ENVIRO-ECONOMIC ANALYSIS OF PRESENT AND ALTERNATIVE METHODS OF PEST MANAGEMENT ON SELECTED OKLAHOMA CROPS

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CHAPTER I

INTRODUCTION

The Problem

The problem with pesticides is that without their use insects could cause severe crop damage, and food costs would increase. With the use of pesticides the risk of causing adverse effects to plants, animals, soil and water exists. Thus, we have a paradox developing from agricultural pesticide use.

Modern agriculture is dependent upon the use of pesticides (insecticides, herbicides and fungicides) to control insects and weeds. It is estimated that national farm output would decrease about 27 percent without pesticides [33, p. 6]. Oklahoma farmers use insecticides to control bollworms, bollweevils, thrips, lacewing beetles, budworms and other insects on cotton. Herbicides are used extensively in Oklahoma to control weeds in cotton. Ranchers in the state increase the carrying capacities of their rangeland by chemically controlling brush and weeds with herbicides.

When pesticides are used to increase agricultural output, or the quality of life for man, both beneficial and adverse economic and environmental effects are created. However, while pesticides are designed to kill insects or weeds they may also kill or damage humans, wildlife, crops and trees if they are not used properly. Such effects from pesticide use are labeled as adverse environmental effects.

Whenever one person's actions affect others, beneficially or adversely, an external benefit or cost is created, such is the case with the use of agricultural pesticides. Adverse environmental effects from pesticide use came to the forefront in 1962 when Rachel Carson wrote Silent Spring. Since that time various environmental groups have actively campaigned against all uses of pesticides even though we do not know the extent of pesticide damages or the economic ramifications of restricting pesticides used in agriculture. These environmental groups have been quite effective in lobbying for restrictive pesticide legislation.

Pesticides are important to agricultural production in Oklahoma. For example, carrying capacity on native rangeland can be doubled by chemically controlling brush and weeds. Since the value of cattle and calf production in Oklahoma was $678,000,000 (about 64 percent of total farm receipts) in 1970, the restriction of pesticides could adversely affect farm income in the state. The increased production of beef in Oklahoma also has been responsible for beef prices being at lower levels than they would have been, thus benefiting consumers. Pesticides are also important inputs in cotton production; without these inputs cotton production in the state would decrease. Cotton production (lint and seed) in Oklahoma amounted to $28,000,000 in farm receipts in 1970, or about 12 percent of the value of all farm crops in the state. Since production of cotton and beef on rangeland depend upon pesticides, any restriction of these inputs adversely affects the state in particular and consumers in general.

Legislation Related to Pesticide Use

The first federal law regulating pesticides is the Federal Insecticide Act of 1910 that protected farmers from substandard and fraudulent products. The Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) of 1947 requires pesticides to be registered with the U.S. Department of Agriculture, and is the next regulatory action by the federal government. The Environmental Protection Agency currently has this regulatory power. The newest FIFRA law, passed in 1972, requires pesticides to be classified as to their uses, general or restricted, and allows only certified applicators to use restricted pesticides [17]. This latest act becomes fully effective in 1976. The act provides that farmers have to prove they are competent in handling pesticides before they can use restricted chemicals. However, farmers can continue to spray their own field with pesticides classed for general use. The question now is which chemical will be for general use and which will be restricted?

Pesticides can be removed from the market place by federal decree. The use of DDT on cotton for insect control is no longer permitted because the Environmental Protection Agency cancelled its registration of DDT as of December 31, 1972. Farmers are being allowed to use the DDT they have on hand but no more can be purchased in the United States for cotton treatment. EPA initiated registration cancellation proceedings against Mirex, 2,4,5-T, Aldrin and Dieldrin and EPA is currently reviewing these pesticides prior to ruling on their future use [39, pp. 124-126]. The cancellation of 2,4,5-T could adversely affect the ranchers in Oklahoma who control brush on rangeland with this herbicide.

Legislation designed to regulate pesticide use also originates at state levels. Oklahoma laws require that all commercial applicators of pesticides be licensed. A license is issued after an applicator passes a written test and posts a surety bond guaranteeing that the applicator will appear in court when sued for damages due to pesticide application. Three proposed bills to restrict DDT use in Oklahoma failed to be approved in the Oklahoma Senate in 1970. No bills of this nature are pending in the 1972 session of the legislation and none were proposed during the 1971 session.

Oklahoma annually experiences damage to cotton from 2,4-D and 2,4,5-T (phenoxy herbicides) being used on small grains and rangeland to control weeds and brush, respectively. To reduce the extent of injury to cotton, several counties (Canadian, Coal, Bryon, and Love) are designated as phenoxy herbicide controlled counties by the State Board of Agriculture. A purchaser of phenoxy herbicides in these counties must sign a statement to abide by directions on the label. A more restrictive law (Pesticide Applicator Law) to protect cotton specifies that no phenoxy herbicides may be used between dates set in the spring and fall; however, this does not apply to individual farmers. As of November, 1972, parts of Coal, Canadian, Bryan, Alfalfa, Harmon, Pittsburg, and Love Counties are covered under the Pesticide Applicator Law.

Objectives

The general objective of the thesis was to determine the level of pesticide use and extent of environmental damage and benefits under alternative strategies for controlling cotton and rangeland pests. Specific objectives were to:

1. Determine the relationship between present pesticide use and environmental quality in Oklahoma.
2. Analyze present and alternative methods of controlling pests on cotton and pastureland with respect to economics and quality of the environment.
3. Examine various incentives that are available to encourage adoption of alternative pest control measures.

The objectives of the thesis were accomplished by surveying selected counties in Oklahoma to determine the extent of chemical pest control on cotton and rangeland. Pesticide residue data for Oklahoma were compared to past and present pesticide use. The effect of pesticides on man and the environmental quality were also of major importance in this enviro-economic analysis of pesticide use on selected crops in Oklahoma.

Cotton and grass production on rangeland were the crops selected for this study because these two enterprises are large users of pesticides and the primary pesticides used on these crops (toxaphene, DDT and 2,4,5-T) were under review by EPA prior to restriction. Using 1964 and 1966 data, cotton in Oklahoma and Texas received about 70 percent of the insecticides used in the two states and about 19 percent of the herbicides [10; 14, pp. 34 and 47]. Ranchers use about 40 percent of all the herbicides used in the two states on rangeland [14, p. 34].

Area Selected for Study

The six largest cotton growing counties in Oklahoma were selected in the first round of study area selection. The second step in the selection process involved selecting from these six counties, four counties that spray or dust the largest acreage of crops. The 1969 Census of Agriculture reports the acres of crops other than hay sprayed for insects and this was used to determine the counties using the most pesticide [38]. The final counties selected in this process were: Jackson, Harmon, Tillman and Washita (Figure 1).

Of the cotton survey counties Washita County had the largest acreage of cotton planted in 1971, followed by Tillman County with 42,500 acres, and Jackson with 37,600 acres (Table 1). In 1972 the cotton survey counties accounted for 44 percent of the total cotton harvested in Oklahoma. Figures on irrigated and dryland cotton for the survey counties in 1971 indicated that the following acreages were irrigated: 40 percent in Jackson County; about 30 percent in Harmon County; and about eight percent in Washita and Tillman Counties [35, p. 11-13].

Rangeland and pasture survey counties were selected on the basis of extent of previous and current brush and weed control work. The Extension Agronomist at Oklahoma State University suggested that we survey counties representing each of the different brush species in Oklahoma. Washita County was originally selected because of the mesquite control work there; this county was later dropped due to the small amount of chemical brush and weed control in the county. Woodward County was selected because ranchers there control schinnery oak, sand sage and weeds on rangeland (Figure 1). Pittsburg County was selected because it is representative of counties controlling blackjack oak in Oklahoma and because this county was one of the first in Oklahoma to chemically control brush on rangeland. Osage County also was selected because it is one of the largest ranching counties in Oklahoma and the Census of Agriculture reported that ranchers there

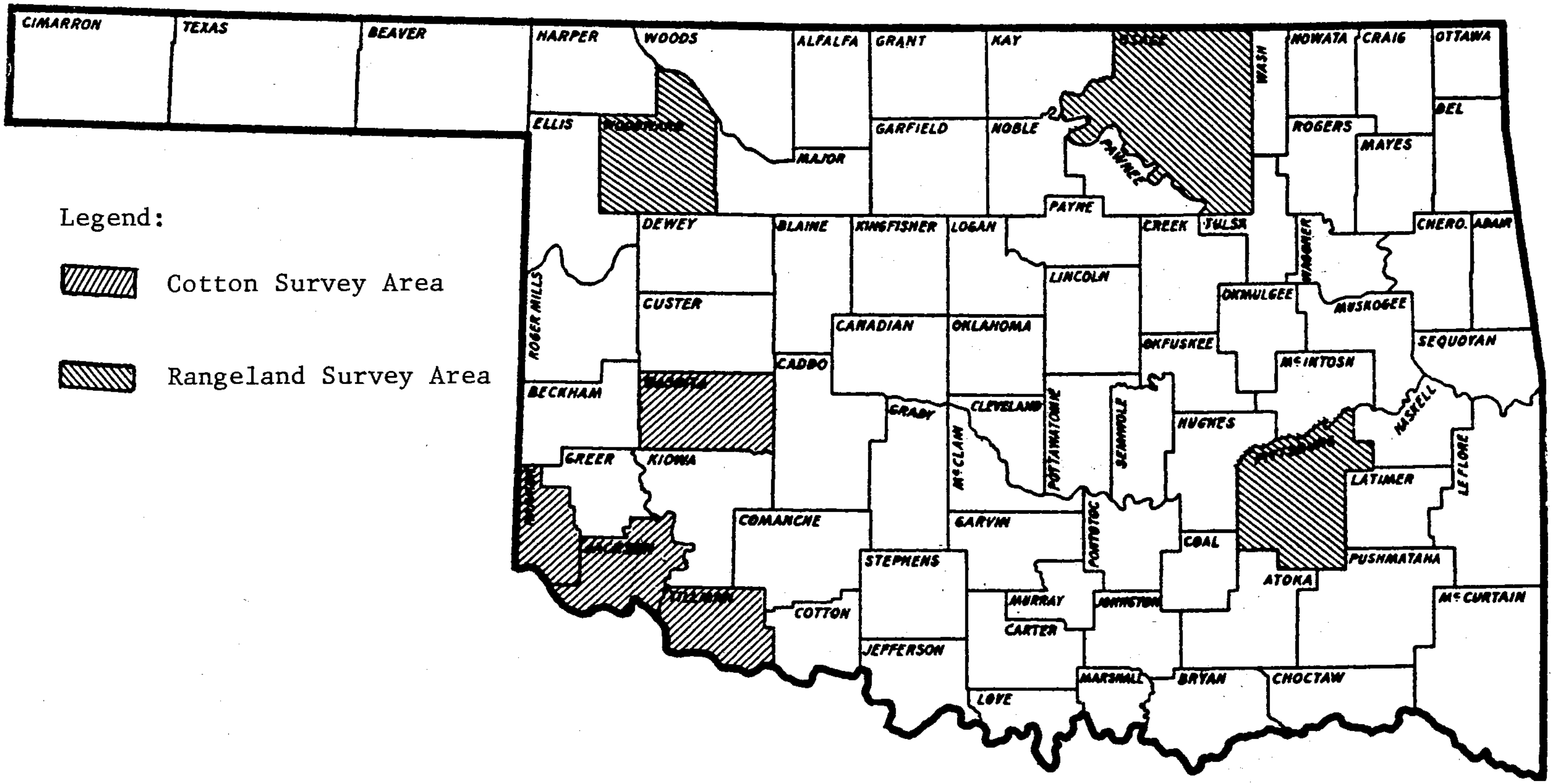

Figure 1. Oklahoma Counties Selected for Survey of Pesticide Use on Cotton and Rangeland

TABLE I

ACRES OF COTTON PLANTED AND HARVESTED IN SELECTED COUNTIES OF OKLAHOMA, 1961-1972

Year	Jackson Planted	Jackson Harvested	Harmon Planted	Harmon Harvested	Tillman Planted	Tillman Harvested	Washita Planted	Washita Harvested
1961	61,800	59,000	42,300	40,700	77,100	72,300	76,500	71,200
1966	51,800	48,600	37,000	35,000	48,000	41,800	49,600	42,300
1969	43,900	40,320	30,720	29,200	61,300	58,440	58,800	57,060
1970	45,400	37,550	32,100	25,750	63,500	57,370	62,700	61,900
1971	37,600	32,500	26,500	24,500	42,500	37,800	62,600	58,000
1972[1]	51,900	51,900	30,700	30,700	64,800	62,900	78,300	78,000

[1]Preliminaty data from the Oklahoma Crop and Livestock Reporting Service.

Source: Oklahoma Cotton: Acreage, Yield, and Production. Oklahoma City: Oklahoma Crop and Livestock Reporting Service, 1961-1971.

treated more rangeland in 1969 than any other county in Oklahoma [38, p. 463].

A helpful source of data in selecting the rangeland survey counties was the summary of the brush control program carried out under the Agricultural Stabilization and Conservation Service. The summary reported the number of acres the ASCS cost-shared with ranchers for chemical brush control. Ranchers in Osage, Woodward and Ellis Counties did more brush control work under the ASCS cost-share program than ranchers in the other counties of Oklahoma in 1967-1971 [41]. No cost share program for chemical brush control was in operation in Pittsburg County during 1967-1971.

Osage County has approximately 1,230,000 acres of pasture and rangeland grazed, Pittsburg County has about 622,500 acres and Woodward County has about 541,400 acres [29, pp. 50-55]. The number of acres of rangeland is a relatively constant value in the survey counties because urban growth is not developing on the pastureland of the area.

Organization of Remainder of Thesis

The remainder of the thesis is organized into five chapters. The methods of analysis as well as a review of literature and other major sources of data are presented in Chapter II. The results of the survey are presented in Chapter III. An appraisal of current environmental quality from present pesticide use is in Chapter IV. An enviro-economic analysis of alternative methods to control pests on selected crops in Oklahoma is presented in Chapter V. The summary and conclusions are presented in Chapter VI.

CHAPTER II

PROCEDURE AND REVIEW OF LITERATURE

The Survey

The purpose of the survey was to obtain time series data on pesticide use for selected crops in Oklahoma. This involved determining the number of acres treated annually and the application rates used each year as well as the number of applications per year. Information on the beneficial and adverse environmental effects of pesticide use was also obtained. Information was obtained by personal interviews with licensed applicators, selected farmers, and technical advisers. This latter group included County Extension Directors, Area Specialized Agents, State Board of Agriculture Fieldmen, Soil Conservation Service personnel and Agricultural Stabilization and Conservation Service personnel. All licensed applicators and technical advisers were interviewed by one enumerator and all farmers were interviewed by another numerator. This was done to insure constant interpretation of the survey within groups.

Selection of Respondents

Pesticide applicators in Oklahoma are required to be licensed by the State Board of Agriculture. The 1971 list of licensed aerial and ground applicators was used to obtain names and addresses of applicators in the area of the survey counties. Since applicators spray crops in several areas each year farmers, county extension personnel and licensed applicators were asked to identify the transient applicators. An effort was then made to survey these transient applicators who have reportedly treated the selected crop during the last ten years in the survey counties.

All the technical advisers in the survey counties were interviewed. In cases where there were no specialized area agents in the survey county, the agents in the adjoining county or area were interviewed. The State Board of Agriculture fieldmen investigate all reported cases of pesticide damage so the fieldmen assigned to the survey counties also were interviewed.

Farmers and ranchers interviewed were selected from a list provided by the technical advisers. The enumerator interviewed those farmers and ranchers who have used pesticides on the selected crops in the past five years. The number of farmers surveyed was dependent upon the extent of pesticide use in the county reported by the 1969 Census of Agriculture [38]. Five to ten percent of the cotton farmers reportedly treating cotton with pesticides in 1969 were interviewed. The number of ranchers surveyed in the rangeland counties was about ten percent of those who chemically treated weeds or brush on pastures in 1969.

Evaluation of Questionnaires Used

Three questionnaires, one for each group interviewed, were developed to obtain data on the extent of pesticide use and environmental effects of pesticide use (Appendix). The farmer's questionnaire provided a useful estimate of the types and rates of pesticides used over the past three years. Farmers response to questions 18, 19, 20, and 21 of Survey A was of limited use in the analyses because farmers defined pesticides as chemicals that kill insects and did not consider a herbicide as a pesticide. These particular questions (18-21 of Survey A) should have been reworded so that the enumerator used the same definition as the farmer (Appendix).

For future use of the surveys a question should be added to Schedule A, asking farmers how many acres of the selected crop they personally spray each year. Question 22 of Schedule A should be explored further to determine the possible crops farmers would substitute for the cotton if no pesticides were available. Farmers as a whole were generally cooperative. This was probably due to the method of selecting farmers who have cooperated with the extension service in the past.

No problems were encountered in using the licensed applicator's questionnaire. The form proved to be well planned for obtaining data on the extent of pesticide applications and chemical misused. The licensed applicators surveyed did not object to discussion of adverse environmental effects caused by their spraying and their answers usually coincided with the technical advisers reports on environmental damage. To improve this particular questionnaire other questions could be added, e.g., the health of the owner and his employees; the number of years of experience; and the businesses' capital outlays in equipment and expenditure for labor.

In general, no problems were encountered in using the technical adviser's questionnaire form. This group appeared to be well informed and willing to cooperate in the study. However, licensed applicators were generally better informed and gave more accurate information on application rates being used, number of acres treated in the county by year, and the extent of environmental damage. To get good estimates of acreage treated all of the licensed applicators working in the study area should be interviewed. Their estimates of the total acreage should be compared with data reported by technical advisers, and adjusted for acreage treated by farmers. Based on our interview experience, the licensed applicators generally had a more accurate estimate of the extent of farmer application of pesticides than did the technical advisers.

Review of Literature

The literature surrounding the pesticide issue fell into four broad categories: (1) described only adverse environmental effects; (2) discussed theoretical effects of pesticide restriction and methods of analysis; (3) reported the economic effects of restricting pesticides; and (4) proposed alternatives to agricultural pesticides. Rachel Carson's book, Silent Spring, was an example of the first category. Silent Spring alerted the public to the possible dangers involved in chemical control of pests by pointing out reported wildlife kills. Like other books that have been written in this category, the author failed to recognize the economic trade-offs of not using pesticides.

Since pesticide use may result in externalities, the economic theory surrounding the analysis of its use is based on treatment of social costs and benefits. The limitations of enviro-economic analysis of pesticide use and inavailability of data were discussed by Headley and Lewis [21] in the Pesticide Problem. Edwards [13], in his analysis of economic externalities of pesticide use, concluded that the state of the art did not allow estimation of the optimal quantity of pesticides on specific crops.

A new tool for environmental research, the environmental matrix, was used in this thesis because it allows for analysis of qualitative data as well as quantitative data. References for this method of analysis stem from Brubaker's [4, p. 189] work with environmental quality. An environmental matrix currently is required on all construction projects funded by the federal government that may possibly damage the environment.

The U. S. Department of Agriculture has published several reports discussing the economic effects of restricting individual pesticides [10; 18]. These reports were useful in making estimates of aggregate impact of pesticide restrictions and the extent of pesticide use on selected crops in Oklahoma.

Suggested alternatives to pesticide use have been in the literature since researchers discovered that insects can build up a resistance to insecticides. A very complete appraisal of the biological, genetic and non-pesticide means of insect control was done by the Council on Environmental Quality. One publication in particular defines the present state of the arts surrounding integrated insect control and assisted in selecting the alternative methods of pest control analyzed in Chapter V [40].

Other Sources of Data

Results from a survey by the State Department of Health provided much needed data concerning the incidence of pesticide poisoning in Oklahoma and the number of deaths due to pesticides. The Poison Control

Center operated by the State Department of Health provided information on the number of emergency calls received each year and the number of these calls due to agricultural pesticides.

Sources of pesticide residue data were the U. S. Geological Survey, Oklahoma Department of Pollution Control and the Environmental Protection Agency (EPA). The Geological Survey tested water for pesticide residues in four rivers in Oklahoma over the past five years. Some of the sites the Geological Survey sampled were reported monthly and others were reported annually. Oklahoma's Department of Pollution Control samples 26 sites in Oklahoma for pesticide residues. The samples are taken three times each year and are analyzed for the presence of chlorinated hydrocarbons. The Environmental Protection Agency's National Soils Monitoring Program tested soils in Oklahoma for pesticide residues beginning in 1969. The soil samples were selected at random from cropland and non-cropland sites across the state, and provided an estimate of the extent of pesticide residues in the soil.

Methods of Analysis

Partial budgeting, matrix presentation and demand analysis were used in the enviro-economic analysis of alternative pest control practices and were also used to analyze the present level of pesticide use on selected crops in Oklahoma. The farm budget is a financial plan for the operation of the farm for some period of time [5, p. 92]. The purpose of such budgets in this thesis was to compare the profitability of different organizational plans. Partial budgets for the selected crops were developed to show the difference in net returns between farmers using pesticides to control pests and those not using pesticides.

