc. Commodity prices, particularly, have been widely fluctuating over the past three to seven years and at the same time costs have generally risen. Thus the marketing skills of a manager must be taken into account at the individual farm. The projected average price used here can be deceiving. Managers with above average marketing skill could probably take advantage of including selected corn and livestock activities. Below average marketers would do well to stay with soybeans as much as is agronomically feasible as evidenced by the soybean price range analysis.

Chemical Efficacy Implications

Already some insight about the most economical treatments for BCW has been gained. In order to gain additional insight, five additional runs of the model were made. In all five runs, corn was forced in on 265 acres, initial capital was $10,000, borrowing was allowed, but no livestock activities were included (Plan 9). After a run was made and the preferred treatments specified, these activities were removed and a following run was made. The effect on the objective function and the activities entering each successive run are shown in Table 14. In all runs, corn on bottom and upland with no BCW problems was selected for the obvious reason that there are never cutworm problems and it is not necessary to treat with insecticide. Lorsban as a rescue treatment was selected for the remaining land. For the second run these rescue activities were removed and the next best treatments were selected. Finally the model was given a choice only between no chemicals and suffering the yield loss, or replanting infested acreage to regain some yield. The model indicated that no replanting would be done at a level of fifty percent stand loss or less every other year. This roughly corresponds to the recommendations of others.[15] It is also of interest to note that in the instance

[15]W.B. Showers et al., "Simulated Black Cutworm Damage to Seedling Corn," *Journal of Economic Entomology* 72, (1979), pp.432-436.

TABLE 14

Preferred Insecticide Treatments for Corn Acreage on the Average Northwest Missouri Farm[1]

Run #	IOVC[2]	Preferred Treatment
1	27491	Lorsban 4EC Rescue
2	26399	Lorsban 10g at planting
3	25830	5% Sevin Bait
4	25334	Mocap 10g at planting on bottomland Toxaphene 6E rescue on upland
5	23738	Replant or do nothing are alternatives Replanting was not selected

[1]This preference ranking is based entirely on coefficients used for this study as explained.
[2]Income over variable costs.

where 265 acres of corn are required and no livestock options exist, the savings between the Lorsban rescue treatment and the at planting treatment amounts to $4.12 per acre of corn grown, indicating that the value of a perfectly accurate field scout increases over the previously mentioned case where only 150 acres of corn are required and the financial cushion of a profitable livestock activity is available.

CONCLUSIONS

The six original objectives of this study along with the conclusions are as follows:

Objective 1: Prepare a model that will evaluate currently available management strategy alternatives for corn production, given the information presently available about the habitat and life cycle of the BCW and the effectiveness of control methods available.

Conclusion: The model was prepared using the most reliable data sources. The basic budgets are the keystone of the model and the results can be no better than the budgets. It is believed that they are representative of the area and can be relied upon as a guide in farm management decision making. Sensitivity analysis of optimum solutions generated by the model suggest that the most economically viable cropping activity, soybeans, is not very sensitive to changes in most budget coefficients. Two livestock enterprises, dairying and farrow-to-finish hog production, emerged as valuable assets to the overall farm plan; however, the model results strongly indicated that buying corn for feed was more economically attractive than producing it on the farm if other cropping alternatives were available. In fact, IOVC declined by a minimum of fifteen dollars per acre of corn that was forced into the model in order to feed livestock. A higher cost was incurred if any but the best cutworm-free conditions prevailed. A weakness in the model, for which there is no remedy, is the necessity of projecting chemical efficacy and the resulting yield losses. With one-half of the farm acreage forced to corn, changes in IOVC varied distinctly as yield coefficients were modified. In all cases with 1980 corn-soybean price ratios, corn had to be forced into the farm plan either by requiring a certain number of acres in corn or by holding down soybean acreage. Thus, the effect of insecticide efficacy may be of relatively minor concern in a diversified farm situation.

Objective 2: Evaluate, through the model, the extent of optimality presently occurring on a typical Northwest Missouri farm.

Conclusion: The optimal farm plan generated by the model specified continuous soybeans as the best cropping activity. If for agronomic or other reasons this is not practical, alfalfa, if marketable, and milo were the next most preferred crops. If soybeans cannot be grown continuously, but must be rotated with another crop every other year, then the present cropping system is quite nearly optimal. However, to the extent that soybeans can be continuously cropped or the extent that milo or alfalfa can substitute into the rotation in place of corn, IOVC can be increased above the present level.

Objective 3: Project, with the model, the optimum cutworm control strategy for the typical Northwest Missouri crop farm both with and without livestock enterprises.

Conclusion: The first conclusion is simply that the livestock activities included have little bearing on what the cropping system will be. The range analysis indicates that for a 3:1 milo-corn ration it would require a 31 cents per bushel buy-sell differential for milo and a 19 cents per bushel differential for corn before it would be more profitable to produce the feed on the farm than to buy it, when hogs are included.[16] This leads to the primary conclusion for this objective. From a cutworm management viewpoint, the best strategy is to avoid corn enterprises entirely. Soybeans particularly, and milo secondly, are more attractive from an economic standpoint as well as from the viewpoint of a manager averse to the financial disasters that occur if the corn crop does not yield at least as well as projected in the best estimates of the model. The question naturally arises concerning the effect of cutworms on other crops. Reports of serious cutworm damage to soybeans or milo are rare. There are three reasons why cutworms are significantly less serious on these crops. First is the fact that initial plant stands are two to ten times thicker than corn plantings. Second, a milo or soybean plant has greater ability to compensate for the loss of a neighboring plant than does a corn plant. Third, milo and soybeans can be planted after the peak of the cutworm cycle with little effect on yields.

[16]For the situation in this paper where the farm can sell milo or corn for $2.20 or $2.60 per bushel, respectively, the range analysis indicates that he would be better off buying milo and corn for any amount less than $2.51 and $2.79, respectively.

Objective 4: Examine the effect of having no legal cutworm control chemicals. What will such a situation do to the optimum cropping situation projected previously?

Conclusion: Since corn is not recommended in the optimum solution, the withdrawal of cutworm chemicals would have little impact if the optimum plan were followed. However, if corn continues to be an important crop in the area, as it undoubtedly will, adverse economic impact is probably inevitable if BCW control chemicals are withdrawn from the market. In the case where corn was forced into the model at 265 acres, IOVC was cut by almost fourteen percent when no treatment was available, compared to the case where the best chemical treatment was used. As corn acreage declines from that amount, the adverse effect on IOVC will undoubtedly decline as well. Only if each farmer could select acreage immune from cutworm damage would the financial effect be nil.

Objective 5: Attempt an answer to the question: Is an effective cutworm control chemical essential to maintaining corn production in Northwest Missouri?

Conclusion: Following from Objective 4, the answer seems to be yes. From overall projections with the model this is not the most significant question that should be asked and answered. More appropriately one should ask if corn production can be maintained at all, regardless of the insect situation. The high cost of production, the variability of yields due to weather, and the relatively low return per acre are far more serious problems than the cutworm question. Some producers may be able to attain the higher yields required to make corn a profitable enterprise. Historical average data for the area do not lend optimism to that possibility.

Objective 6: Impute a value for a 100% accurate field scout.

Conclusion: Even while proposing this objective, there was an awareness of the probable futility in pursuing an exact answer. Too many variables enter the picture to support a set figure; however, a possible range can be suggested. Assuming, (a) that the scout is 100% reliable and spots the outbreak at less than two to three percent damage, (b) that the chemical applicator is immediately available and operable, and (c) that the Lorsban rescue treatment is used and works according to projections, the savings incurred after payment of all variable inputs except scouting amount to $2.66-$4.12 per acre. The high estimate is for corn forced into the model at 265 acres, the low estimate for corn forced in at 150 acres. If application is delayed or; if chemical results are poor, only a guess can be projected as the value of a scout. In the non-dairy plans presented, where there is ideal family labor in period 3, it would pay the farmer to scout fields himself or with family help. Since there is extra family labor available, the scout's professional skills or additional services would have to be considered in order for the farmer to hire a scout. Hiring a scout strictly for the cutworm problem is probably not justified. In the instance where no family time is available, the range of $2.66-$4.12 appears to be a maximum compensation assuming 100 percent accuracy.

Summary and Recommendations for Further Research

This farm management study, which used linear programming to determine the optimum management plan to deal with cutworms in corn, indicates that the most economically viable plan is one that excludes corn production entirely in favor of soybeans primarily, or secondly, milo. Even the economically attractive dairy operation did not prefer on-farm produced corn over purchased corn. This suggests that corn production in Northwest Missouri is likely to decrease over the next few years unless cost-return ratios are favorably altered by either monetary or biological factors. Further research by agronomists, entomologists, and economists should be directed toward making the entire cost-return relationship in corn production more favorable. This sort of a broad based interdisciplinary approach appears to demand more urgent attention than approaches directed toward minimizing losses in selected phases of corn production such as the period of vulnerability to BCW early in the plant's development.

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