Partial budgets were also developed to estimate the net return to farmers using one of the alternative pest control methods analyzed in Chapter V.

An environmental impact matrix was developed for analyzing alternative pest control strategies because it allowed for analysis of quantitative and qualitative data (Figure 2). A matrix that considered the economic, environmental and social factors surrounding pesticide use was developed for this study so the net overall impact of the alternative pest control strategy could be determined relative to other strategies.

The parameters in the matrix (Figure 2) were selected from environmental impact matrices used for resource development projects and the system of accounts suggested by the Water Resources Council [45, p. 24173]. The parameters in the matrix were worded as "change in," meaning a change in the parameter from the condition existing under the present system of control. For example, the parameter for the quantity of output was worded as "change in quantity of output." Thus, it compared the output from each alternative to the output from the present system of control (Figure 2).

The major areas of the matrix (economics, environmental quality and social well-being) were weighted equally (10.00 points each) because the Water Resources Council Guidelines required that these areas be given equal weight in making decisions surrounding resource use [45]. The weights for individual parameters were based on values arrived at by a panel of researchers (agricultural economists, agronomists, entomologists and zoologists) at Oklahoma State University. Parameters weights were assigned according to the importance of the parameter in

Parameters	Parameter Weights	Alternative Methods to Control Pests	
		Raw Score	Weighted Score
Impact on Economic Factors	10.00		
A. Change in quantity of output	1.00		
B. Change in quality of output	0.50		
C. Change in cost of goods for consumers	2.50		
D. Change in farm income	2.50		
E. Change in employment in the region	0.50		
F. Change in the number of farms	1.00		
G. Change in number of acres	2.00		
Sum of Economic Impact			
Impact on Environmental Factors	10.00		
A. Effect on rare and endangered species	2.00		
B. Plant and animal habitat (aquatic and terrestial)	3.00		
1. Change in number of acres available for wildlife	1.00		
2. Change in soil erosion	1.00		
3. Change in food and cover	1.00		
C. Diversity and stability	2.50		
1. Change in aquatic environment	1.25		
2. Change in vegetation toward or away from climax vegetation	1.25		
D. Direct effect on fish and wildlife	2.50		
1. Change in the type of fish and wildlife in ecosystem	0.75		
2. Change in acute effects on fish and wildlife	1.00		
3. Change in chronic effects on fish and wildlife	0.50		
4. Change in parasites on animals	0.25		
Sum of Environmental Impact			
Impact on Social Well-Being	10.00		
A. Recreational opportunities	3.00		
1. Changes in water based recreation	1.50		
2. Changes in land based recreation	1.50		
B. Anxiety factors	3.50		
1. Change in anxiety due to pesticide residues in food	0.70		
2. Change in air pollution	0.70		
3. Change in drift damage	0.70		
4. Change in stream water quality	0.70		
5. Change in number of pests in the environment	0.70		
C. Other human life considerations	3.50		
1. Change in aesthetics	0.75		
2. Change in number of poisonings (not fatal)	1.25		
3. Change in number of deaths from pesticides	1.50		
Sum of Social Well-Being Impact			
Overall Impact			

Figure 2. Environmental Impact Matrix

the policy decision making framework (Figure 2). The parameter weights thus represented the value society as a whole might place on the parameter and not the value one segment of society would give the parameter.

To assign numerical raw scores to the alternatives, for each parameter, a scale from -5.00 to +5.00 was used. The value of the parameter existing under the present system was given a neutral value of zero. Alternatives that improved upon the existing situation from the present method of control received a positive value while those that produced effects worse than the present situation were given a negative value. Where quantitative values for each alternative's result were available, extreme values were assigned raw scores on the scale and lesser values were interpolated with respect to the extremes and the present system's zero value.[1] Thus raw scores between alternatives maintained the proportion the quantitative data initially had. Zero was assigned as an alternative's raw score if no change from the present situation in the parameter was expected.

Qualitative changes in parameters were ranked with respect to the present method of control along the scale and assigned values according to the magnitude of the change from the present method of control. If the effects on a particular parameter of using alternative B were twice as beneficial (or detrimental) as the effects from alternative A, then

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[1]For example, assume the present system has profits of $10.00 per acre and alternatives A and B have profits of $40.00 and $4.00 per acre, respectively. The raw score for the present system is zero by definition and the raw score for alternative A should be +5.00 because of the large increase in profit. The score for alternative B was estimated at -1.00 by adjusting between the present system's score and the score for alternative A.

the raw score of B was twice that of A. The raw score of B was then based upon its relative relationship to the effects of the present method of control, which was discussed in Chapters III and IV of this thesis.

Multiplying the raw scores by their respective parameter weights gave each alternative a weighted score for each parameter. The sum of the weighted scores for each alternative within each major area (economics, environmental quality and social well-being) indicated the effect of the alternative on the major area. The total of all weighted scores for an alternative indicated its net overall impact on society. If the net overall impact was positive, the alternative was more desirable than the current system of pest control. Conversely, if the net overall impact was negative, the alternative was less desirable than the present method of control. Since each alternative had a net overall value of its impact on society, the alternatives could be ranked from highest to lowest or best to worst.

The alternative methods of pest control for the selected crops analyzed in this thesis were those considered to be feasible in Oklahoma at this time or in the near future. Alternative methods to control sand sage and schinnery oak analyzed in Chapter V were: (1) reduced application rates; (2) deep plow rangeland and establish love grass; (3) not control brush and reduce cattle numbers; and, (4) dormant season mowing. Selected alternative methods to control post and blackjack oak were: (1) clear brush mechanically and establish bermuda grass; (2) establish fescue to supplement bermuda grass; (3) use no control and reduce cattle numbers. Alternatives to control insects on cotton analyzed were: (1) use non-persistent insecticides; (2) utilize a scouting program to monitor insect levels and recommend control as insects reach an economic threshold; (3) plant strips of grain sorghum among rows of cotton; and, (4) use no insect controls.

The method used to estimate the edonomic benefits to society from pesticide use on selected crops was to measure the consumers' surplus. Consumers' surplus is an estimate of the change in consumers' food costs as a function of changes in farm production, and has been used in other studies of externalities surrounding pesticide use [13].

The consumers' surplus method of estimating consumers' economic benefits (welfare) has been criticized because it utilizes average prices and is usually estimated from elasticities of demand which are based on very restrictive assumptions [21]. The restrictive assumptions usually are: constant income, constant number of consumers, no change in tastes and preferences and constant elasticities of demand for the study period. The criticism of this methodology and the limiting assumptions surrounding its use are recognized. However, for lack of a better economic tool, it was used in this thesis to estimate consumers' economic benefits from increase in farm output.

An increase in farm output creates a positive consumers' surplus or a net savings for consumers if the elasticity of demand is less than unity. Since elasticity of demand for cotton and beef is less than unity (-0.80 for cotton and -0.74 for beef) an increase in output due to pesticide use creates net consumer savings [3, p. 9; 32, p. 216-221]. Consumers' surplus or net consumer savings from a change in farm output is estimated by equations 2.1 - 2.4 as follows:

$$Y = P_2 (X_2 - X_1) - P_1 (X_2) \tag{2.1}$$

$$P_2 = (P_1)(\% \Delta P_1) + P_1 \tag{2.2}$$

$$\% \Delta P_1 = \frac{\Sigma d}{\% \Delta X_2} \tag{2.3}$$

$$\% \Delta X_2 = \frac{X_1}{X_2} \tag{2.4}$$

where:

Y is the change in consumers' surplus,

P_1 is average price for period,

P_2 is price that would have prevailed without a change in output,

X_1 is the change in output,

X_2 is the total output for the period,

Σ_d is elasticity of demand.

CHAPTER III

COSTS AND RETURNS OF CURRENT PEST CONTROL METHODS

Cotton farmers in Oklahoma controlled insects and weeds with cultural practices as well as insecticides and herbicides such as Toxaphene, methyl-parathion, Treflan, Planavin and summer fallow. Ranchers have managed brush and weeds on rangeland with mowers, bulldozers, and chemicals such as 2,4-D, 2,4,5-T, and Silvex. Following is a discussion of the results of a survey to determine the extent of pesticide use under the present systems of pest control. Also presented were economic analyses of present pesticide uses on cotton and rangeland in Oklahoma.

Current Situation in Rangeland Management

Application Rates Recommended and Used on Rangeland

The recommended practice by the U. S. Department of Agriculture (USDA) to control post and blackjack oak in Oklahoma is to use two or more aerial applications of 2,4,5-T at two pounds per acre initially and one and one half to two pounds of 2,4,5-T per acre the next year or two, and repeat this every eight to ten years. Silvex has been used in place of 2,4,5-T at two pounds per acre with similar results. The recommended practice by USDA to control schinnery oak is to spray one half pound of 2,4-D per acre for two or three consecutive years [43, pp. 27-29].

The Oklahoma State University Agronomy Department recommended that ranchers use two pounds of 2,4,5-T per acre for blackjack oak control and one-half pound of 2,4-D per acre for schinnery oak control. The recommended application for controlling weeds in pasture is three-fourths pound to one and one-half pounds of 2,4-D per acre [19].

The application rates farmers and licensed applicators reported using to control oak brush in the survey counties has been relatively stable over the past ten years (Table II). In Osage and Pittsburg Counties two pounds of 2,4,5-T per acre has been the application rate used since 1961 for controlling post and blackjack oak on rangeland. In Woodward County the application rate of 2,4,5-T for schinnery oak control decreased from two pounds to one and one-half pounds per acre between 1961 and 1972 (Table II).

The application rates reportedly being used by farmers and licensed applicators to control weeds in the survey counties has been constant at one pound of 2,4-D per acre in all survey counties except Woodward County. Woodward County farmers and licensed applicators reported using 2,4-D at 0.6 pounds to 1.1 pound per acre between 1961 and 1972 (Table II). The application rates of 2,4-D used on schinnery oak in Woodward County have been constant at one pound per acre since 1966.

Extent of Herbicide Use to Control Weeds and Brush on Rangeland

The number of acres of rangeland treated each year is dependent upon the weather. A dry spring with higher velocity winds than normal

TABLE II

MOST FREQUENTLY USED APPLICATION RATES OF PHENOXY HERBICIDES FOR BRUSH AND WEED CONTROL ON RANGELAND AS REPORTED BY OKLAHOMA FARMERS AND LICENSED APPLICATORS FOR SELECTED YEARS, 1961 TO 1972

(Survey Data)

	Osage		Pittsburg		Woodward		
Year	2,4,5-T Blackjack and Post Oak	2,4-D Weed	2,4,5-T Blackjack and Post Oak	2,4-D Weed	2,4,5-T Schinnery Oak	2,4-D Sand Sage	2,4-D Weed
			- lbs. per acre -				
1961	2.0	--	2.0	1.0	2.0	--	--
1966	2.0	1.0	2.0	1.0	2.0	1.0	0.6
1970	2.0	1.0	2.0	1.0	1.1	1.0	1.1
1971	2.0	1.0	2.0	1.0	1.2	1.0	0.6
1972	2.0	1.0	2.0	1.0	1.5	1.0	0.5

does not provide good spraying conditions so the number of acres treated is reduced in these years [12, pp. 36-41]. The number of acres treated by year in the survey counties was obtained from interviewing licensed applicators in the area, farmers, and local technical advisers. In 1972 Osage County ranchers treated an estimated 54,000 acres of rangeland for brush and 52,000 acres for weeds (Table III). Ranchers in Pittsburg County treated an estimated 26,000 acres of brush and 50,000 acres of weeds on rangeland in 1972. Woodward County ranchers treated an estimated 36,000 acres of brush and 8,000 acres of weeds on rangeland in 1972.

One-half of the ranchers surveyed in Osage and Pittsburg Counties owned spray equipment for weed and brush control. In Woodward County only one-third of the ranchers reported owning or leasing a spray rig. The ranchers using their own spray rigs reported doing part or all of their own weed control and some reported controlling young regrowth. Ranchers in the survey counties sprayed about 50 percent of the total acres sprayed for weed control in 1971 and in 1972. Brush control was done almost entirely by licensed applicators in Osage County. In Pittsburg County 40 to 50 percent of the brush was controlled by farmers using their own equipment. In Woodward County, ranchers treated about 25 percent of the brush controlled in 1971 and 1972.

In these counties the trend has been towards an increase in the total acres of rangeland treated each year for brush and weeds. With the development of an inexpensive ($695) power-takeoff ground sprayer (the fogger) the number of acres treated in these counties likely will increase over the next few years. One possible problem in the past from using "the fogger" was that the chemical came out as a fine mist that drifted extensively and the resulting damage was to non-target vegetation, such as gardens. This is further discussed in Chapter IV of this thesis.

The total quantity of pesticide used each year in the survey counties was estimated from information obtained by surveying licensed applicators, farmers and local technical advisers. The estimate was made by adding the pounds of technical material applied by licensed applicators to the estimated pounds applied by farmers. The latter was estimated by multiplying the application rates farmers reported by the estimated number of acres they treated. In 1972, 100,000 pounds of 2,4,5-T and 53,900 pounds of 2,4-D were applied to brush and weeds on rangeland in Osage County (Table III). Pittsburg County ranchers used an estimated 47,700 pounds of 2,4,5-T, about 59,500 pounds of 2,4-D in 1972. About 24,200 pounds of 2,4,5-T and 18,700 pounds of 2,4-D were applied in Woodward County in 1972.

In the three survey counties the quantity of 2,4-D and 2,4,5-T used increased in 1972 over 1971 and 1970 (Table III). Favorable spraying weather was the major factor causing this large increase in 1972. The treated acreage in 1972 was also especially large because of the added acreage that should have been treated in 1971 but was not due to unfavorable weather conditions.

Prices of 2,4-D and 2,4,5-T

The price of 2,4-D in Oklahoma has been about the same as the average price in the U.S. over the past eight years (Table IV). The price of 2,4-D fluctuated between \$.90 and \$.98 per pound. The price

TABLE III

ACRES TREATED AND QUANTITY OF HERBICIDES USED IN THE OKLAHOMA SURVEY COUNTIES ON RANGELAND TO CONTROL BRUSH AND WEEDS FOR SELECTED YEARS, 1961 TO 1972

(Survey Data)

	Osage County				Pittsburg County					Woodward County			
	Acres		Chemicals		Acres		Chemicals			Acres		Chemicals	
Year	Brush	Weeds	2,4,5-T	2,4-D	Brush	Weeds	2,4,5-T	2,4-D	Weed Killer	Brush	Weeds	2,4,5-T	2,4-D
			(lbs.)				(lbs.)					(lbs.)	
1961	27,000	---	54,000	---	17,500	---	27,000	18,000	--	9,000	--	14,500	--
1966	42,500	32,000	85,000	34,800	24,000	42,000	42,500	48,000	4,200	17,000	4,000	29,500	3,100
1970	41,000	41,000	79,100	40,600	26,000	49,000	48,600	50,000	3,900	22,000	4,000	12,200	12,000
1971	42,400	41,000	79,800	42,700	20,000	52,000	36,600	54,700	4,200	17,000	6,000	14,500	9,700
1972	54,000	52,000	100,000	53,900	26,000	49,000	47,700	59,500	5,700	36,000	8,000	24,200	18,700

TABLE IV

PRICES PAID BY FARMERS AND RANCHERS FOR PHENOXY HERBICIDES, OKLAHOMA AND UNITED STATES, 1964 TO 1971

Year	2,4,5-T United States	2,4,5-T Oklahoma	2,4-D United States	2,4-D Oklahoma
	$/lb.			
1964	2.36	n/a[1]	0.91	0.91
1965	2.45	n/a	0.90	0.92
1966	2.47	n/a	0.90	0.90
1967	2.46	n/a	0.91	0.91
1968	2.39	2.62	0.97	0.98
1969	2.44	2.62	0.92	0.87
1970	2.34	2.45	0.90	0.91
1971	2.45	2.63	0.96	0.95

[1]Data not available.

Source: U. S. Department of Agriculture, Agricultural Prices - Annual Summary, Statistical Reporting Service, Crop Reporting Board (Washington, D.C., 1964-1972).

of 2,4,5-T in Oklahoma varied between \$2.45 and \$2.63 per pound between 1968 and 1971. The average price per pound in the U.S. was less than that in Oklahoma.

Costs of having licensed applicators control weeds or brush on rangeland typically is a function of the application rate per acre, the degree of applicator competition in the area and the number of acres treated. In 1972 the total cost per acre to control brush (oak), as reported by licensed applicators, was \$6.62 in Osage County, \$7.46 in Pittsburg County and \$5.68 in Woodward County (Table V). In the three counties surveyed the cost per acre to control brush in 1972 was higher than in 1971. This was reportedly due to the non-availability of 2,4,5-T in 1972. The lower costs of brush control in 1970 and 1971 compared to 1972 in Woodward County was also due to the unusually large number of applicators in the area in the earlier years.

In 1972 the total cost per acre to control weeds in pasture as reported by licensed applicators, was \$1.78 in Osage County, \$2.25 in Pittsburg County and \$2.88 in Woodward County (Table V). The cost per acre for weed control within each of the survey counties has been relatively constant over the selected years. Prices applicators charged in different counties were not compared because of the differences in the application rates applied per acre.

Current Situation with Pest Management in Cotton

Application Rates Recommended and Used on Cotton

Treflan and Planavin were the most widely used herbicides for the control of weeds in cotton in the survey counties. The Agronomy Department at Oklahoma State University recommends that Treflan be applied

TABLE V

COSTS PER ACRE FOR BRUSH AND WEED CONTROL FOR SELECTED COUNTIES IN OKLAHOMA AS REPORTED BY LICENSED APPLICATORS FOR SELECTED YEARS, 1961 TO 1972

(Survey Data)

Year	Osage (Blackjack Oak)	Pittsburg (Blackjack Oak)	Woodward (Schinnery Oak)	Osage (Weed)	Pittsburg (Weed)	Woodward (Weed)	Woodward (Sand Sage)
				- ($/acre)-			
1961	6.68	6.50	6.50	n/a[1]	2.25	n/a[1]	n/a[1]
1966	5.57	6.24	6.50	1.90	2.25	2.86	2.25
1970	5.66	6.39	3.07	1.90	2.17	2.90	2.38
1971	5.66	6.48	4.86	1.89	2.19	2.90	2.42
1972	6.62	7.46	5.68	1.78	2.25	2.88	2.34

[1]Data was not available.

at one-half to one pound per acre and that Planavin be applied at rates from one-half to one pound per acre [20].

Several insecticides have been recommended for cotton but the most widely used insecticide mix to control the bollworm complex in the survey counties is toxaphene and methyl-parathion. The Oklahoma State University Entomology Department recommends using toxaphene at one to two pounds per acre and methyl-parathion at one-quarter pound to one-half pound per acre for controlling the bollworm complex [16, pp. 67-70].

The licensed applicators surveyed reportedly used Treflan at one-half to three-quarters of a pound per acre to control weeds in cotton (Table VI). Farmers reported using Treflan at rates of one-half to one pound per acre. In 1961 licensed applicators reportedly used some propozene and carmex at one and one-quarter pints per acre. These herbicides have since decreased in use to almost zero.

In 1971 licensed applicators in Harmon and Tillman Counties reportedly used from two-thirds pound to two pounds of toxaphene, and one-third to one pound of methyl-parathion plus one pound of DDT per acre to control cotton insects (Table VI). Harmon and Tillman Counties reportedly used DDT even though it was not recommended for use in 1971 by entomologists at Oklahoma State University (Table VI). The primary insecticides used in 1961 were toxaphene, DDT and methyl-parathion. The quantity of technical material applied per acre in 1971 was less than that applied in 1961 (Table VI).

Some farmers in Tillman and Washita defoliated cotton with arsenic acid to allow earlier stripping. The application rates in use for arsenic acid in Tillman County declined from three and one-half pints

TABLE VI

APPLICATION RATES USED BY LICENSED APPLICATORS FOR INSECT AND WEED CONTROL ON COTTON, IN FOUR OKLAHOMA COUNTIES FOR SELECTED YEARS, 1961 TO 1971

(Survey Data)

	Harmon County			Jackson County		Tillman County				Washita County		
	Insects		Weeds	Insects	Weeds	Insects		Defoliant	Weeds	Insects	Defoliation	Weeds
Year	Early[1]	Late[2]				Early[1]	Late[2]			Late[2]		
1961	0.20 lb. Bidrin (2)[3]	1 lb. toxaphene 0.50 lb. DDT (9-10)[3]	n/a[4]	2 lb. toxaphene 1 lb. DDT 0.50 lb. parathion (6-10)	n/a[4]	0.50 lb. dieldrin (2)	3 lb. toxaphene 1.5 lb. DDT 0.75 lb. parathion (5-9)	1.75 qt. arsenic acid (1)	1.25 lb. propozene or 1.25 lb. carmex (1)	n/a[4]	n/a[4]	n/a[4]
1966	0.22 lb. Bidrin (2)[3]	2.1 lb. toxaphene 1.0 lb. DDT 0.5 lb. parathion (7-9)	n/a[4]	2 lb. toxaphene 1 lb. DDT 0.50 lb. parathion (5-8)	0.75 lb. Treflan/ acre (1)	0.17 lb. dialox (2)	3 lb. toxaphene 1.5 lb. DDT 0.75 lb. parathion (5-6)	1.50 qt. arsenic acid (1)	0.63 lb. Treflan (1)	n/a[4]	1 qt. arsenic acid (1)	n/a[4]
1970	0.22 lb. Bidrin (2)[3]	2.2 lb. toxaphene 1.1 lb. DDT 0.6 lb. parathion (9-5)	0.63 lb. Treflan (1)	1.50 lb. toxaphene 1 lb. parathion (4-7)	0.75 lb. Treflan/ acre (1)	0.32 lb. dialox (2)	2 lb. toxaphene 1 lb. DDT 0.50 lb. parathion (4-7)	1.67 qt. arsenic acid (1)	0.55 lb. Treflan (1)	1.15 lb. toxaphene 0.64 lb. parathion (5-6)	0.03 gal. Paraquat or 1 gal. sodium chlorate (1)	0.75 lb. Treflan (1)
1971	0.22 lb. Bidrin (2)[3]	2 lb. toxaphene 1 lb. DDT 0.50 lb. parathion (5-6)	0.63 lb. Treflan (1)	1.50 lb. toxaphene 1 lb. parathion (3-6)	0.75 lb. Treflan/ acre (1)	0.50 lb. dialox (2)	2 lb. toxaphene 1 lb. DDT 0.60 lb. parathion (5)	1.50 qt. arsenic acid (1)	0.70 lb. Treflan (1)	0.66 lb. toxaphene 0.33 lb. parathion (4-7)	1.50 gal. chlorate urea 0.20 gal. Paraquat (1)	0.63 lb. Treflan (1)

[1]Early insects controlled are fleahoppers, thrips, and lacewing beetles.

[2]Late insects controlled are bollworms, tobacco budworms, and bollweevils.

[3]Number in parenthesis denote number of applications.

[4]Data was not available.

per acre in 1961 to one and one-half pints per acre in 1971 (Table VI). The primary defoliant in Washita County was Paraquat, which was applied at various rates and sometimes mixed with chlorate urea. The manufacturers recommended application rate for arsenic acid was one and one-half quarts per acre; for sodium chlorate, one and one-half to two gallons per acre; and, for Paraquat, one-fifth of a gallon per acre [48]. The rates reported being used in survey counties were less than or equal to the recommended rates in 1961, 1966, 1970 and 1971 (Table VI).

Extent of Pesticide Use to Control Weeds and Insects on Cotton

The number of acres of cotton treated annually for weeds and insects in the survey counties was determined from the survey of licensed applicators, farmers and local technical advisers. The number of acres of cotton treated with a herbicide in Jackson County in 1971 was 30,000 acres, about 80 percent of the total acres planted (Table VII). The acreage treated in 1971 was about 2,000 acres more than in 1970. An estimated 21,200 pounds of Treflan, 400 pounds of Caporal, 60 pounds of carmex and 400 pounds of other herbicides were used in 1971. Reported herbicide use on cotton in Harmon County in 1971 was about 22,000 acres, about eighty-three percent of planted acreage (Table VII). Herbicide use in Tillman and Washita Counties was not as extensive as in Harmon County. Acres treated in 1971 were 44 and 40 percent of acres planted in Tillman and Washita, respectively.

All of the cotton farmers interviewed in Jackson, Harmon, Tillman and Washita Counties owned or leased a ground sprayer to apply

TABLE VII

QUANTITY OF PESTICIDES APPLIED AND ACRES OF COTTON TREATED FOR INSECT AND WEED CONTROL, IN FOUR COUNTIES IN OKLAHOMA, FOR SELECTED YEARS, 1961 TO 1971

(Survey Data)

Year	Acres of Insect Control	Insecticides Used (Lbs.)					Acres of Weed Control	Herbicides Used (Lbs.)			
		Toxaphene	Methyl-Parathion	DDT	Dialox	Other		Treflan	Caporal	Planavin	Others
					- Jackson County -						
1961	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	50	170
1966	22,000	190,800	99,900	125,300	---	---	21,000	15,600	---	---	---
1970	29,000	177,100	86,600	20,500	500	400	28,000	19,800	400	400	---
1971	15,000	188,900	104,500	900	150	40	30,000	21,200	400	60	400
					- Harmon County -						
1961	---	135,000	27,500	65,000	1,100	---	n/a	n/a	n/a	n/a	n/a
1966	23,800	180,700	50,200	86,400	1,400	100	16,000	10,000	---	---	---
1970	24,600	148,850	45,900	56,000	1,700	40	20,000	14,800	---	---	---
1971	24,000	128,300	40,200	50,400	1,800	---	22,000	16,000	---	---	---
					- Tillman County -						
1961	28,500	194,100	74,500	175,800	---	61,000	4,300	1,200	---	---	3,000
1966	18,700	175,800	47,600	105,600	1,100	400	9,000	12,400	---	---	---
1970	14,700	135,000	35,300	67,200	1,200	---	13,000	8,000	---	---	---
1971	9,000	99,700	25,800	49,000	---	---	18,500	12,800	---	---	---
					- Washita County -						
1961	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
1966	22,000	50,000	70,000	1,000	---	10,000	15,000	---	---	---	---
1970	2,500	13,600	7,000	---	---	---	30,900	24,000	---	---	---
1971	5,000	21,800	10,700	---	---	---	25,000	18,000	---	---	---

herbicides. However, the survey was limited to farmers who do chemically control insects and weeds in cotton so this was not considered necessarily typical of all farmers. The cotton farmers surveyed reported doing most of their own herbicide work. This agreed with the reports from local technical advisers. Licensed applicators surveyed in the study area indicated that they apply only about 25 percent of the total herbicide treatment in these counties. Cotton farmers surveyed in Harmon, Tillman and Washita Counties did about 70 percent of the total weed control on cotton while in Jackson County cotton farmers did about 60 percent. Six farmers in Jackson County were licensed applicators and applied herbicides to a supplement farm income. From the survey it was determined that these farmers treated about 40 percent of the commercially treated cotton in 1971.

Total acres of cotton in Jackson County treated in 1971 was estimated from the survey data at 15,000 acres, a decrease of 14,000 acres from 1970 (Table VII). The acres treated for insects in Harmon County decreased by an estimated 600 acres and in Tillman County the number of acres of cotton treated for insects decreased 5,700 acres from 1970 to 1971. The insect population was dependent upon the vigor of the cotton plants which in turn, depended upon the amount of moisture. Thus in a dry year like 1971 in Jackson and Tillman Counties, farmers had fewer insect problems than they did in a wet year like 1970, and therefore less spraying was done. Even though cotton farmers own spray rigs in the cotton survey counties, almost all the chemical insect control was done by licensed applicators during the survey years. Only two farmers in Washita County of all the farmers surveyed in the four counties, did all of their own chemical insect control.

The total pounds of each chemical used by year in each county was estimated based on the most frequently used application rate reported, the number of acres treated and the number of applications applied. In Jackson County in 1971 it was estimated that 188,900 pounds of toxaphene, 104,500 pounds of methyl-parathion, 900 pounds of DDT, 150 pounds of Dialox and about 10 gallons of Sygon were used for cotton insect control (Table VII).

Farmers used less DDT on cotton in 1971 than in 1966 in all four cotton study counties (Table VII). In Jackson County estimated DDT use on cotton in 1970 was 20,000 pounds less than in 1971, while toxaphene use increased 11,000 pounds and methyl-parathion use increased 18,000 pounds while acres treated decreased by 14,000 acres. In Jackson County the application rates for toxaphene and methyl-parathion were reduced by 50 percent from 1970 to 1971 due primarily from the reduced number of applications in 1971. Harmon County had a 46 percent increase in methyl-parathion and a slight decrease in toxaphene use between 1961 and 1971 while DDT use decreased 22 percent, with a relatively constant number of acres treated each year. The Entomology Department at Oklahoma State University suggested that the reason for the shift from DDT was due to the increased resistance to DDT by harmful cotton insects.

The use of defoliants and dessicants in the cotton survey counties has been limited primarily to Tillman and Washita Counties. Both counties treated about 10,000 acres in 1971 (Table VIII). This was a 3,500 acre increase in Washita County over 1970 and a 600 acre decrease for Tillman County. The use of defoliants depended primarily on the weather. If a wet winter was expected, farmers defoliated their cotton so they could strip cotton as soon as possible. In Washita County the

TABLE VIII

ACRES TREATED AND QUANTITY OF DESICCANTS USED IN TILLMAN AND WASHITA COUNTIES, OKLAHOMA, BY SELECTED YEARS, 1961 TO 1971

(Survey Data)

Year	Acres of Cotton Defoliated or Desiccated	Desiccant Used (Gallons)			
		Arsenic Acid	Chlorate	Paraquat	Other
		- Tillman County -			
1961	14,200	5,100	--	--	50
1966	12,700	4,200	--	--	110
1970	11,200	2,300	--	--	80
1971	10,600	750	--	--	10
		- Washita County -			
1961	n/a	--	--	--	--
1966	7,000	1,750	--	--	--
1970	8,100	255	7,300	135	--
1971	11,600	305	11,605	882	--

trend has been from arsenic acid to Paraquat and sodium chlorate. No such trend was observed in Washita County.

Prices of Insecticides and Herbicides Used on Cotton

The price of DDT, toxaphene and methyl-parathion declined annually from 1968 to 1970; however, in 1971 the price increased (Table IX). Methyl-parathion was \$2.55 per pound in 1968, \$2.10 per pound in 1970 and \$2.35 per pound in 1971 (Table IX).

By contrast the price of Treflan has decreased about \$11 per gallon since it was introduced in the mid-60's. Treflan's suggested retail price was \$21 per gallon in Oklahoma in 1972. The suggested retail price of Planavin has been \$21 per gallon for the past three years in Oklahoma. Prior to that Planavin was a 75 percent wettable powder that was not comparable to the present mixture so a price change over time was not available. Sodium chlorate, a major cotton defoliant, has been \$1 per gallon for the past six years whereas Paraquat, another defoliant, sold for \$27 per gallon in 1966 and \$30 per gallon in 1972.

Farmers' costs of insecticides applied is dependent upon the chemical used, the application rates and the number of applications. The most frequently used insecticide mixture for the bollworm complex in Jackson County is one and one-half pounds of toxaphene and one pound of methyl-parathion. This mixture cost from \$2.50 to \$2.95 per application in 1972 (Table X). The applicators in Jackson County reported treating fields an average of four times in 1972. The cost for bollworm complex (late insects) control in Harmon County in 1971 reportedly cost

TABLE IX

PRICE OF TOXAPHENE, DDT AND METHYL-PARATHION PER POUND IN THE UNITED STATES AND OKLAHOMA, FOR YEARS, 1966 TO 1971

Year	Toxaphene		DDT		Methyl-Parathion	
	U.S.	Okla.	U.S.	Okla.	U.S.	Okla.
				- ($/lb.) -		
1966	--	--	0.33	0.41	--	--
1967	--	--	0.34	0.40	--	--
1968	0.60	0.75	0.37	0.45	2.41	2.55
1969	0.60	0.72	0.38	0.39	2.54	2.50
1970	0.59	0.66	0.40	0.32	2.61	2.10
1971	0.62	0.71	0.38	0.42	2.58	2.35

Source: U. S. Department of Agriculture, Agricultural Prices-Annual Summary, Statistical Reporting Service, Crop Reporting Board (Washington, D.C.), 1966-1971.

TABLE X

COSTS PER ACRE TO CONTROL INSECTS AND WEEDS IN COTTON, REPORTED BY LICENSED APPLICATORS FOR FOUR COUNTIES IN OKLAHOMA, SELECTED YEARS, 1961 TO 1971

	Harmon			Jackson		Tillman				Washita		
Year	Early Insects	Late Insects	Weeds	Insects	Weeds	Early Insects	Late Insects	Defoliants	Weeds	Insects	Defoliants	Weeds
							- $/acre -					
1961	2.85 (2)[1]	2.85- 3.50 (9)	n/a[2]	1.60- 2.85 (8)	n/a[2]	1.85- 2.85 (3)	2.50- 2.85 (6)	3.00- 4.00 (1)	4.40 (1)	n/a	n/a	n/a
1966	2.00- 2.85 (2)[1]	2.50- 3.00 (8)	n/a[2]	1.60- 3.00 (6)	5.25 (1)	1.25- 1.85 (2)	2.75- 2.85 (5)	3.00- 4.00 (1)	6.50 (1)	n/a	n/a	n/a
1970	1.60- 2.85 (2)[1]	2.50- 2.90 (6)	5.25 (1)	2.00- 2.95 (5)	6.00- 7.00 (1)	1.70 (2)	2.55- 2.75 (5)	2.75- 4.50 (1)	5.25 (1)	3.35 (6)	2.75- 4.00 (1)	n/a
1971	1.95- 2.85 (2)[1]	2.85- 2.90 (5)	5.25 (1)	2.50- 2.95 (4)	5.50- 6.75 (1)	1.65- 2.75 (3)	2.55- 2.75 (5)	2.75- 4.50 (1)	5.25 (1)	3.00- 3.35 (5)	2.75- 4.00 (1)	n/a

[1]Numbers in parentheses ( ) indicate the average number of applications.

[2]Data for these years was not available.

$2.85 to $2.90 per acre. The average number of applications was five so the total cost was about $14.50 per acre.

The costs per acre of weed control in cotton reported for the cotton survey counties was between $5.25 and $6.75 per acre in 1971 (Table X). The cost was also quoted as $2.50 per acre and the farmer provided the herbicide. The farmers' costs to have licensed applicators defoliate cotton was between $2.75 and $4.00 per acre in 1972. The cost per acre to control weeds and defoliate cotton appeared to be stable over the survey period.

Economic Factors of Present Pesticide Use

This section discusses the economics of using pesticides to control weeds and brush on rangeland, and weeds and insects on cotton. The economic factors related to chemical pest control are: change in yields, farmer's net income, quality of output, number of acres of cropland farmed and change in prices for consumers.

Economic Factors Surrounding Weed and Brush Control on Rangeland

Change in Yields. The pounds of beef produced per acre increased as a result of chemical weed and brush control on rangeland. In Osage and Pittsburg Counties the technical advisers surveyed reported the added production per acre was about 40 pounds of beef per year after controlling blackjack oak and 10 to 20 pounds of added beef per acre per year after controlling weeds on rangeland. Technical advisers surveyed in Woodward County reported that schinnery oak control increased beef production about 40 pounds per acre, sand sage control increased beef production 20 pounds per acre and weed control on rangeland added ten pounds of beef per acre.

Ranchers in Osage County reported that they had increased pasture carrying capacity as much as three times through brush and weed control. This was particularly true in the early years after chemical control was started. However, as brush began to regrow, carrying capacity steadily decreased to about double the initial level of production. Two-thirds of the ranchers surveyed reported they have increased beef production over double their original yields. The remaining third reported an increase but were not sure of the amount.

Ranchers in Pittsburg County reported that chemical weed control prevented total weed takeover of rangeland and doubled carrying capacity over a ten year period. Ranchers in Woodward County reported that brush and weed control doubled carrying capacity of rangeland over a period of three to five years.

Change in Ranchers' Net Income. Ranchers increased their net incomes per acre by controlling weeds and/or brush on rangeland in the survey counties. A partial budget for rangeland improvement showed that weed control in Woodward County increased net returns per acre about $1.13, brush control increased net returns about $4.40 per acre (Table XI). In Pittsburg and Osage Counties the increase in net returns per acre for weed control was about $1.13 and the net return from controlling weeds and brush was $2.44 per acre. The change in net return per acre was estimated by adjusting budgets developed by the O.S.U. Department of Agricultural Economics for the counties in this study. The budgets were estimated on a per cow basis but were adjusted to a per acre basis for this study. Controlling weeds and brush in Osage

TABLE XI

COMPARISON OF COSTS AND RETURNS FOR DIFFERENT LEVELS OF WEED AND BRUSH CONTROL ON OKLAHOMA RANGELAND

Parameter	Unit of Measure	No Brush or Weed Control	Chemical Control of Weeds	Chemical Control of Brush	Chemical Control of Brush and Weeds
		- Osage and Pittsburg Counties -			
Carrying Capacity	Acres/AUY	17.0	12.5	10.0	9.0
Cost of Inputs[1]	$/Acre	4.21	5.72	7.16	7.95
Cost of Control	$/Acre	0	0.65	1.75	2.00
Value of Beef Prod.	$/Acre	9.21	12.52	15.65	17.39
Returns[2]	$/Acre	5.00	6.13	6.75	7.44
Change in Return Per Acre Over No Control	$/Acre	0	1.13	1.75	2.44
		- Woodward County -			
Carrying Capacity	Acres/Auy	16.0	12.0	9.0	8.0
Cost of Inputs[1]	$/Acre	1.71	2.82	3.42	3.63
Cost of Control	$/Acre	0	1.00	1.50	2.25
Value of Beef Prod.	$/Acre	9.78	13.05	17.39	19.57
Returns[2]	$/Acre	8.07	9.76	12.47	13.69
Change in Return Per Acre Over No Control	$/Acre	0	1.69	4.40	5.62

[1]Inputs include supplementary feed, labor, and veterinarian services.

[2]Returns to land, labor, capital, and management.

and Pittsburg Counties reduced the number of acres necessary for one AUY[1] by about eight acres (Table XI).

Beef production for the budgets was valued at the average 1972 price Oklahoma ranchers received, and the input costs were based on 1971-1972 costs. The average costs reported for weed and brush control in 1972 was used in formulating the budgets. The cost of weed control was amortized over three years because ranchers usually treat the rangeland every three years. Brush control was an annual expense for two years and brush was retreated at eight year intervals. If the total cost is divided equally over the eight years, annual costs would be $1.75 and $1.50 per acre in Pittsburg-Osage Counties and Woodward County, respectively (Table XI).

By controlling both brush and weeds a rancher saved money and increased carrying capacity because of the interaction of the spraying. For example, in a weed and brush control system ranchers treat brush each of the first two years and then wait until the ninth or tenty year when brush is again treated. Weeds are treated every third year. The annual cost per acre for this system is $2.00 in Woodward County and about $2.25 in Osage and Pittsburg Counties.

Change in Quality of Output. Elwell [15, pp. 3-5] reported that there was no change in the chemical composition of grasses treated with phenoxy herbicides. More specifically, there was no change in the percentage of total nitrogen, total carbohydrates or total sugars of native grasses treated with 2,4,5-T or Silvex. However, several ranchers

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[1]AUY is one animal unit year or the amount of forage necessary for one cow year long and her calf up to weaning weight.

surveyed reported that cattle preferred treated grasses to untreated grasses. Elwell stated that this preference was due to the increased density and rapid growth of grasses caused by an increase in sunlight, release of soil nutrients and improved soil moisture in areas where brush was controlled.

Since grass is not the end product, researchers have examined the effects of 2,4-D and 2,4,5-T on the quality of meat produced on treated rangeland. No disflavoring of meat has been caused by phenoxy herbicides. This was largely due to animals' rapid elimination of 2,4-D and 2,4,5-T [45, pp. 46-57].

Change in Cropland. Rangeland is unique in that as brush is controlled the number of acres grazed remains constant. The only change in land use after brush control is initiated is a shift to more intensive use of rangeland. The change in land use most likely reduces soil erosion. Cox and Elwell [8, pp. 411-415] have shown that well managed grassland in Oklahoma has less soil erosion than adjacent areas that are primarily brush. As more and more brush is controlled in Oklahoma we can expect to see little or none of the uncontrolled land abandoned and the total acres grazed will remain relatively constant while production per acre increases.

Change in Prices. The increased yield on rangeland where brush is controlled results in added beef available for consumption. Assuming all other things (demand, income, and tastes and preferences) equal the increase in consumers' surplus or net savings for consumers from the added beef production was estimated. Added beef production in Oklahoma was used rather than that in the study counties to emphasize the benefits derived from brush control in Oklahoma.

The extent of consumer savings was estimated by using the average price received for beef, the price elasticity of demand for beef at retail, the estimated increase in Oklahoma's beef production and the total beef production and imports in the United States. The retail price elasticity of demand for beef used is -0.74 and was assumed constant over the years studied [32, pp. 216-221]. (The other assumptions of consumers' surplus or savings are discussed in Chapter II of this thesis.) The savings for consumers were estimated at $13,508,000 in 1969 and about $15,880,000 in 1971 (Table XII). The increased production of beef in Oklahoma did not decrease the price of beef but kept the price of beef from being higher than it normally would have been.

Economic Factors Surrounding Weed and Insect Control on Cotton

Change in Yield. Cotton yield was affected by the level of insect infestation, which in turn was affected by rainfall. In a wet year cotton grows vigorously and attracts insects which necessitates additional chemical insect treatments. Since increased moisture generally increases yields, farmers can afford the additional costs of chemically controlling insects. Technical advisers surveyed reported that farmers that did not control insects on cotton lost from 50 to 150 pounds of lint per acre, depending upon the amount of rainfall. Weeds in cotton are worse during wet years but the effects on yields are relatively stable from year to year. Technical advisers reported that farmers who did not control weeds lost from 20 to 40 pounds of cotton per acre.

In Jackson County technical advisers reported that farmers lost from 50 to 150 pounds of cotton lint per acre by not controlling

TABLE XII

ESTIMATED SAVINGS IN CONSUMERS' MEAT COSTS DUE TO CONTROLLING BRUSH AND WEEDS ON RANGELAND IN OKLAHOMA BY YEAR, 1961 TO 1971

Year	Added Beef Production In Oklahoma (X_1)	National Beef Production[2] (X_2)	Average National Price Received for All Beef Cattle[3] (P_1)	Average National Price If No Added Production In Oklahoma (P_2)	Reduction In Consumers' Food Bill for Meat[1] (Y)
	(thou. lbs.)	(thou. lbs.)	($/cwt.)	($/cwt.)	($)
1961	71,265	31,342,443	20.20	20.27	6,486,000
1962	81,054	32,444,859	21.30	21.38	7,290,000
1963	93,384	33,861,777	19.90	19.98	7,563,000
1964	103,751	35,921,138	18.00	18.07	5,638,000
1965	111,211	34,944,808	19.90	19.99	8,372,000
1966	97,373	36,224,180	22.20	22.28	6,321,000
1967	123,589	37,260,105	22.30	22.40	8,249,000
1968	128,562	37,885,957	23.40	23.51	9,780,000
1969	132,081	38,781,941	26.20	26.33	13,508,000
1970	138,784	41,265,857	27.10	27.23	13,494,000
1971	140,681	42,379,656	29.00	29.14	15,880,000

[1]Consumers' savings were calculated by: $Y = P_2(X_2 - X_1) - P_1X_2$; $P_2 = (P_1)(\%\Delta P_1) + P_1$; $\%\Delta P_1 = \frac{-0.74}{-\%\Delta X_1}$; $\%\Delta X_1 = \frac{X_1}{X_2}$.

[2]U. S. Department of Agriculture, Agricultural Statistics, Government Printing Office, Washington, D. C., 1960 to 1972.

[3]U. S. Department of Agriculture, Livestock and Meat Statistics, Economic Research Service, Statistical Reporting Service, Agricultural Marketing Service, Statistical Bulletin No. 333, Washington, D.C., 1960-1971.

insects and about 20 pounds per acre if they did not control weeds. In Harmon County technical advisers estimated the loss in yield from not controlling insects was about 140 pounds of cotton lint per acre and about 30 pounds of lint per acre if farmers did not control weeds. In Tillman County technical advisers estimated that farmers lost 100 to 150 pounds of cotton lint on irrigated land and about 80 pounds per acre on dryland cotton if they did not control insects. In Washita County failure to control insects reduced cotton yields about 100 pounds per acre, and failure to control weeds reduced yields about 40 pounds per acre.

The Oklahoma State University Extension Entomology Department annually surveys county extension directors in cotton producing counties to determine the extent of yield losses due to insects. In 1966 the estimated loss in yield on cotton not treated for insects was 88 pounds of lint per acre; in 1971 the estimated loss was 111 pounds per acre (Table XIII). The estimated value of lost cotton production in Oklahoma ranged from an estimated $2,412,400 in 1970 to $8,626,900 in 1971 (Table XIII).

No statewide estimate of the loss of cotton due to no weed control was made because of the lack of statewide estimates for loss in yield per acre on untreated cotton.

<u>Change in Farmers' Net Income</u>. The added returns per acre for controlling insects on cotton were greater for irrigated cotton than for dryland cotton. Without insecticide treatment little or no cotton could be grown on irrigated cropland. Also there have been few major insect problems on dryland cotton; thus, insecticides are seldom used. Cotton farmers surveyed reported they would not plant cotton on

TABLE XIII

LOSS IN COTTON PRODUCTION IN OKLAHOMA DUE TO FAILURE TO CONTROL INSECTS, 1966-1971

Year	Loss In Yield[1]	Estimated Acres Not Treated	Cotton Lost Due To No Control	Average Price Received By Farmers[2]	Value of Cotton Lost
	(lbs/ac.)	(acres)	(thous. lbs.)	($/lb.)	(thous. $)
1966	88	245,500	21,604,000	0.187	3,888,700
1967	88	295,500	26,004,000	0.210	5,460,800
1968	78	286,500	22,347,000	0.210	4,692,900
1969	78	357,400	27,877,000	0.185	5,017,900
1970	41	294,200	12,062,000	0.205	2,412,400
1971	111	268,000	29,748,000	0.290	8,626,900

[1]Source: Arnold, Don. Estimated Losses and Production Costs Attributed to Insects and Related Anthropods. Extension Entomology, Oklahoma State University, Stillwater, Oklahoma, 1966-1971.

[2]College of Agriculture. Current Farm Economics. Oklahoma State University Agricultural Experiment Station and the Department of Agricultural Economics, selected issues, 1966-1972.

irrigated cropland if they were not able to use insecticides. Since soil moisture was the major factor in determining the extent of insect problems on cotton, budgets for the study areas were developed for four levels of water use (Table XIV). The budgets were based on average yields for each level of water use. At the lowest level of water use in Table XIV (light rain and no irrigation) the net return per acre for cotton was $62.30, if no cotton was grown (due to an absence of insecticides). The increased net return per acre from insect control was the difference of $62.30 per acre and the net return per acre of the next best crop. Under high rainfall and sufficient irrigation water (water use level IV) cotton yields were increased as well as insect infestations as shown by the insect control costs. Net returns with this alternative were estimated at $138 to $158 per acre (Table XIV).

Little insect control has been done on dryland cotton. This probably is due to the small increases in net returns per acre received by controlling insects. Dryland cotton budgets estimated for three different rainfall levels were compared to an average yield without insect control. As water availability increases the insects increase. Without insect controls, yields were expected to be relatively constant at 200 pounds of cotton per acre. With high rainfall and insect control yields have reached 350 pounds per acre (Table XIV). The change in net returns per acre for high rainfall levels with insect control was $18.00 per acre greater than no insect control (Table XIV).

Change in Quality of Output. No change in cotton quality was found in cotton grown with no bollweevils, not in that grown with levels of infestation of 25, 50 and 75 percent [51, pp. 138-140]. The

TABLE XIV

COSTS AND RETURNS FROM CONTROLLING INSECTS ON COTTON IN SOUTHWESTERN OKLAHOMA

Parameter	Unit of Measure	No Chemical Control of Insects	Chemical Insect Control At Different Levels of Water Use[1] I	II	III	IV
			- Irrigated Cotton -			
Yield:[2]						
Lint	lbs./acre	0	350	600	700	900
Seed	lbs./acre	0	560	960	1120	1440
Costs:[3]						
Operating	$/acre	0	40.25	69.00	80.50	103.50
Insecticides	$/acre	0	0	6.00-9.00	18.00-21.00	18.00-30.00
Herbicides	$/acre	0	5.25	5.25	5.25	5.25
Value of Prod.	$/acre	0	107.80	184.80	215.60	277.20
Net Returns[5]	$/acre	0	62.30	101.50-104.55	108.80-111.80	138.40-158.40
			Chemical Insect Control At Different Levels of Rainfall[4] I	II	III	
			- Dryland Cotton -			
Yield:[2]						
Lint	lbs./acre	200	250	300	350	
Seed	lbs./acre	320	400	480	560	
Costs:[3]						
Operating	$/acre	19.93	24.91	29.89	34.87	
Insecticides	$/acre	0	3.00	6.00	9.00	
Herbicides	$/acre	5.25	5.25	5.25	5.25	
Value of Prod.	$/acre	61.60	77.00	92.40	107.80	
Net Returns[5]	$/acre	36.40	43.80	51.80	58.68	

[1]Levels of water use: I Light rainfall (14 inches) and no irrigation water,
II Moderate rainfall (18 inches) and light irrigation (9 inches),
III Light rainfall (14 inches) and sufficient irrigation (18 inches), and,
IV High rainfall (30 inches) and sufficient irrigation (18 inches).

[2]Yields at each water consumption level were estimated by researchers in the Entomology Department at Oklahoma State University.

[3]Operating costs average 11.5 cents per pound of lint produced according to budgets by area agents in survey areas.

[4]Levels of rainfall: I Light rainfall (14 inches)
II Moderate rainfall (18-20 inches)
III Heavy rainfall (30 inches)

[5]Net returns to land, labor, capital, and management.

difference in gross revenue between cotton that had insect control and cotton which did not have insect control was due to increased yields per acre. There are some reports that bollweevils tend to discolor cotton but this does not affect prices received by farmers. Pesticide residue on cotton lint has not caused any reported decrease in quality of clothing [46]. However, desiccants on cotton seed prevents it from being used for livestock feed [46]. Desiccants were used on about 22,200 acres in the survey area in 1971, thus affecting about 8.9 million pounds of cotton seed. The effected seed can be used for planting so it is not wasted.

Change in Cropland. The use of insecticides on cotton increases total output or reduces the number of acres needed to produce a given output. Cotton acreage and output in Oklahoma has varied tremendously, 43 percent, over the past eleven years in Oklahoma. To estimate the impact of using pesticides on the number of acres farmed, the increase in the number of acres needed to maintain the 1972 level of output without pesticides was estimated. Oklahoma produced 128,000,000 pounds of cotton on 510,000 harvested acres in 1972. That year was used for analysis purposes because the 1972 farm program is most likely typical of farm programs for the next several years. If no insect controls were used, the yields per acre decreased 100 to 150 pounds per acre for dryland, and to zero for irrigated cotton if farmers grew no cotton on irrigated cropland. To maintain 1972 cotton production in the survey counties, without insecticides, an additional 175,600 acres of cotton would be needed. To maintain Oklahoma's 1972 cotton production an additional 343,000 acres of cotton would be needed.

<u>Change in Prices</u>. A portion of the cotton produced over the past decade in Oklahoma was produced because chemical insect controls were used. This increased output resulted in prices being lower than they would have been without insect controls; thus giving consumers a net savings or resulting in a positive change in consumers' surplus. The price elasticity of demand for cotton at the domestic mill level (-0.80) is less than 1.00 so an increase in quantity supplied results in a decrease in consumers' total expenditure for cotton [3, p. 9]. In Oklahoma the added production due to insect control depends upon the level of insect infestation; thus the net consumers' net savings was estimated for a range of yield losses. The estimated added yield in Oklahoma was the yield saved times the estimated cotton acreage treated for insects in Oklahoma (Table XV).

The estimated added yield in 1972 was 7.2 million pounds to 21.7 million pounds, depending upon which estimate of added yield for insect control used (Table XV). The estimated consumers' net savings from added production ranges from $500,000 to $1,400,000 in 1970 and from $700,000 to $1,300,000 in 1972.

TABLE XV

CONSUMER SAVINGS DUE TO INSECT CONTROL IN OKLAHOMA, BASED ON DIFFERENT YIELD ESTIMATES, 1970-1972

Year	Estimated Number of Acres Treated for Insects in Oklahoma[1]	Additional Cotton Produced By Controlling Insects			Consumers' Savings From Added Output Through Insect Control[1]		
		50 lb./ac.	100 lb./ac.	150 lb./ac.	50 lb./ac.	100 lb./ac.	150 lb./ac.
		(mil. lbs.)			($1,000)		
1970	145,800	7.3	14.6	21.9	0.5	0.9	1.4
1971	128,000	6.4	12.8	19.2	0.4	0.7	1.1
1972	144,900	7.2	14.5	21.7	0.7	0.7	1.3

[1]Estimated from survey data.

[2]Estimated by consumers' surplus equations 2.1 - 2.4 in this thesis.

CHAPTER IV

ADVERSE AND BENEFICIAL ENVIRONMENTAL EFFECTS OF PESTICIDE USE

Pesticides used on selected crops in Oklahoma affect environmental quality by persisting in soil and water, destroying or improving non-target plants, as well as having long and short term effects on fish and wildlife. Pesticides also have affected man at work, at home and at play. The first section of this chapter describes the changes in environmental quality that have occurred and/or may occur by continued use of pesticides. The last part of the chapter discusses the effects of pesticides on social well-being, i.e., public health and food and water supply contamination.

Effects on Environmental Quality from Use of Herbicide on Rangeland

Persistence in Soil and Water

The soil persistence of a herbicide has been defined as the length of time a chemical remains active in the soil. Persistence of a herbicide is a function of volatility, photo-decomposition, absorption, leaching, plant uptake, microbial decomposition and chemical decomposition. Phenoxy herbicides have been shown to be relatively volatile in warm temperatures. Low rates (one to two pounds per acre) of 2,4,5-T and 2,4-D undergo microbial breakdown in warm moist soils [48, pp. 342 and 155]. In Oklahoma 2,4-D persisted for about twenty days in the three soils tested, and 2,4,5-T persisted for about four months [2, p. 31 and p. 41].

Other studies [31;48] have shown that 2,4-D persisted in soil about one month with little or no leaching under summertime conditions and a temperate climate. Several studies [31] have shown that at normal and extreme application rates (one to four pounds per acre) 2,4-D had little or no effect on soil micro-organisms, and no mortality was reported in earthworms immersed for two hours in concentrations of 2,4-D at levels of 100 parts per million (ppm). The chemical 2,4-D is used at a rate of one pound per acre in Oklahoma for weed control on rangeland.

Phenoxy herbicides degraded rapidly in water. Tests indicated that a concentration of 1,000 ppm of 2,4-D in water decreased to 0.01 ppm in thirty days. In a study in Oklahoma, 10 ppm of 2,4-D was found to have persisted in farm ponds for about six weeks after treatment; however, after the fourth day it was not detectable in bluegill fish in the pond [48, pp. 93-100]. Open lagoons were treated with 2,4-D at a rate of 689 ppb to 967 ppb in another test; after thirty-one days only one to two percent of the initial application remained. The persistence of 2,4,5-T in water was similar to that of 2,4-D [48, p. 342].

The Environmental Protection Agency (EPA) has been given the responsibility of testing soil samples for pesticide residues. Of the 172 soil samples taken in Oklahoma in 1969 and 1970 none had 2,4-D or 2,4,5-T residues. The samples were taken from cropland and rangelands selected at random throughout the state for the National Soils Monitoring Program.

Pesticide residue analysis of water in Oklahoma by the Geological Survey has not shown an accumulation of 2,4-D or 2,4,5-T in the state's water supplies over the past five years. The highest level of 2,4-D found by the Geological Survey was 0.85 ppb in Deep Fork near Arcadia. However, no 2,4-D residue was found one month later (Table XVI). The highest level of 2,4,5-T found was 0.16 ppb in the Deep Fork near Arcadia; the next month's reading had a residue of 0.01 ppb (Table XVI). These rivers are not in the survey area, however, brush and weeds are controlled in the vicinity of each river.

Effects on Livestock, Wildlife and Fish

Phenoxy herbicides have produced little or no hazards to wildlife when used as recommended [48, pp. 155 and 343]. Since phenoxy herbicides usually were used on rangeland, the first animals to contact the chemical were cattle and wildlife. To determine the effect of phenoxy herbicides on cattle, tests were conducted by the U. S. Department of Agriculture. After a twenty-eight day feeding period with either 300 ppm Silvex (mixture of 2,4-D and 2,4,5-T) or 300 ppm of 2,4-D in their feed, cattle were slaughtered and the meat, fat, kidney, and liver were tested for pesticide residues. Three hundred ppm was included in feed to simulate the level of herbicide residue cattle were subjected to on treated rangeland. Cattle slaughtered within twenty-four hours of the last feeding had no 2,4-D residues in the muscle and liver, and only 0.13 ppm and 2.62 ppm 2,4-D in the fat and kidney, respectively. Cattle slaughtered seven days after the last herbicide feeding had no

TABLE XVI

RESIDUES OF PHENOXY HERBICIDES FOUND IN THREE OKLAHOMA RIVERS, 1968-1971[1]

Month and Year	2,4-D Canadian Near Whitefield	2,4-D Kiamichi Near Big Cedar	2,4-D Deep Fork Near Arcadia	2,4,5-T Canadian Near Whitefield	2,4,5-T Kiamichi Near Big Cedar	2,4,5-T Deep Fork Near Arcadia
			- (ppb) -			
1968						
Jan.	---	---	---	---	---	---
Feb.	.00	---	---	.03	---	---
Mar.	.00	---	---	.02	---	---
Apr.	.06	---	---	.04	---	---
May	.01	.00	---	.03	.00	---
June	---	---	---	---	---	---
July	.00	---	---	.03	---	---
Aug.	---	---	---	---	---	---
Sept.	.00	.00	---	.03	.00	---
Oct.	---	---	---	.05	---	---
Nov.	.15	---	---	.05	.00	---
Dec.	.00	---	---	.00	---	---
1969						
Jan.	.15	---	---	.09	---	---
Feb.	.00	---	---	.04	---	---
Mar.	.00	---	---	.04	---	---
Apr.	.00	---	---	.05	---	---
May	.00	---	---	.04	---	---
June	---	---	---	.04	.00	---
July	.00	---	---	.03	---	---
Aug.	---	---	---	.03	---	---
Sept.	---	---	---	---	---	---
Oct.	.00	.00	---	.02	---	---
Nov.	.00	---	.00	.03	.00	---
Dec.	.00	---	.85	.00	---	.02
1970						
Jan.	---	---	.10	---	---	.01
Feb.	.00	---	.00	.04	---	.02
Mar.	.00	.00	.00	.02	---	.05
Apr.	.00	---	.16	.03	---	.03
May	.00	---	.17	.07	---	.05
June	---	---	.29	.03	---	.04
July	.00	---	.00	.03	---	.11
Aug.	---	---	.00	.03	---	.04
Sept.	.00	---	.00	.01	---	.02
Oct.	---	---	---	---	---	.03
Nov.	.00	---	.00	.00	---	.03
Dec.	.00	---	.00	.02	.00	.04
1971						
Jan.	.00	---	.07	.03	---	.04
Feb.	.00	---	.00	.02	---	.03
Mar.	.00	.00	.01	.00	---	.03
Apr.	.00	---	.00	.01	---	.06
May	.00	---	.00	.01	---	.00
June	---	---	.00	---	---	.01
July	.00	---	.00	.00	---	.15
Aug.	.00	---	.00	.00	---	.16
Sept.	.00	---	.05	.02	---	.01
Oct.	---	---	.07	---	---	.01
Nov.	---	---	.00	---	---	.03
Dec.	---	---	---	---	---	.01

[1]Samples were not taken where --- are shown.

Source: Unpublished data from U. S. Department of Interior, Geological Survey.

detectable 2,4-D or Silvex in the muscle, fat, liver or kidney [42, pp. 6-7]. For the past decade cattle have been put on feed for more than three months after leaving pastures, so any 2,4-D or 2,4,5-T that was present should have had sufficient time to have been eliminated from the animal prior to human consumption.

Other studies indicate that the elimination of phenoxy herbicides from the tested cattle is typical for all animals; i.e., 2,4-D and 2,4,5-T do not significantly accumulate in warm blooded animals [31, pp. 93-99].

The toxicity of 2,4-D and 2,4,5-T on animals varied by weight of the animal. For a 770 pound cow the lethal dose for 2,4-D was one half pound, one quart of technical material. The lethal dose of 2,4,5-T for a 770 pound cow was one quarter of a pound, one pint of technical material. The lethal dose of 2,4,5-T for a grown deer was estimated at three ounces or three fourths of a pint. For a cow to receive a lethal dose of 2,4,5-T from grazing on a treated pasture it was estimated the cow would have to eat all the vegetation on one-eighth of one acre immediately after it was treated with two pounds of 2,4,5-T. This is physically impossible. It is recommended that ranchers defer grazing for the first year after treatment. In the counties surveyed for weed and brush control no loss of livestock or deer on treated rangeland was reported during the study period (1961-1972).

Even though phenoxy herbicides have not been highly toxic to wildlife their use to control brush can change the mix of vegetation in the area, thus affecting wildlife. This change can be either beneficial or harmful for wildlife, and it has been subject to much debate among environmentalists. One report showed cottontail rabbits preferred untreated vegetation to treated vegetation, while another report showed deer had no preference between untreated and herbicide-stimulated browse growth [31; 48]. The debate over whether or not the deer population increases or decreases after 2,4-D treatment of rangeland has created two opposing forces. One group claims a decrease in deer population, and the other claims a population increase after treatment. However, it is generally accepted that the deer population increases if 2,4-D or 2,4,5-T use stimulates browse growth or regrowth at the base of trees [31; 48].

Spraying of oak brush in Oklahoma has created additional browse at the base of trees as the oaks resprout. If deer populations have been suppressed by limited browse and grass, the use of herbicides to control brush actually increases the number of deer in an area by increasing available feed. There has been no research done in Oklahoma to determine the effect of brush spraying in Oklahoma on deer or other wildlife numbers. However, some ranchers and licensed applicators reported increased wildlife on treated rangeland.

The effect of 2,4-D and 2,4,5-T on fish was a function of the concentration in the water, the length of exposure, and the particular species. Fish were relatively succeptible to 2,4-D and 2,4,5-T. The most sensitive species (bluegill) was killed after a forth-eight hour exposure to water contining 0.3 ppm 2,4-D or 0.5 ppm 2,4,5-T [31, pp. 92-100 and 126].

There was no apparent danger to fish in Oklahoma because the highest residues of 2,4-D and 2,4,5-T reported by the Geological Survey in the state's rivers were 0.00085 ppm of 2,4-D and 0.00011 ppm of 2,4,5-T, much less than the lethal concentration above. If future use of phenoxy herbicides continues as it has over the past ten years, there is little chance of sufficient accumulation in the rivers to become lethal to fish.

Phenoxy herbicides have not been magnified in the food chain because of the rapid elimination from animals and its inability to be stored in the fat of birds, fish and animals. Birds do, however, show adverse affects when subjected to 2,4-D or 2,4,5-T [31]. Mallard ducks and chickens stopped laying eggs when exposed to levels of 1,250 to 2,500 ppm of 2,4-D in the feed. This level was many times higher than what birds normally find in the environment (the normal residue immediately after brush treatment was 300 ppm of 2,4,5-T). The lethal concentration of 2,4-D and 2,4,5-T for birds was very high. The lethal dose for two week old mallard ducks was 5,000 ppm 2,4-D and 2,500 ppm 2,4,5-T caused a death to two week old pheasants [31, p. 126].

Some beneficial side effects on birds from 2,4-D and 2,4,5-T use have been reported. When right-of-ways were treated with 2,4-D, wild turkeys grazed on the treated areas and increased in number because of the improved quality of habitat. Another study [31, pp. 94 and 126] reported that young turkey and ruffled grouse increased in numbers after right-of-ways were treated with 2,4,5-T.

Effects on Vegetation

Phenoxy herbicides were developed as narrow spectrum herbicides in that they kill only broad leafed plants and trees. For this reason they have proven to be lethal to fruit trees, broad leafed vegetable plants, and shrubbery around homes. The phenoxy herbicides are relatively volatile so if a change in the weather occurred during or immediately after treatment the herbicide was capable of extensive damage to non-target vegetation by drifting from the application site.

State Board of Agriculture fieldmen investigated all reported cases of pesticide damage. The complaints most frequently investigated by the Board's fieldmen were related to phenoxy herbicide drift onto gardens, shrubbery, cotton and pecan and locust trees. The value or cost of the damage to farm crops has been determined by observing the decrease in yield at harvest and valuing it at the current market price. This was easily done with cotton and pecans, but valuation became more difficult for individuals' gardens and fruit or shade trees. The State Board of Agriculture fieldmen reported that in 1972, Osage County licensed applicators paid total settlements of $1,680 for damage to non-target vegetation that occurred while treating brush and weeds on rangeland (Table XVII). No cash settlements were reportedly made in Woodward County in 1972 and none were reported in Pittsburg County in 1972.

The damage done in Pittsburg County has been primarily damage to small family gardens and cotton (Table XVII). Osage County's external costs from phenoxies was mainly for gardens and pecan trees. In Woodward County locust trees are grown for posts and are very susceptible to 2,4,5-T or 2,4-D and losses of these trees make up the majority of the external costs in that county. Licensed applicators reported they tried to make cash settlements immediately after they knew of the damage to avoid costly lawsuits. Cases which were settled on the spot were never reported and therefore never investigated by the technical advisers.

TABLE XVII

EXTERNAL COSTS DUE TO CONTROLLING WEEDS AND BRUSH ON RANGELAND WITH PHENOXY HERBICIDES IN THREE OKLAHOMA COUNTIES, FOR SELECTED YEARS, 1966 TO 1971

(Survey Data)

Survey Respondents	Osage County				Pittsburg County					Woodward County			
	1972	1971	1970	1966	1972	1971	1970	1969	1966	1972	1971	1970	1966
Applicators:													
Cash Settlements	725[2]	850[2]	250[2]	1,450[2]	50[2]	80[2]	800[1]	5,000[1]	500	0	1,300[3]	1,000[3]	500[3]
Law Suit Settlements Against Applicators	0	0	28,000	0	0	0	0	11,750	6,400	0	0	0	0
Technical Advisers:													
Cash Settlements	1,680[2]	250[2]	0	1,800[2]	0	0	700[1]	5,000[1]	0	0	500[3]	2,500[3]	2,600[3]
Unsettled Law Suits (not reported above)	5,000	0	0	0	0	0	0	0	0	0	0	0	0

[1] Cotton damage

[2] Garden damage

[3] Tree damage

For the selected years in the survey three lawsuits were settled against applicators and the settlements ranged from $6,400 to $28,000 (Table XVII). Failure of some applicators to report all cash settlements accounted for the difference in cash settlements for applicators and technical advisers.

There were some non-quantifiable benefits to plants from 2,4-D and 2,4,5-T used on rangeland. Some unpalatable plant species became palatable to cattle, sheep and deer (e.g. they grazed jimson-weeds, wild parsnips, sunflowers, and cocklebururs) because of succulent regrowth [31; 48].

Effects on Environmental Quality from Use of Insecticides on Cotton

The major insecticides used on cotton in Oklahoma are toxaphene, methyl-parathion and DDT. The minor insecticides used are azinphos-methyl and dicrotophos (marketed under trade names of Guthion and Bidrin).

Persistence in Soil and Water

Toxaphene and DDT have been shown to be persistent in the soil but methyl-parathion is not persistent. Methyl-parathion applied at five pounds per acre persisted for thirty days in a silt-loam soil [31, p. 63]. DDT has persisted in soil for extended periods of time. One study showed that DDT applied at ten to twenty pounds per acre persisted in soil for more than four and ten years, respectively [31, p. 280]. At the end of seventeen years 39 percent of a 100 ppm DDT applied on a sandy loam soil remained in the soil [31, p. 281].

Toxaphene has persisted in soil for extended periods of time, but at levels equal to ten to twenty percent of the initial application. There is no leaching from the soil by toxaphene. A test in Texas showed that after eleven years of continued use only 10 to 20 percent of the chemical remained and it was bound tightly in the upper twelve inches of soil. The remainder had been decomposed by soil micro-organisms and votilized into the air. Even though toxaphene has persisted in the soil there was no evidence that continued use will cause a buildup in the soil [22, p. 158-164].

No information on soil and water persistence of Guthion or Bidrin was found. However, their action in the environment was much like methyl-parathion, an insecticide of very short persistence in soil and water.

DDT is the only one of the three major insecticides used on cotton in Oklahoma that has persisted in water. DDT has persisted in water for many years, and it has been shown that deposits of DDT on the bottom were available to the water by leaching. DDT has possibly reached water supplies by massive erosion and could be dissolved by water, upon contact.

It was shown that toxaphene did not leach from soil into water supplies so the only way it could get into water was by massive erosion or intentional application. When toxaphene entered water it was irreversibly absorbed in sediments and became unavailable to the surrounding water by leaching. The concentration of the residue in sediments then decreased by 20 percent of its present level every three months [22, pp. 130-134].

The Environmental Protection Agency (EPA) took 172 soil samples in Oklahoma in 1969 and 1970. The samples were selected at random from cropland and rangeland for the National Pesticide Monitoring Program. A sample from Jackson County was the only sample that had a toxaphene residue, that being 1.6 ppm. None of the samples taken in Oklahoma had residues of methyl-parathion, guthion, or bidrin. Of the 172 samples taken in 1969 and 1970 in Oklahoma only nineteen contained DDT residues and the highest residue reported was 0.57 ppm of DDT in Johnston County (Table XVIII). Jackson County was the only county in the study area that pesticide residues were found in.

It has been shown that the persistence of methyl-parathion in water is very short. One study [31, p. 61] showed that it persisted for 175 days but no application rate was given. Another report showed that a low application rate of 0.12 ppm methyl-parathion persisted in water for 144 hours [31, p. 62].

Water samples have been taken at 26 sites in Oklahoma to determine the presence of chlorinated hydrocarbons (three of the sample sites were in the study areas). In 1970 two samples were taken at each site, in 1971 three samples were taken and in 1972 two samples were taken. No toxaphene residue was reported in the 182 samples taken but DDT residue was reported in 24 of the samples. The largest residue of DDT reported was 0.00154 ppm on the Verdigris River near Inola [28]. The residue study revealed that DDT and its derivatives were not accumulating in the water supplies in Oklahoma.

The Geological Survey has sampled three Oklahoma rivers for chlorinated hydrocarbons: Deep Fork near Arcadia, Canadian near Whitefield and the Kiamichi near Big Cedar. The highest DDT residue found in the

TABLE XVIII

CHLORINATED HYDROCARBON INSECTICIDE RESIDUES IN OKLAHOMA SOIL, 1969 TO 1970

County	1969 Samples				1970 Samples			
	O,P',DDT	P',P',DDT	P,P',DDE	P,P',TDE	O,P',DDT	P'P',DDT	P,P',DDE	P,P',TDE
	- PPM in Soil -				- PPM in Soil -			
Beaver	0.01	0.02	0.02					
Beckham						0.01		
Bryan	0.09		0.06	0.02	0.03	0.10	0.11	0.02
Caddo						0.06	0.06	0.01
Comanche					0.03	0.10	0.32	
Cotton		0.03	0.09	0.01				
Garvin		0.02	0.02					
Greer		0.02	0.03					
Jackson		0.02	0.03					
Jackson					0.20	0.54	0.89	0.08
Johnston					0.12	0.57	0.03	0.05
Kiowa		0.01	0.01					
Kiowa			0.02					
McCurtain					0.02	0.07	0.12	0.01
Oklahoma					0.03	0.18	0.14	0.02
Wagoner					0.04	0.21	0.20	
Washington		0.02	0.01					
Washita							0.01	

Source: Unpublished data from the Environmental Protection Agency for the National Pesticide Monitoring Program.

Deep Fork River between 1969 and 1971 was 0.00003 ppm in 1970 (Table XIX). The highest residue in the Canadian River between 1967 and 1971 (sampled monthly) was 0.00001 ppm DDT found in 1970. Between 1967 and 1970 the Kiamichi River was sampled semi-annually but no DDT residue was found. The results suggest that DDT residues have not been accumulating in the state's water supplies. These rivers are not in the study area, however, pesticides are used in each watershed.

No water samples in Oklahoma have been tested for the presence of methyl-parathion, guthion or bidrin, so no information was available concerning their occurrence in the environment. It was doubtful, however, that these insecticides accumulated in the environment because of their short persistence in soil and water.

Effects on Livestock, Wildlife and Fish

The effect of DDT and toxaphene on wildlife has been well documented while the effect of methyl-parathion on wildlife was relatively unknown. Numerous incidents involving wildlife deaths associated with the use of DDT have been reported from various parts of the world [27]. DDT has caused a reduction in eggshell thickness and in breeding success in several species of birds of prey and fish-feeding birds in Britain and North America since its introduction in 1944 [27]. DDT was not dealth with in detail here because the Environmental Protection Agency has removed its registration of DDT as a cotton insecticide.

Toxaphene is not acutely harmful to wildlife (deer, rabbits, and birds). It is registered for use as an insecticide for cattle, horses, pigs, and other livestock. The chronic effects of toxaphene have been estimated by experiments on monkeys and dogs. Over a two-year period

TABLE XIX

RESIDUES OF DDT AND ITS DERIVATIVES FOUND IN THREE OKLAHOMA RIVERS, 1967-1971[1]

Date	Canadian River			Kiamichi River			Deep Fork River		
	DDD	DDE	DDT	DDD	DDE	DDT	DDD	DDE	DDT
		(ppb)			(ppb)			(ppb)	
1967									
June	---	---	---	---	---	---	---	---	---
July	---	---	---	---	---	---	---	---	---
Aug.	---	---	---	---	---	---	---	---	---
Sept.	---	---	---	0.00	0.00	0.00	---	---	---
Oct.	---	---	---	---	---	---	---	---	---
Nov.	---	---	---	---	---	---	---	---	---
Dec.	0.01	0.00	0.01	---	---	---	---	---	---
1968									
Jan.	0.00	0.00	0.01	---	---	---	---	---	---
Feb.	0.00	0.00	0.00	---	---	---	---	---	---
Mar.	0.00	0.00	0.00	---	---	---	---	---	---
Apr.	0.00	0.00	0.00	---	---	---	---	---	---
May	0.00	0.00	0.00	0.00	0.00	0.00	---	---	---
June	---	---	---	---	---	---	---	---	---
July	0.00	0.00	0.00	---	---	---	---	---	---
Aug.	---	---	---	---	---	---	---	---	---
Sept.	0.00	0.00	0.01	---	---	---	---	---	---
Oct.	0.00	0.00	0.00	0.00	0.00	0.00	---	---	---
Nov.	0.00	0.00	0.00	---	---	---	---	---	---
Dec.	0.00	0.00	0.00	---	---	---	---	---	---
1969									
Jan.	0.02	0.00	0.00	---	---	---	---	---	---
Feb.	0.00	0.00	0.00	---	---	---	---	---	---
Mar.	0.00	0.00	0.00	---	---	---	---	---	---
Apr.	0.00	0.00	0.00	0.00	0.00	0.00	---	---	---
May	0.00	0.00	0.00	---	---	---	---	---	---
June	0.00	0.00	0.00	---	---	---	---	---	---
July	0.00	0.00	0.00	---	---	---	---	---	---
Aug.	0.00	0.00	0.01	---	---	---	---	---	---
Sept.	0.00	0.00	0.00	---	---	---	---	---	---
Oct.	0.00	0.00	0.00	0.00	0.00	0.00	---	---	---
Nov.	0.00	0.00	0.00	---	---	---	0.03	0.00	0.00
Dec.	0.00	0.00	0.00	---	---	---	0.05	0.00	0.00
1970									
Jan.	---	---	---	---	---	---	0.01	0.00	0.02
Feb.	0.00	0.00	0.00	---	---	---	0.02	0.00	0.01
Mar.	0.00	0.00	0.01	---	---	---	0.03	0.00	0.03
Apr.	0.00	0.00	0.00	---	---	---	0.08	0.00	0.03
May	0.00	0.00	0.00	---	---	---	0.01	0.00	0.01
June	0.00	0.00	0.00	---	---	---	0.03	0.00	0.01
July	0.00	0.00	0.00	---	---	---	0.02	0.00	0.01
Aug.	0.00	0.00	0.00	---	---	---	0.02	0.00	0.00
Sept.	0.00	0.00	0.00	---	---	---	0.01	0.00	0.00
Oct.	---	---	---	---	---	---	---	---	---
Nov.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec.	0.00	0.00	0.00	---	---	---	0.01	0.00	0.00
1971									
Jan.	0.00	0.00	0.00	---	---	---	0.01	0.00	0.02
Feb.	0.00	0.00	0.00	---	---	---	0.02	0.00	0.02
Mar.	0.00	0.00	0.00	---	---	---	0.03	0.00	0.01
Apr.	0.00	0.00	0.00	---	---	---	0.00	0.00	0.00
May	0.00	0.00	0.00	---	---	---	0.00	0.00	0.00
June	0.00	0.00	0.00	---	---	---	0.01	0.00	0.02
July	0.00	0.00	0.00	---	---	---	0.00	0.00	0.00
Aug.	0.00	0.00	0.00	---	---	---	0.00	0.00	0.00
Sept.	0.00	0.00	0.00	---	---	---	0.00	0.00	0.00
Oct.	---	---	---	---	---	---	0.00	0.00	0.00
Nov.	---	---	---	---	---	---	0.00	0.00	0.00
Dec.	---	---	---	---	---	---	0.00	0.00	0.00

[1]Samples were not taken where --- are shown.

Source: Unpublished data from the U. S. Department of Interior, Geological Survey dogs were fed 200 ppm toxaphene daily in their diet and at the end of the experiment they showed only moderate degeneration of the liver. Monkeys were fed ten to fifteen ppm for two years with no signs of toxication and no evidence of damage to body tissues [22, pp. 105-110]. After many years of using toxaphene in agriculture, it has not been retained in the bodies of animals. So it is very unlikely that toxaphene can reach lethal levels by magnification in the food chain.

Toxaphene is not toxic to birds but it has caused reduced egg production in quail. When quail were fed 500 ppm of toxaphene none of the hens laid eggs during the experiment, but they resumed laying within three weeks of normal feeding. The eggs produced after exposure to toxaphene were as fertile as those in the control group [24]. Several species of birds have been analyzed to determine the extent of toxaphene residues in wildlife. There were no residues found in a nationwide survey of starlings in 1967-1968, of grouse and pheasant in South Dakota in 1965-1967, of eagles in 1964-1965, of mallards and black ducks in 1965-1966, and of pheasants in South Dakota in 1964-1967 [22, pp. 167-168]. There have been no cases of bird kills from methyl-parathion or toxaphene in Oklahoma reported to the Department of Wildlife Conservation, however, methyl-parathion is toxic to birds.

When treated orally with methyl-parathion young pheasants and young mallards were killed by 8.2 and 10.0 mg/kg. Adult pheasants showed some toxicity to absorption of methyl-parathion; when a concentration the equivalent of one-half pound per acre was applied to birds in a cage, about two percent died [31, p. 61-62]. Only minor incidents of birds being killed by methyl-parathion were reported, usually only individual birds in cotton fields.

Guthion is moderately toxic to birds. For young mallards the lethal dosage of guthion in feed was shown to be 1,900 to 2,000 ppm; for young pheasants, 1,800 to 2,000 ppm., and for young bobwhite quail 400 to 500 ppm [31, pp. 8-9, and pp. 32-33]. Similar information was unavailable for Bidrin.

Toxaphene is very toxic to fish; because of this it is used as a piscicide (a fish killing chemical) even though it is not recommended or registered for that use. When used on farms as recommended, with caution taken to prevent water contamination, fish are not killed by toxaphene [22, p. 131]. Some farm ponds in the study area have had small fish kills due to toxaphene drift and one kill of 100 carp was reported in Skull Creek.

Methyl-parathion has been moderately toxic to fish but due to its short persistence in water few fish kills have been caused by this insecticide. This insecticide has not proven to be harmful to fish unless it was intentionally applied to water or water was contaminated in cleaning of spray equipment. There have been no cases of fish kills in Oklahoma caused by methyl-parathion reported to the Oklahoma Department of Wildlife Conservation.

Bidrin has not been very toxic to fish because of the high concentration needed to kill fish. Rainbow trout were killed in experiments by 8,000 ppb Bidrin in water if exposed for 48 hours [31, pp. 32-33]. Guthion was more toxic to fish; the most sensitive fish specie tested was the large mouth bass which was killed by 96 hours of exposure to 5.0 ppb Guthion. If a smaller dose of Guthion entered water, the insecticide did not accumulate in fish. Fish treated with Guthion eliminated 50 percent of the chemical the first week after treatment [31, pp. 8-9].

Based on intensive investigation of all reports and sources of information, it can be concluded that the use of toxaphene, DDT and methyl-parathion has reportedly caused little damage to wildlife and other crops in 1971, 1970, 1969 and 1966 in the cotton survey counties. The most costly accident during the study period was one reported by the technical advisers in Jackson County, when 16 head of cattle were killed by methyl-parathion. In this case the failure to clean the spray equipment prior to treating the cattle was the cause of the loss.

In Harmon County technical advisers reported that there had been only one case of environmental damage from cotton pesticides. In 1971 about 40 beehives, valued at twenty dollars each, were destroyed by insecticides. The loss of 14 beehives, valued at $300, was the extent of environmental damage reported in Tillman County during the study period.

The environmental damage in Washita County was higher than the other three counties in the years surveyed. Technical advisers in Washita County reported that in 1971 a farmer treated his grain sorghum with methyl-parathion and reduced the number of beneficial insects in the area, requiring 300 acres of cotton in the vicinity having to be sprayed four times. The estimated cost was $13.40 per acre for 300 acres or $4,020 plus an estimated 50 to 100 pound reduction in yield on the 300 acres.

None of the farmers surveyed reported having been poisoned by cotton insecticides even though one in eight farmers surveyed did some of their own insect spraying. The farmers reported very few cases of damage caused by their neighbors spraying and/or non-spraying. One individual in Jackson County complained that he had to spray his cotton more often because his neighbors did not spray. Others commented that early spraying only killed the beneficial insects and let the bollworm complex become more damaging, necessitating additional spraying.

Cotton has been very toxic to the phenoxy-herbicides used in the study area for weed and brush control on pasture and rangeland. Many farmers and technical advisers reported damage to cotton from 2,4-D or 2,4,5-T. One example occurred in 1971 when employees of the city of Altus sprayed weeds adjacent to a cotton field and damaged the cotton. The farmers who suffered damage sued the City of Altus and won a settlement for about $5,000. Other cases of damage to cotton mentioned to the researcher involved individuals, farmers, licensed applicators, and right-of-way maintenance crews on the railroad. These cases were not fully investigated because the concern of this portion of the research was to determine the effects on the environment of insecticides used on cotton and not herbicides used on rangeland in the cotton study area. No damage to cotton from toxaphene or methyl-parathion was reported by technical advisers in the study area.

Effects on Environmental Quality from Use of Herbicides on Cotton

Cotton farmers have used three main herbicides to control weeds: Treflan, Caporal, and Planavin. Farmers in Washita and Tillman Counties desiccated cotton primarily with three herbicides: Paraquat, sodium chlorate and arsenic acid. The environmental affects of the herbicides are discussed below.

Persistence in Soil and Water

Treflan, Planavin, and Caporal have persisted in the soil for one to six months. When used as recommended they leave no harmful residues for the next crop in the rotation. These herbicides are absorbed tightly to organic matter and clay colloids after application and do not leach through the soil but stay in place for microbial decomposition. On soil where Treflan was used for four consecutive years no accumulation of the herbicide was found [49].

Sodium chlorate persisted in soil for over one year when applied at 300 pounds per acre [31, p. 125]. Similar application rates of sodium chlorate persisted for periods of one-half year to five years in different soils and temperatures [37, p. 685]. Sodium chlorate usually was applied at rates of two and one-half to four pounds per acre in the study area, so it was doubtful that the herbicide persisted in the soil for extended periods.

Arsenic acid reacts with soil to form insoluble calcium arsenate upon application. Applications of 200 to 500 pounds per acre of calcium arsenate have been made without yield reductions in different crops and different soils. It has been illegal to apply more than 4.4 pounds per acre of arsenic acid in any one year and cotton farmers usually apply one and one-half pounds per acre. Thus, it is doubtful that continued use at this level will cause accumulation in the soil [1].

Paraquat interacts with soil immediately upon contact and breaks down, thus preventing any residue build in soil. Paraquat applied to ponds at 2.1 and 2.5 ppm persisted in the water for 6 to 23 days. There also was no buildup in the sediments [31, p. 117].

Effects on Livestock, Wildlife and Fish

Cotton herbicides (Treflan, Planavin and Caporal) create no danger for fish and wildlife if they are applied according to recommendations. In one experiment Treflan treated soil (up to sixteen pounds of Treflan per acre) was dumped into ponds to test the effects on fish. The test concluded that there were no adverse effects on fish at levels of application equal to sixteen pounds per acre [48, pp. 353-356]. As the recommended rates were 0.5 to 1.0 pounds per acre, even massive erosion probably would not put a lethal dose of Treflan in fish ponds. Caporal was fed to various fish and game birds without any acute adverse effects. To estimate the chronic toxicity of these herbicides dogs and mice were used in feeding tests lasting two years. Treflan, Planavin, and Caporal did not produce any gross or microscopic signs of systematic toxicity in the test animals over the feeding period [48, p. 110].

Sodium chlorate caused death at concentrations of 3,157 ppm for channel catfish exposed for 24 hours and 4,200 ppm for rainbow trout exposed for 24 hours. This was less toxic than Paraquat which was lethal to 50 percent of a bluegill population when exposed for 24 hours in water with 400 ppm Paraquat [31, pp. 116 and 125].

In Britain, Paraquat reportedly killed horses following use on grassland and stubble [27]. In the survey counties no cases of wildlife or livestock having been killed by Paraquat, sodium chlorate or arsenic acid were reported. The manufacturers of Paraquat caution users to avoid grazing treated areas to prevent livestock loss. This warning may have helped prevent livestock losses in the survey counties.

Effects on Vegetation

Treflan, Planavin and Caporal, herbicides developed to inhibit weed and grass growth in cotton, have been used in the survey counties. The herbicides have been responsible for little or no non-target vegetation damage because they were incorporated in the soil soon after being applied. There were, however, some complaints that after using these herbicides one could not replant wheat if the cotton got hailed out. This limitation was short lived, only four to five months.

Sodium chlorate, Paraquat and arsenic acid adversely affected non-target plants by causing lethal damage or a burn on the tips of the leaves. Drift from these herbicides have caused leaf burn on wheat and other feed crops. Paraquat has been recommended for clearing cropland prior to planting (using non-tillage methods). Thus it is possible that non-target plants are injured if the herbicide drifts.

There were no reports of environmental damage from Paraquat and sodium chlorate in the survey counties during the study period. Arsenic acid has caused minor external costs for some fields adjacent to cotton fields. In all of the cases of arsenic acid damage, the herbicide drifted onto forage adjacent to cotton fields and burned the tops. This did not hurt the yield of wheat or grain sorghum but the crop could not be grazed. In 1966 the loss in grazing due to herbicide drift was estimated by technical advisers at $400 in Harmon County. Estimated damage from herbicides was $300 in 1969 and $455 in 1970 in Washita County. About $325 worth of damage was reported by licensed applicators in Tillman County in 1971.

Relationships Between the Present Use of Pesticides and Social Well-Being

Public Health

The use of pesticides on cotton and rangeland affected the well-being of people by affecting public health, food supply and water supply. Health of people in the vicinity where chemical pest control is practiced is a function of the chemical used, precautions taken, the type of spray system used and similar factors that govern toxicity. Toxicity of a pesticide is the capacity of the substance to produce injury, either acute or chronic. Pesticides that cause acute toxicity result in immediate poisoning. Chronic toxicity results in poisoning only after an extended period of continued exposure.

Acute toxicity of pesticides has been measured in terms of the average lethal dose (LD) per unit of body weight required to kill half of a large experimental population (LD_{50}). LD_{50} values have been standardized in terms of milligrams of chemical per kilogram of body weight (mg./kg.). The LD_{50} levels for the pesticides used on Oklahoma crops are presented in Table XX as well as the LD_{50} levels of common chemicals found in the home. The least toxic pesticide used on cotton is sodium chlorate with an LD_{50} of 12,000 mg/kg, i.e., over one quart to cause death to a 150 pound man. Rated by a toxicity rating scale sodium chlorate has a value of 5, meaning that it is almost non-toxic (Table XX). The most toxic pesticide used on cotton is Guthion with an LD_{50} of 18, and a toxicity rating of 2, meaning that it is very toxic. The herbicides, 2,4-D and 2,4,5-T both have toxicity ratings

TABLE XX

ACUTE ORAL TOXICITY VALUES OF SELECTED PESTICIDES AND COMMON CHEMICALS TO RATS

Chemical Substance	Acute Oral Toxicity LD_{50} (mg./kg.)	Toxicity Rating[1]
Herbicides		
2,4-D	850	4
2,4,5-T	750	4
Treflan	>5,000	5
Planavin	2,000	4
Caporal	3,750	4
Paraquat	150	3
Sodium Chlorate	12,000	5
Arsenic Acid	48	2
Insecticides		
DDT	118	3
Toxaphene	69	3
Methyl-Parathion	24	2
Guthion	18	2
Bidrin	22	2
Household Items		
Gasoline	150	3
Aspirin	750	4
Table Salt	3,320	4

[1]Numerical toxicity rating is based on a modification of the classification of pesticides in the Federal Insecticide, Fungicide, and Rodenticide Act and from "Clinical Toxicology of Cmmmerical Products" by Gleason, M. N., Gosselin, R. E., and Hodge, H. D., Williams and Wilkins Co., Baltimore, Md., 1957.

Toxicity Rating	Class	LD_{50}, (mg./kg.)	Probable Lethal Dose, 150-lb. Man
1	Extremely Toxic	less than 5	A taste (< 7 drops)
2	Very Toxic	5 - 49	7 drops - 1 teaspoonful
3	Moderately Toxic	50 - 499	1 teaspoonful to 1 ounce
4	Slightly Toxic	500-4,999	1 ounce to 1 pint (lb.)
5	Almost Non-Toxic	5,000 - 14,999	1 pint to 1 quart
6	Non-Toxic	15,000 and above	more than 1 quart

of 4, meaning they are slightly toxic or about as toxic as aspirin. Gasoline is moderately toxic (Table XX).

Acute Poisoning in Oklahoma. The office of Oklahoma Vital Statistics reported that between January 1, 1962, and January 1, 1970, a total of 20 people died from pesticide poisoning in Oklahoma. Eight of the twenty deaths were farm residents. Six of these eight farm residents were farmers, and two were farmers' wives. The latter two deaths were most likely suicides. No farm children were fatally poisoned by pesticides from 1962 to 1972, but seven children in urban areas were killed by pesticides during the same period [30].

To estimate the extent of non-fatal pesticide poisoning in Oklahoma three indices of poisonings were available: (1) number of emergency calls at the Oklahoma Poison Control Center; (2) a survey of practicing physicians in the state; and, (3) a survey of hospital emergency rooms in the state. The number of people calling the Oklahoma Poison Control Center for emergency information has fluctuated between 2,200 and 3,000 per year for the past six years (1966-1972). (Data was obtained from unpublished data computed by the Poison Control Center.) Of the total calls received the number related to agricultural pesticides has been constant at 5.0 percent of the total. In 1967 the Center received 147 emergency calls requesting information about poisoning due to agricultural pesticides, in 1969 the emergency calls reached a high of 172, and in 1972 the number of calls was 153. The remainder of the emergency calls pertained to other poisons such as: Drano, Raid, De-Con, several different aerosols and common household items such as aspirin and moth balls. The number of emergency calls due to agricultural pesticide poisoning appears to be stable even though cotton farmers have increased the use of methyl-parathion, a chemical more hazardous to man than DDT or toxaphene (Table XX).

Another index of the acute pesticide poisoning in Oklahoma was the survey of practicing physicians by the State Health Department. In 1970 the 148 physicians surveyed reported seeing 124 poison cases with only one case resulting in death (a suicide). The State Health Department estimated from this survey that about 1,200 poison cases occurred in Oklahoma in 1970. The chemicals involved and the respective number of cases reported by the survey were: 23 from rat poison (mostly D-Con); 4 from DDT; 18 from parathion; and, 13 from household insecticides (Raid, Real Kill, and others). The other cases were caused by: shrub sprays, cattle spray, mercury, chlordane, arsenic, and moth balls. The one fatal poisoning was caused by arsenic. Only three percent of the physicians surveyed believed the number of poisonings was increasing, while 60 percent of the physicians believed the number of poisonings over time was stable. Eight percent of the physicians responding believed there had been a decrease while the remainder had no opinion.

An unpublished survey in Oklahoma, by the State Health Department, of 1,210 practicing physicians reported that in 1972 the respondents saw 371 poison cases related to pesticides. It was estimated that if all practicing physicians had reported seeing pesticide poisonings at the same rate, there would have been about 860 poison cases due to pesticides in Oklahoma. There were no fatal poisonings reported in 1972. Doctors surveyed generally believed the annual number of pesticide poisonings were remaining stable.

Another index of acute poisoning was a survey of hospital emergency rooms in Oklahoma to determine the number of pesticide poison cases treated in 1972. The 69 surveys returned reported 183 poison cases. If this was expanded statewide, the estimated number of cases treated was 408 in 1972. The majority (65 percent) of the poison cases treated were in Oklahoma City and Tulsa, thus suggesting the majority of the pesticide poisonings in Oklahoma occurred in metropolitan areas rather than farming areas.

Since acute poisoning occurs immediately after exposure, the amount of work lost by pesticide applicators was assumed to be an index of the extent of acute pesticide poisoning. Of the 47 licensed applicators interviewed only one reported missing any work due to pesticide poisoning. The one case involving work loss was caused by an accident in the storage of methyl-parathion that prevented the applicator from working for six months, resulting in a loss of income of about $10,000 and causing $1,000 in medical expenses.

The average number of years of experience for the owners of pest control businesses (licensed applicators) was 8.2 years; 25 percent reported owning their own business less than four years, and 38 percent had been in business over ten years. Only one reported case of pesticide poisoning among 47 licensed applicators during the study period suggests that there have not been many acute poisonings when pesticides are used properly by experienced people. One rancher in Osage County reported having been poisoned by a cattle spray and lost one month of work. No cotton farmers reported losing work from pesticide poisoning.

The Oklahoma Industrial Court handles cases of temporary and total disability of workers, but they reported that there had been no cases in Oklahoma where a worker had been disabled by agricultural pesticides.

Agricultural workers were not eligible for workman's compensation, but employees of licensed applicators have been covered by the program.

Recently a lawsuit was filed in Oklahoma against one licensed applicator to recover damages caused to a flagman in 1971 while employed in McCurtain County. The case alleged permanent blindness in one eye because the flagman was sprayed with 2,4,5-T. The suit asked for $150,000 in damages for the alleged negligent injury and $350 in medical expenses, the case has not been settled yet [9, p. 17].

In California, where many more migrant farm workers were exposed to agricultual pesticides in the fields, several have been killed [47]. The Southwest Oklahoma Migrant Health Department in Hollis, Oklahoma, reported in 1972 that no cases of agricultural pesticide poisoning or sickness among migrant workers in Oklahoma have been detected or reported since 1970 when the office began keeping records of causes of sickness.

Chronic Poisoning in Oklahoma. No cases of chronic poisoning in Oklahoma were discovered by this study. This was probably due to the inability of the questionnaire used to determine long term health problems associated with pesticide users, failure to interview employees, the seasonality of jobs associated with pesticide use, and the uncertainty of the cause and effect relationship between pesticide use and sickness. Of all the chemicals used on the selected crops in Oklahoma, only DDT persists in warm blooded animals for extended periods of time. The chronic effects of DDT on man are not fully understood, but the Environmental Protection Agency (EPA) has removed its registration on DDT for use on cotton to protect future generations of man.

The morbidity of pesticides could have been related to pesticide use if we could be sure of the different diseases caused by pesticides. The State Department of Health maintains morbidity figures for Oklahoma. No one is sure of the true chronic effects of DDT. For example, some researchers here reported that long term DDT exposure caused cancer in humans while others have indicated that DDT exposure reduced the incidence of cancer in humans and acted as a deterent to tumors in mice [25, pp. 181-184; 26, pp. 770-775].

Since 1964 other research on the chronic effects of pesticide exposure has been done by the Public Health Service in 14 agricultural states. The studies have observed the health problems of farm workers, applicators and pest control operators on a regular basis. The general inference to date is that no specific health hazards are associated with long term normal exposure to pesticides [36, pp. 79-81].

Vectors. Public health could have been improved by agricultural insect control indirectly through the reduction of houseflies and mosquitoes. The hypothesis that insecticides used on cotton in Oklahoma helped to control houseflies, mosquitoes, and other insects could not be tested because of a lack of data in the area. The Oklahoma Health Department has not made annual fly or mosquito counts in communities where cotton was grown so no analysis of the situation was possible with the data collected by this study.

According to the State Health Department the number of houseflies in a city are a function of the garbage disposal system (open or closed cans), the number of dogs and animals in the city, and that agricultural insecticide use has no affect on the number of houseflies.

Also the level of mosquitoes in a city is solely a function of the amount of rainfall in the area.

Lawton, Tulsa, and Oklahoma City officials have taken housefly and mosquito counts; however, there are few cotton fields treated for insects in these areas. In the future the problem of pests may become such that insect counts will be made. Then insect population level can be regressed on the use of agricultural pesticides to reveal the interrelationship between pesticides and household insects.

Food Contamination

The use of pesticides on selected crops in Oklahoma likely has not decreased the quality of food in the United States. Pesticide residues on cotton have not been of any significant problem to man. On the other hand, residues of 2,4-D have shown up infrequently in the market system in meat. Samples of food in interstate commerce were analyzed by the Food and Drug Administration for pesticide residues. Between June, 1969, and April, 1970, three of 25,000 samples contained 2,4-D or 2,4,5-DB (a derivative of 2,4,5-T). The residues were in potatoes, meats and oils at 0.028, 0.012 and 0.123 ppb, respectively. No 2,4,5-T was found in the samples [7, pp. 313-330].

An estimate of the daily intake of pesticide residues by food class for two periods has been made by the Food and Drug Administration. It was estimated the daily intake of 2,4-D was zero in 1968 through 1970 in all classes of food [11, pp. 331-342]. No estimate was made for 2,4,5-T because there was no residue found in the foods sampled in the major markets.

DDT was found frequently in food samples while toxaphene was found infrequently. There have been no reports showing the residue of these two insecticides in cotton lint even though the major use of DDT and toxaphene is on cotton. Also, there were no reports available that indicated pesticide residues on fiber have been harmful to man.

Water Supply Contamination

In Oklahoma the level of pesticide residues in water supplies has not become a problem. The level of residues found in the state's water supplies by the various agencies between 1967 and 1972 (Table XIX) has not been greater than the allowable levels established by the Federal Government [34, p. 7]. If the future use of agricultural pesticide was no greater than in the past, water supplies in Oklahoma should continue to be below the allowable levels of pesticides.

CHAPTER V

ENVIRO-ECONOMIC ANALYSIS OF ALTERNATIVE METHODS TO CONTROL PESTS

The methods to control insects on cotton, brush and weeds on rangeland discussed in Chapters III and IV, were not the only methods available to farmers and ranchers. However, some of the alternative methods found in the literature could not be adapted to the needs of Oklahoma farmers in the near future [40]. Agronomy and entomology researchers at Oklahoma State University and researchers at the Southern Great Plains Research Station suggested feasible alternative methods to control pests (brush on rangeland and insects on cotton) in Oklahoma. These alternatives are described and analyzed using an environmental matrix. Incentives to encourage adoption of the alternative methods of control are discussed in this Chapter. The methodology behind an environmental matrix is discussed in Chapter II of this thesis.

Analysis of Selected Alternative Methods of Brush and Weed Control

Selected methods of control for sand sage and schinnery oak were different than those selected for post and blackjack oak. Thus, a separate environmental impact matrix was developed for sand sage, schinnery oak, and the post and blackjack oaks. One alternative, reduced cattle numbers, was common to all types of brush control. The selected alternative control methods for sand sage and schinnery oak were: (1) reduce application rates of quantity of phenoxy herbicide applied per acre; (2) deep plow rangeland and establish love grass; (3) no control of brush and reduce cattle numbers; and, (4) dormant season mowing. The selected alternative methods to control post and blackjack oak were: (1) clear brush mechanically and establish bermuda grass; (2) establish fescue grass on hillsides to supplement bermuda grass; and, (3) no control of brush and reduce cattle numbers.

Selected Methods to Control Sand Sage and Schinnery Oak

Reduce Application Rates of Herbicides. Sand sage and schinnery oak in western Oklahoma have been controlled in experiments at the Southern Great Plains Research Station by an annual application of one eighth to one sixteenth pound of 2,4,5-T per acre. This alternative has proven to give control of brush and weeds equal to that of the present method of control of two pounds of 2,4,5-T per acre. The herbicide is applied by ground equipment that blows a mist of water and 2,4,5-T. Spray trails, light roads for spray rigs, at 66 foot intervals across the range are cultivated in with two 18 inch sweeps behind a tractor. The trails do not need to go straight, so they can be shifted to avoid large clumps of schinnery oak or sand sage where necessary. The estimated return per acre for a ranch using this alternative was $15.72 per acre, a two dollar per acre increase over the present method of control (Table XXI). The estimated impact of this alternative on the economic parameters in the environmental matrix

TABLE XXI

COMPARISON OF ALTERNATIVE METHODS TO CONTROL WEEDS, SAND SAGE, AND SCHINNERY OAK ON RANGELAND IN WOODWARD COUNTY, OKLAHOMA

(Based on 1971 to 1972 Data)

Parameter	Unit	Present System to Control Brush & Weeds	Reduced Application Rates	Deep Plow and Establish Love Grass	Dormant Season Mowing[1]	Reduce Cattle Numbers
Carrying Capacity	Acres/AUY	8.0	8.0	8.5	16.0	25.0
Cost of Inputs	$/Acre	3.63	3.63	7.64[2]	1.71	1.10
Cost of Control	$/Acre	2.25	.22	--	0.50	--
Value of Beef Prod.	$/Acre	19.57	19.57	22.78	9.78	6.26
Net Returns[3]	$/Acre	13.69	15.72	15.14	6.77	5.16

[1] Applicable to sand sage only.

[2] Includes establishment costs of love grass.

[3] Net returns to land, labor, capital and management.

was 3.4 when used for sand sage control and 3.0 when used for schinnery oak control (Tables XXII and XXIII). The difference in impacts was due to the difference in the environmental factors surrounding sand sage and schinnery oak.

Reducing application rates as an alternative method of control generally is more beneficial in overall environmental impact than the present system of control. For example, more grouse, quail and prairie chickens were observed on this alternative's experimental range sites than on rangeland controlled by the present methods. The reason behind this increase was that the alternative provided cover as well as feed, and the diesel oil used as a carrier in the present method was not applied.

Even though phenoxy herbicides have not been harmful to wildlife, the alternative reduces the amount of herbicide applied by about six pounds of 2,4-D or 2,4,5-T per acre over a ten year period. The overall impact of reduced application rates on the environmental parameters was 7.00 for sand sage control and 7.25 for schinnery oak control (Tables XXII and XXIII). The difference in the environmental impact values was due to the difference in the quality of the environment associated with the two types of brush.

The impact of reduced application rates on social well-being was 4.15 for sand sage control and 7.50 for schinnery oak control (Tables XXII and XXIII). The net overall impact from this alternative was 14.55 for sand sage control and 17.75 for schinnery oak control. This particular alternative method for controlling sand sage and schinnery oak was superior to the present method and the other alternatives analyzed below. The alternative resulted in higher income for ranchers,

TABLE XXII

ANALYSIS OF SELECTED ALTERNATIVE METHODS TO CONTROL SAND SAGE ON RANGELAND IN OKLAHOMA

Parameters	Parameter Weights	Reduced Application Rates[1]		Deep Plow and Establish Love Grass[2]		Dormant Season Mowing[3]		Use No Controls On Brush and Weeds, Reduce Cattle Numbers[3]	
		Raw score	Weighted score	Raw score	Weighted score	Raw score	Weighted score	Raw score	Weighted score
I. Impact on Economic Factors	10.00								
A. Change in quantity of output	1.00	0	0	-0.20	-0.20	-3.00	-3.00	-5.00	-5.00
B. Change in quality of output	0.50	0	0	0	0	0	0	0	0
C. Change in cost of goods for consumers	2.50	0	0	0	0	-1.09	-2.73	-5.00	-12.50
D. Change in farm income	2.50	1.20	3.00	1.10	2.75	-3.50	-8.75	-5.00	-12.50
E. Change in employment in the region	0.50	0	0	0.50	0.25	-0.50	-0.25	-0.50	-0.25
F. Change in the number of farms	1.00	0.40	0.40	0	0	-2.40	-2.40	-5.00	-5.00
G. Change in number of acres farmed	2.00	0	0	0	0	0	0	0	0
Economic Impact			3.40		2.80		-17.13		-35.25
II. Impact on Environmental Factors	10.00								
A. Effect on rare and endangered species	2.00	1.00	2.00	-1.00	-2.00	-1.00	-2.00	-1.00	-2.00
B. Plant and animal habitat	3.00								
1. Change in number of acres available for wildlife	1.00	0	0	0	0	0	0	0	0
2. Change in soil erosion	1.00	1.00	1.00	-3.00	-3.00	-1.00	-1.00	-2.00	-2.00
3. Change in food and cover	1.00	0	0	-0.50	-0.50	-1.00	-1.00	-2.00	-2.00
C. Diversity and Stability	2.50								
1. Change in aquatic environment	1.25	2.00	2.50	-1.00	-1.25	1.00	1.25	-1.00	1.25
2. Change in vegetation	1.25	0	0	-0.50	-0.63	0	0	-1.00	-1.25
D. Direct Effect on Fish and Wildlife	2.50								
1. Change in the type of fish and wildlife in ecosystem	0.75	1.00	0.75	-0.50	-0.38	-0.50	-0.38	-1.00	-0.75
2. Change in acute effects on fish and wildlife	1.00	0.50	0.50	1.00	1.00	1.00	1.00	2.00	2.00
3. Change in chronic effects on fish and wildlife	0.50	0.50	0.25	1.00	0.50	1.00	0.50	2.00	1.00
4. Change in parasites on animals	0.25	0	0	-0.50	-0.13	-0.50	-0.13	-1.00	-0.25
Environmental Impact			7.00		-6.39		-1.76		-6.50
III. Impact on Social Well-Being	10.00								
A. Recreational Opportunities	3.00								
1. Change in water based recreation	1.50	0	0	-2.00	-3.00	-1.00	-1.50	-2.00	-3.00
2. Changes in land based recreation	1.50	0	0	-0.50	-0.75	1.00	1.50	-1.00	-1.50
B. Anxiety Factors	3.50								
1. Change in anxiety due to pesticide residues in food	0.70	0.50	0.35	2.00	1.40	2.00	1.40	2.00	1.40
2. Change in air pollution	0.70	0.50	0.35	-1.00	-0.70	1.00	0.70	1.00	0.70
3. Change in drift damage	0.70	0.50	0.35	5.00	3.50	5.00	3.50	5.00	3.50
4. Change in stream water quality	0.70	0.50	0.35	-1.00	-0.70	-1.00	-0.70	-2.00	-1.40
5. Change in number of pests in the environment	0.70	0	0	-1.00	-0.70	-0.50	-0.35	-1.00	-0.70
C. Other Human Life Considerations	3.50								
1. Change in aesthetics	0.75	0	0	1.00	0.75	0	0	2.00	1.50
2. Change in number of poisonings (not fatal)	1.25	1.00	1.25	5.00	6.25	5.00	6.25	5.00	6.25
3. Change in number of deaths from pesticides	1.50	1.00	1.50	5.00	7.50	5.00	7.50	5.00	7.50
Social Well-Being Impact			4.15		13.55		18.30		14.25
Overall Impact			14.55		9.96		-0.59		-27.50
Rank			1		2		3		4

[1]Reduced application rates of phenoxy herbicides to 1/8 or 1/16 pound per acre and spray brush with a ground rig annually.

[2]Deep plow and establish love grass involved plowing 1/5 of a ranch's brush and planting it to love grass after killing the brush sprouts by planting forage and plowing annually for two years.

[3]Dormant season mowing involved using a shredder mower on sand sage each four or five years; mowing must be done while native grasses were dormant.

[4]Reduce cattle numbers to that level the range can handle while using no controls on brush.

TABLE XXIII

ANALYSIS OF SELECTED ALTERNATIVE METHODS TO CONTROL SCHINNERY OAK ON RANGELAND IN OKLAHOMA

Parameters	Parameter Weights	Reduced Application Rates[1] Raw score	Reduced Application Rates[1] Weighted score	Deep Plow and Establish Love Grass[2] Raw score	Deep Plow and Establish Love Grass[2] Weighted score	Use No Controls On Brush and Weeds, Reduce Cattle Numbers[3] Raw score	Use No Controls On Brush and Weeds, Reduce Cattle Numbers[3] Weighted score
I. Impact on Economic Factors	10.00						
A. Change in quantity of output	1.00	0	0	-0.50	-0.50	-1.50	-1.50
B. Change in quality of output	0.50	0	0	0	0	0	0
C. Change in cost of goods for consumers	2.50	0	0	0	0	-5.00	-12.50
D. Change in farm income	2.50	1.00	2.50	1.00	2.50	1.00	2.50
E. Change in employment in the region	0.50	0	0	1.00	0.50	-1.00	-0.50
F. Change in the number of farms	1.00	0.50	0.50	0	0	-5.00	-5.00
G. Change in number of acres farmed	2.00	0	0	0	0	0	0
Economic Impact			3.00		2.50		-17.00
II. Impact on Environmental Factors	10.00						
A. Effect on rare and endangered species	2.00	1.00	2.00	-1.00	-2.00	-1.00	-2.00
B. Plant and animal habitat	3.00						
1. Change in number of acres available for wildlife	1.00	0	0	0	0	0	0
2. Change in soil erosion	1.00	1.00	1.00	-1.50	-1.50	-3.00	-3.00
3. Change in food and cover	1.00	0	0	-1.00	-1.00	-2.00	-2.00
C. Diversity and Stability	2.50						
1. Change in aquatic environment	1.25	2.00	2.50	-1.00	-1.25	-1.00	-1.25
2. Change in vegetation	1.25	0	0	-0.50	-0.62	-1.00	-1.25
D. Direct Effect on Fish and Wildlife	2.50						
1. Change in the type of fish and wildlife in ecosystem	0.75	1.00	0.75	-0.50	-0.37	-1.00	-0.75
2. Change in acute effects on fish and wildlife	1.00	0.50	0.50	2.00	2.00	4.00	4.00
3. Change in chronic effects on fish and wildlife	0.50	0.50	0.25	1.00	0.50	0.50	0.25
4. Change in parasites on animals	0.25	1.00	0.25	-0.50	-0.13	-1.00	-0.25
Environmental Impact			7.25		-4.37		-6.25
III. Impact on Social Well-Being	10.00						
A. Recreational Opportunities	3.00						
1. Change in water based recreation	1.50	0	0	-0.80	-1.20	-1.00	-1.50
2. Changes in land based recreation	1.50	2.00	3.00	-1.00	-1.50	-2.00	-3.00
B. Anxiety Factors	3.50						
1. Change in anxiety due to pesticide residues in food	0.70	0.50	0.35	2.00	1.40	2.00	1.40
2. Change in air pollution	0.70	0.50	0.35	-1.00	-0.70	1.00	0.70
3. Change in drift damage	0.70	1.00	0.70	5.00	3.50	5.00	3.50
4. Change in stream water quality	0.70	0.50	0.35	-1.00	-0.70	-2.00	-1.40
5. Change in number of pests in the environment	0.70	0	0	-1.00	-0.70	-1.00	-0.70
C. Other Human Life Considerations	3.50						
1. Change in aesthetics	0.75	0	0	1.00	0.75	2.00	1.50
2. Change in number of poisonings (not fatal)	1.25	1.00	1.25	5.00	6.25	5.00	6.25
3. Change in number of deaths from pesticides	1.50	1.00	1.50	5.00	7.50	5.00	7.50
Social Well-Being Impact			7.50		14.60		14.25
Overall Impact			17.75		12.73		-9.00
Rank			1		2		3

[1]Reduced application rates of phenoxy herbicides to 1/8 or 1/16 pound/acre and use a ground rig to spray brush annually.

[2]Deep plow and establish love grass involved plowing 1/3 of a ranch's brush and planting it to forage for two years and planting it to love grass the third year.

[3]Reduce cattle numbers to that level the range can handle and use no controls on brush.

higher environmental quality and a higher social well-being for people of the area and the nation, than the other methods of controlling sand sage and schinnery oak.

Deep Plowing and Love Grass Establishment. Sand sage and schinnery oak have been controlled after the rangeland was deep plowed and planted to love grass. This practice destroys the brush and provides superior grazing. It is recommended that only one fifth of the total acreage of rangeland be planted to love grass in order to provide sufficient rangeland to rotate grazing of the love grass and to provide winter grazing. Ranchers using this alternative generally rotated their native and love grass pastures so that eight to ten acres were sufficient for one animal unit year long (six to seven acres of native grass and about two acres of love grass). The estimated net return from this alternative was $15.14 per acre assuming a rotation of cattle from love grass to native rangeland (Table XXI). The impact of this alternative on the economic parameters in the environmental matrix was 2.80 for sand sage control and 2.50 for schinnery oak control (Tables XXII and XXIII).

Love grass did not offer as good a habitat for wildlife as the present method of brush control because the love grass offered little or no cover and less feed for wildlife. Soil erosion on the freshly plowed rangeland has been a problem because the soil is usually sandy and ranchers generally plow one-quarter of a section at a time. The overall impact of this alternative on the environmental parameters was -6.39 for sand sage control and -4.37 for schinnery oak control (Tables XXII and XXIII). Since these values were less than zero the

the alternatives' impact on the environment was less desirable than the present method of controlling sand sage and schinnery oak.

The effect of deep plowing and love grass establishment on the social well-being parameters was 13.55 for sand sage control and 14.60 for schinnery oak control. The net overall impact of this particular alternative was 9.96 for sand sage control and 12.73 for schinnery oak control (Tables XXII and XXIII). The net overall value of this alternative made it more desirable than the present system of control.

Dormant Season Mowing. Sand sage has been controlled by mowing the brush with a shredder type mower. It was suggested that this practice be done every four or five years during the dormant season to minimize damage to the grass. The practice has not killed the sage but it has prevented the brush from taking over the rangeland. The carrying capacity of rangeland under this alternative was about 16 acres per cow per year compared to eight acres per cow per year under the present method of control. The estimated net return per acre for dormant season mowing was $6.77 (Table XXII). The impact on the economic parameters for this alternative method of control of sand sage was -17.13, making it less desirable from an economic standpoint than the present method of control.

The impact on the environmental parameters of this alternative was -1.76, primarily because of the reduction in cover for wildlife and the increase in sedimentation of streams from increased erosion (Table XXI). The impact on the social well-being parameters was 18.30 primarily because of the reduction in herbicide drift damage and the reduction in the possibilities of pesticide poisonings. The net overall impact for dormant season mowing was estimated at -0.59, making it slightly less desirable than the present method of brush control (Table XXII).

Reduce Cattle Numbers. Ranchers reported that in the absence of chemical means of brush control they planned to reduce their herd numbers to the level the range could carry. The carrying capacity was expected to decrease as brush began crowding out the grass. It was estimated that ranchers using such a program would experience net returns of about $8.53 less per acre than with the present method of control (Table XXI).

Reducing cattle numbers and doing nothing to control brush would result in an overstory of brush and an understory of grass, the reverse of the present situation. The resulting habitat was considered to be less beneficial to wildlife than the present system of control. The increase in brush also caused an increase in soil erosion and therefore an increase in sedimentation of lakes and streams. The impact on the _environmental_ parameters for this alternative was -6.50 in sand sage areas and -6.25 in schinnery oak areas (Tables XXII and XXIII). The impact on _social well-being_ from this alternative was 14.25 for sand sage areas and 14.25 in schinnery oak areas, due primarily to the reduction in the possibility of pesticide poisonings (Tables XXII and XXIII). The net _overall_ impact was -27.50 for sand sage control and -9.00 for schinnery oak control; thus, it was less desirable than the present method of control.

Selected Methods to Control Post and Blackjack Oak

Clear Brush Mechanically and Establish Bermuda Grass. Post and blackjack oak in creek bottoms have been successfully removed mechanically (saws or bulldozers). The soil was usually tilled for two or three years to discourage sprouts and then planted to bermuda grass. It has not been necessary to use a herbicide to control weeds on tame pastures; however, one treatment of 2,4-D after planting bermuda grass to control weeds was recommended to provide a better stand. Since bermuda was a warm season grass, ranchers must move cattle to native pastures for the winter and spring. The estimated net return per acre for this alternative was $6.20, a decrease of $1.20 per acre from the net return from the present method of control (Table XXIV). The estimated impact of this alternative on the economic parameters was 3.00 for post and blackjack oak control (Table XXV).

In Osage and Pittsburg Counties the creek bottoms have been the primary habitat for deer. If these areas were cleared and planted to bermuda grass the number of deer may decrease. The wild game birds in the area of bermuda grass pastures have not increased since they have had less cover and less grass seed for food than before. With the reduction in brush, the number of ticks in the vicinity is expected to decrease because the sun in the open pastures would kill them [23, pp. 725-730]. The erosion from a brush covered range has been shown to be 44 percent greater than with a grass cover, so soil erosion is most likely less than with the current method of brush control [8]. The reduction in the use of phenoxy herbicides under this alternative was expected to result in a reduction in the damage from herbicide drift and the possibilities of pesticide poisoning for man and wildlife. For these reasons the environmental impact and social well-being impact

TABLE XXIV

COMPARISON OF ALTERNATIVE METHODS TO CONTROL BLACKJACK AND POST OAK ON RANGELAND IN OSAGE AND PITTSBURG COUNTIES, OKLAHOMA

(Based on 1971-1972 Data)

Parameter	Unit	Present System Control Brush and Weeds	Clear Brush and Plant Tame Grasses	Plant Fescue to Supplement Bermuda Pasture in Winter	Reduce Cattle Numbers
Carrying Capacity	Acre/AUY	9.0	10.0	3.0	20.0
Cost of Inputs	$/Acre	7.95	9.45[1]	43.04[1]	4.75
Cost of Control	$/Acre	2.00	--	--	--
Value of Beef Prod.	$/Acre	17.93	15.65	52.18	7.83
Net Returns[2]	$/Acre	7.44	6.20	9.14	3.08

[1]Includes annual establishment costs and operating costs.

[2]Net returns to land, labor, capital and management.

TABLE XXV

ANALYSIS OF SELECTED ALTERNATIVE METHODS TO CONTROL POST AND BLACKJACK OAK ON RANGELAND IN OKLAHOMA

Parameters	Parameter Weights	Clear Brush and Plant Bermuda, Supplement with Native Rangeland[1] Raw score	Weighted score	Clear Brush and Plant Bermuda, and Fescue Grasses[2] Raw score	Weighted score	Use No Controls On Brush and Weeds, Reduce Cattle Numbers[3] Raw score	Weighted score
I. Impact on Economic Factors	10.00						
A. Change in quantity of output	1.00	-0.50	-0.50	2.00	2.00	-1.50	-1.50
B. Change in quality of output	0.50	0	0	0	0	0	0
C. Change in cost of goods for consumers	2.50	0	0	5.00	12.50	-1.58	-3.95
D. Change in farm income	2.50	1.00	2.50	1.75	4.38	-1.50	-3.75
E. Change in employment in the region	0.50	0	0	1.00	0.50	-1.00	-0.50
F. Change in the number of farms	1.00	1.00	1.00	2.00	2.00	-3.80	-3.80
G. Change in number of acres farmed	2.00	0	0	0	0	0	0
Economic Impact			3.00		21.38		-13.50
II. Impact on Environmental Factors	10.00						
A. Effect on rare and endangered species	2.00	1.00	2.00	-1.00	-2.00	-1.50	-3.00
B. Plant and animal habitat	3.00						
1. Change in number of acres available for wildlife	1.00	0	0	0	0	0	0
2. Change in soil erosion	1.00	-1.00	-1.00	1.00	1.00	-2.00	-2.00
3. Change in food and cover	1.00	-0.50	-0.50	2.00	2.00	-1.00	-1.00
C. Diversity and Stability	2.50						
1. Change in aquatic environment	1.25	-2.00	-2.50	-1.00	-1.25	1.00	1.25
2. Change in vegetation	1.25	-1.00	-1.25	1.00	1.25	-1.00	-1.25
D. Direct Effect on Fish and Wildlife	2.50						
1. Change in the type of fish and wildlife in ecosystem	0.75	-1.00	-0.75	1.00	0.75	-2.00	-1.50
2. Change in acute effects on fish and wildlife	1.00	1.00	1.00	-1.00	-1.00	2.00	2.00
3. Change in chronic effects on fish and wildlife	0.50	1.00	0.50	0	0	2.00	1.00
4. Change in parasites on animals	0.25	-0.80	-0.20	0	0	-1.00	-0.25
Environmental Impact			-2.70		0.75		-4.75
III. Impact on Social Well-Being	10.00						
A. Recreational Opportunities	3.00						
1. Change in water based recreation	1.50	-1.00	-1.50	1.00	1.50	-2.00	-3.00
2. Changes in land based recreation	1.50	1.00	1.50	2.00	3.00	-1.00	-1.50
B. Anxiety Factors	3.50						
1. Change in anxiety due to pesticide residues in food	0.70	1.00	0.70	0	0	2.00	1.40
2. Change in air pollution	0.70	2.50	1.75	1.00	0.70	5.00	3.50
3. Change in drift damage	0.70	2.50	1.75	1.00	0.70	5.00	3.50
4. Change in stream water quality	0.70	-1.00	-0.70	0	0	-2.00	-1.40
5. Change in number of pests in the environment	0.70	-1.00	-0.70	0	0	-2.00	-1.40
C. Other Human Life Considerations	3.50						
1. Change in aesthetics	0.75	2.50	1.88	0	0	5.00	3.75
2. Change in number of poisonings (not fatal)	1.25	3.00	3.75	1.00	1.25	3.00	3.75
3. Change in number of deaths from pesticides	1.25	3.00	3.75	1.00	1.25	3.00	3.75
Social Well-Being Impact			12.18		8.40		12.35
Overall Impact			12.48		30.53		-5.90
Rank			2		1		3

[1]Clear oak brush mechanically in bottoms and slight slopes and then establish bermuda grass to supplement native pastures.

[2]Clear oak brush mechanically in bottoms and establish bermuda grass, supplement with fescue grass established on slopes by spraying and burning existing brush.

[3]Reduce cattle numbers to the level the range can carry, and use no brush control program.

were -2.70 and 12.18, respectively, to control post and blackjack oak (Table XXV). The net overall input of this alternative was 12.48, giving it second ranking among the selected alternatives analyzed.

Establish Fescue to Supplement Bermuda Grass. This alternative combined with the one above (bermuda grass established in creek bottoms after mechanical clearing) improved the available native pasture for winter grazing. Fescue grass has proven to provide cool season grazing in eastern Oklahoma. In experiments fescue grass was established by spraying the timber once with two pounds of 2,4,5-T per acre, following that up with a cool burn[1] in the fall and then seeding fescue and fertilizing by airplane [34]. One acre of fertilized fescue grass established in this manner provided sufficient feed for one cow for five to six months. Under this program (rotating cattle from bermuda in the summer to fescue in the winter), three acres of pasture could carry an animal unit a full year. The estimated return per acre for this alternative was $9.14 per acre, about $2.30 per acre more than the present system of control (Table XXIV). The increase in labor to move cattle (for rotation) and clearing brush increased employment in the area (Table XXIV). This alternative produced more beef per acre than the current method of control, providing more beef for the market and therefore resulting in an increase in consumers' surplus or net savings in food costs for consumers. The estimated economic impact of this alternative on the economic parameters in the environmental matrix was

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[1]A cool burn is the term for a controlled fire to clear under brush and litter on rangeland. It usually takes advantage of low winds, and sufficient fire lines are usually prepared before burning.

21.38 (Table XXV). The fixed cost of this alternative was estimated at $130.00 per acre.

Where fescue has been established for cool season grazing the local deer populations have increased as well as the populations of other wildlife species. The animals were attracted to the fields because they were the only green fields in the area during the winter. The increase in wildlife, particularly deer, could prove to be an economic asset if ranchers were able to sell hunting rights to their lands. The environmental and social well-being impacts of this alternative brush control method were 0.75 and 8.40, respectively (Table XXV). The net overall impact of this alternative control method was 30.53, the highest of the alternatives analyzed for blackjack and post oak control.

Reduce Cattle Numbers. Over one half of the ranchers interviewed in Osage and Pittsburg Counties said they would reduce cattle numbers if they could not control brush and weeds with phenoxy herbicides. Technical advisers predicted that the rangeland would gradually change from grassland to an oak brush overstory and a grass understory. This change in the mixture of plants on rangeland would reduce the carrying capacity to about one cow per 20 acres. It would also reduce the quality of the environment. Ranchers in Osage and Pittsburg Counties who reduced cattle numbers could expect a net return of $3.08 per acre (Table XXIV). The impact on the economic parameters is -13.50 (Table XXV).

The environmental quality would most likely decrease if oak brush was not controlled because the food supply for grazing and seed eating wildlife would probably decrease. Since soil erosion under such an alternative would increase, sedimentation of streams most likely increases [8]. The increase in brush also would cause an increase in ticks, decreasing the quality of life for wildlife and livestock and also the quality of the recreational experience [23, pp. 725-730]. The impact of the alternative on the environmental and social well-being parameters was -4.75 and 12.35, respectively (Table XXV). The primary reason for the positive impact on social well-being was the reduction in the possibility of pesticide poisonings and deaths from pesticides. The net overall rating of this alternative was -5.90, making it considerably less desirable than the alternative of bermuda and fescue grass establishment described above, with an overall impact of 30.53.

Analysis of Alternative Methods to Control the Bollworm Complex on Cotton

Alternative methods of controlling bollworms, budworms and other harmful insects on cotton have been under investigation for some time in Oklahoma as well as other parts of the nation. The alternatives selected for analysis were those that have been successfully used in Oklahoma and have been used or could be implemented in the near future. The alternative control measures were for irrigated cotton, since dryland cotton has not had significant insect problems. The alternatives were: (1) use non-persistent insecticides; (2) utilize a scouting program to monitor insect levels; (3) plant strips of grain sorghum among rows of cotton; and, (4) use no biological or chemical insect controls.

Non-Persistent Insecticides

In recent years cotton farmers have used toxaphene and methyl-parathion to control insects. Toxaphene is moderately persistent in the environment. DDT has been restricted for the same reason in the future. The alternative method of control without toxaphene is to use methyl-parathion or other non-persistent pesticides. Because it has less persistence, farmers have to use methyl-parathion more frequently than under the present method of control (an application each four to six days). This results in an increase in the total number of applications per acre. Assuming four levels of water consumption for cotton, budgets for southwestern Oklahoma were estimated (Table XXVI). As described in Chapter III of this thesis, water consumption affects the growing vigor of cotton and therefore the level of insect infestation. Under the first water consumption strategy, light rainfall and no irrigation, cotton farmers using non-persistent insecticides would experience about the same net returns per acre as the present method of control. However, at the other three levels of water consumption, the estimated net returns per acre under this alternative were less than those for the present method of control (Table XXVI). The impact of this alternative on the economic parameters was -0.50, just slightly less desirable than the present method of control (Table XXVII).

The use of methyl-parathion to control the bollworm complex on cotton created a greater potential problem from acute poisoning of wildlife than the present method of control. However, the non-use of toxaphene would eliminate most fish kills because light applications

TABLE XXVI

COMPARISON OF YIELDS AND NET RETURNS FOR IRRIGATED COTTON GROWERS IN SOUTHWESTERN OKLAHOMA, FOR ALTERNATIVE METHODS OF INSECT CONTROL, AND FOUR LEVELS OF WATER CONSUMPTION

(Based on 1972 Costs)

	Present Control System				Non-Persistent Insecticides				Scouting Program				Strip Cropped Cotton				No Control of Insects			
	I[1]	II	III	IV	I[1]	II	III	IV	I[1]	II	III	IV	I[1]	II	III	IV	I	II	III	IV
Lint Yield (lbs/acre)	350	600	700	900	350	600	700	900	350	600	700	900	350	600	700	900	0	0	0	0
Number of Insecticide Applications	0	2-3	6-7	6-10	0	5-6	9-10	9-13	0	0	3-4	3-7	0	0	0	0	0	0	0	0
Cost of Insect Control ($/acre)	0	6.00-9.00	18.00-21.00	18.00-30.00	0	11.00-13.50	20.00-22.50	20.00-29.25	0	0	7.00-10.00	7.00-16.75	0	0	0	0	0	0	0	0
Net Returns[3] ($/acre)	62.30[2]	101.50-104.55	108.80-111.80	138.40-150.40	62.30	97.00-99.50	107.30-109.80	139.20-148.50	62.30	110.50	119.80-112.80	151.70-161.40	69.70	119.90	140.10	182.90	0	0	0	0

[1]Rainfall and Irrigation Levels:
- I Light rainfall (14 inches) and no irrigation water,
- II Moderate rainfall (18 inches) and limited irrigation, 9 inches available,
- III Light rainfall (14 inches) and sufficient irrigation, 18 inches available, and
- IV High rainfall (30 inches) and sufficient irrigation, 18 inches available.

[2]Operating costs average 11.5¢ per pound of cotton, pre-emerge herbicide costs $5.25 per acre.

[3]Returns to Land, Labor, Capital and Management.

TABLE XXVII

ANALYSIS OF SELECTED ALTERNATIVE METHODS TO CONTROL INSECTS IN COTTON IN SOUTHWESTERN OKLAHOMA

Parameters	Parameter Weights	Use Non-Persistent Insecticides[1]		A Scouting Program to Monitor Insect Levels[2]		Strip Crop Cotton With Other Crops[3]		Use No Controls[4]	
		Raw score	Weighted score	Raw score	Weighted score	Raw score	Weighted score	Raw score	Weighted score
I. Impact on Economic Factors	10.00								
A. Change in quantity of output	1.00	0	0	0	0	0	0	-2.00	-2.00
B. Change in quality of output	0.50	0	0	0	0	0	0	0	0
C. Change in cost of goods for consumers	2.50	0	0	0.55	1.38	0.89	2.22	-5.00	-12.50
D. Change in farm income	2.50	-0.20	-0.50	1.70	4.25	5.00	12.50	-5.00	-12.50
E. Change in employment in the region	0.50	0	0	1.00	0.50	-1.00	-0.50	-2.00	-1.00
F. Change in the number of farms	1.00	0	0	0	0	0	0	-1.00	-1.00
G. Change in number of acres farmed	2.00	0	0	0	0	0	0	0	0
Economic Impact			-0.50		6.13		14.22		-29.00
II. Impact on Environmental Factors	10.00								
A. Effect on rare and endangered species	2.00	-1.00	-2.00	0.50	1.00	4.00	8.00	1.00	2.00
B. Plant and animal habitat	3.00								
1. Change in number of acres available for wildlife	1.00	0	0	0	0	0	0	0	0
2. Change in soil erosion	1.00	0	0	0	0	0	0	0	0
3. Change in food and cover	1.00	0	0	1.00	1.00	2.00	2.00	1.00	1.00
C. Diversity and Stability	2.50								
1. Change in aquatic environment	1.25	1.00	1.25	0.50	0.62	2.00	2.50	2.00	2.50
2. Change in vegetation	1.25	0	0	1.00	1.25	0	0	-1.00	-1.25
D. Direct Effect on Fish and Wildlife	2.50								
1. Change in the type of fish and wildlife in ecosystem	0.75	-1.00	-0.75	0	0	2.00	1.50	1.00	0.75
2. Change in acute effects on fish and wildlife	1.00	-0.50	-0.50	0.50	0.50	2.00	2.00	2.00	2.00
3. Change in chronic effects on fish and wildlife	0.50	1.00	0.50	0.50	0.25	2.00	1.00	2.00	1.00
4. Change in parasites on animals	0.25	0	0	0	0	-1.00	-0.25	-2.00	-0.50
Environmental Impact			-1.50		4.62		16.75		7.50
III. Impact on Social Well-Being	10.00								
A. Recreational Opportunities	3.00								
1. Change in water based recreation	1.50	0	0	0	0	0	0	0	0
2. Changes in land based recreation	1.50	-0.50	-0.75	0.50	0.75	1.00	1.50	-1.00	-1.50
B. Anxiety Factors	3.50								
1. Change in anxiety due to pesticide residues in food	0.70	0	0	0	0	1.00	0.70	1.00	0.70
2. Change in air pollution	0.70	1.00	0.70	0.50	0.35	2.00	1.40	2.00	1.40
3. Change in drift damage	0.70	-0.50	-0.35	0	0	2.00	1.40	2.00	1.40
4. Change in stream water quality	0.70	0.50	0.35	0.50	0.35	2.00	1.40	2.00	1.40
5. Change in number of pests in the environment	0.70	0.50	0.35	0.25	0.17	-1.00	-0.70	-1.00	-0.70
C. Other Human Life Considerations	3.50								
1. Change in aesthetics	0.75	0	0	0	0	-0.50	-0.37	-1.00	-0.75
2. Change in number of poisonings (not fatal)	1.25	-0.50	-0.62	0.50	0.62	4.00	5.00	5.00	6.25
3. Change in number of deaths from pesticides	1.50	-0.50	-0.75	0.50	0.75	4.00	6.00	5.00	7.50
Social Well-Being Impact			-1.07		2.99		16.33		15.70
Overall Impact			-3.07		13.74		47.30		-5.80
Rank			3		2		1		4

[1]Using non-persistent insecticides involved farmers refraining from using toxaphene and using primarily methyl-parathion.

[2]A scouting program involved monitoring levels of beneficial and harmful insects and recommending insecticide application when harmful insects reached an economic threshold.

[3]Strip cotton with other crops involved planting four rows of grain sorghum between each 24 rows of cotton to gain an interaction of insects.

[4]Use no controls typifies the short run effect of restricting all insecticides.

of methyl-parathion do not kill fish if drift inadvertently occurs. The impact of this alternative on the environmental parameters was was -1.50 (Table XVII).

The increased use of methyl-parathion increased the incidence of poisoning of man so the resulting change in the social well-being was in part less desirable than the present system of control. The estimated impact of a non-persistent insecticide strategy on social well-being was -1.07 and the overall impact of the alternative was -3.07 (Table XVII). Overall, the use of non-persistent pesticides to control cotton insects was less desirable than the current method of insect control.

Scouting Program to Monitor Insects

In this altèrnative, trained personnel check the cotton fields each week to determine levels of beneficial and harmful insects and to recommend spraying with registered insecticides when harmful insect populations reach an economically damaging level. An economic threshold[2] for the bollworm complex has been specified through observations of damage to cotton from various levels of insect infestations. This alternative method of control may not reduce the number of insecticide applications but it does insure that the applications are made only when they are needed and that farmers do not just spray on a four or six day cycle as the present method of control does.

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[2]An economic threshold is usually defined as the level at which damage can no longer be tolerated and, therefore, the level at or before which it is desirable to initiate deliberate control activities. In economics the definition is amended to consider a more critical threshold density as that where the loss caused by a pest just equals in value the cost of available control measures.

A pilot scouting program on cotton was conducted in 1972 in southwestern Oklahoma. The resulting yields were equal to or greater than those in fields under the present method of control. On the average, cotton farmers in the scouting program in 1972 saved three to four insecticide applications by following the scouts' recommendations. The net returns under this control method were $6.00 to $11.00 per acre greater than the present system, comparing similar water consumption levels (Table XXVI). The impact from this alternative on the economic parameters in the environmental matrix was 6.13 (Table XXVII).

Based on results from the 1972 cotton scouting program in Oklahoma the resulting environmental quality and social well-being were both improved over the present method of control. The estimated impact on the environmental parameters was 4.62 and the estimated impact on the social well-being parameters was 2.99 (Table XXVII). The net overall impact of this alternative control measure was 13.74, considerably more desirable than the present method of control.

Strip Cropping Cotton

It has been determined that by planting grain sorghum between rows of cotton, the insects in the two crops interact and result in a biological control of the tobacco budworm and the cotton bollworm [51]. Other strip crops have been analyzed in experiments; thus far, grain sorghum has proven to be the best crop. The resulting per acre yields from experimental farms have been equal to the average yields on irrigated cotton in Altus and Tipton, Oklahoma. In four years of testing no insecticides have been needed. However, if bollweevils had reached the economic threshold prior to mid-August, a spray program would have been initiated.

The net returns were $15.00 to $33.00 per acre greater for this alternative (at respective water consumption levels) than the net returns for the present method of control (Table XXVI). This added return was due to the savings in insecticide treatments and the added revenue from the grain sorghum produced as a by-product. The impact from strip cropping grain sorghum in cotton on the economic parameters in the environmental matrix was 14.22 (Table XXVII).

Due to the reduction in insecticide use there was less insecticide entering the environment each year so both men and wildlife benefited. Shattering of grain in the strips of grain sorghum in the cotton provided feed for the wildlife that winter in southwestern Oklahoma, enhancing the environment for wildlife and also improving hunting opportunities in the area. The net impact of this alternative on the environmental and social well-being parameters was 16.75 and 16.33, respectively (Table XXVII). The net overall impact of strip cropping grain sorghum with cotton was 47.30, making it the most desirable of all alternatives analyzed.

No Control of Insects on Cotton

Cotton farmers surveyed in southwestern Oklahoma reported that they would not plant cotton on irrigated farmland if they could not use insecticides and had no biological control alternatives. Farmers reported that they would plant their irrigated land to other crops and plant cotton on dryland only. The quality of the environment under this particular alternative would depend upon the crop substituted for cotton and the type and extent of insecticide control it required. Insecticides presently used on cotton may cause fewer cases of poisoning of humans and wildlife than the insecticides used on the replacement crops, thus causing a decrease in the environmental quality and social well-being. For example, if pasture were planted to replace cotton the herbicide (2,4-D) used to control weeds could cause extensive damage to dryland cotton in the area. The impact on the economic parameters for this program was estimated at -29.00. The environmental and social well-being parameters had impacts of 7.50 and 15.70, respectively (Table XXVII). The net overall impact of this alternative was -5.80, making it less desirable than the present system of insect control on cotton.

Incentives to Encourage Adoption of Alternative Methods to Control Pests

Assume that society prefers to have pests on selected crops controlled by the alternative method that provides the greatest positive overall impact in the environmental impact analysis. The preferred method to control sand sage and schinnery oak would be to use reduced application rates. The preferred method to control blackjack and post oak would be to establish fescue to supplement bermuda grass. The preferred method to control insects on cotton would be to strip crop cotton with grain sorghum.

These three preferred methods of control all involve a change from the present system of control. Several incentives may be considered to induce farmers and ranchers to adopt these alterantive methods of pest control. Inducements or incentives that work through the market, educational and judicial systems have been used in other environmental quality situations. The analysis of incentives was not an all inclusive study of incentives but an analysis of incentives that have been used successfully in the past. Federal cost sharing of fixed costs for chemical and mechanical brush control, as well as bermuda grass establishment has been used until 1973. The program was administered by the Agricultural Stabilization and Conservation Service. Another incentive, a federal crop insurance program, has been used in the Great Plains to protect farmers from weather factors. The program has paid its own way since 1963, when premiums were greater than indemnities. Educational programs, as an incentive for adoption of new techniques, have been used successfully for many years. The best example of its use is the adoption of hybrid corn.

Incentives for Reduced Application Rates

Economic incentives to encourage adoption of this alternative are not necessary because the profit motive is sufficient to induce adoption. The increase in net returns per acre for this alternative over the present method of control is $2.03; the initial fixed cost per acre of the alternative is estimated at $0.25 (Table XXI). Since a rancher is able to pay the fixed costs of this alternative in the first year from added net returns, the profit motive should be sufficient to encourage adoption. By avoiding a formal incentive program such as a cost-sharing program, the taxpayers' cost of obtaining the desired change would be negligible.

Educational programs have been used in the past to speed up adoption of new farming practices and in this particular case such a program may be useful. An educational program conducted through cooperation of the Oklahoma Extension Service and the Southern Great Plains Research Station would serve to encourage ranchers' adoption of the reduced application rates strategy. Such a program should stress the major benefits of the alternative from a rancher's standpoint: increased net returns per acre; annual control of weeds; low fixed costs; and, being able to do the work themselves. The educational program also should be aimed at environmental groups to inform them of the environmental and social benefits of the alternative over the current method of control and no brush control (Tables XXII and XXIII).

Incentives for Establishing Fescue Grass to Supplement Bermuda Grass

The establishment of fescue and bermuda grass as an alternative method to control blackjack and post oak is the preferred method of control, assuming that society wants an alternative that maximizes the positive overall impact. If brushland that has not been controlled were to be cleared and planted to tame grasses an estimated increase in net returns to land, labor, capital, and management of $6.06 per acre would be received (Table XXIV). Capitalizing this at five percent, the present value of added productivity would be $121.20 per acre, just slightly less than the $130.00 per acre of fixed costs for the alternative. A cost-sharing program of 50 percent of the cost of establishing grass averaging about $15.00 per acre, should be sufficient to encourage adoption of the alternative if the land has had no control in the past. The program would be similar to that of the Agricultural Stabilization and Conservation Service of USDA with REAP prior to 1973.

If brushland has been sprayed in the past with 2,4,5-T in a ten year program, the estimated increase in net returns per acre for this combination of fescue and bermuda is $1.70 per acre (Table XXIV). Capitalizing this increase in net returns at five percent results in an increase in land value of $34 per acre, not sufficient to warrant a $130 per acre investment. So if brush is being controlled with 2,4,5-T an incentive based on 75 percent cost-sharing of the fixed costs would be necessary to gain adoption of the alternative. Such an incentive would cost the taxpayers an estimated $97.50 per acre.

An educational program to inform ranchers of the benefits from using fescue and bermuda instead of spraying herbicides would possibly shorten the adoption time period. The program should also be directed toward environmental groups to educate them as to the environmental benefits of the alternative over the present method of control and no control of brush (Table XXV).

Incentives for Strip Cropping Cotton

The preferred alternative to the present method of insect control on irrigated cotton was to plant rows of grain sorghum between rows of cotton. Cotton farmers in the past typically sprayed as a precaution, even if no significant insect damage had occurred. Thus, the alternative method of planting strips of sorghum and using no insecticides involves a drastic change for farmers. The change in production practices may be so drastic for farmers that a formal incentive may be necessary to gain adoption.

A possible incentive would be to provide a subsidized insurance policy to growers, insuring them against decreased yields due to insect damage. Such a program would work the same way private hail insurance policies, and the Federal Crop Insurance Program does. However, the policy would protect the grower against decreased yields due to harmful insects instead of hail damage. The added returns from the alternative are considered sufficient to gain adoption if an insurance program was available. The cost to society of this incentive would be the difference between policy payoffs and growers' premiums. The benefits to society would be reduced pesticide use, increased production, decreased prices and an improved social well-being (Table XXVII). An educational program would speed up the adoption process.

Each of the preferred alternatives required a basic change in production practices for farmers so an incentive was needed to insure adoption. The incentives could work through the market place as cost-sharing of fixed costs or through state of federal regulations as pesticide restrictions. The educational program suggested as an incentive to encourage adoption, would work through the adoption process and thus the social system in the area.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Summary

Method

The general objective of this thesis was to determine the level of pesticide use and the extent of environmental damage and benefits under alternative strategies for controlling cotton and rangeland pests. The specific objectives were: (1) to determine the relationships between present pesticide use and environmental quality in Oklahoma; (2) to analyze present and alternative methods of controlling pests on cotton and pastureland with respect to economics and the quality of the environment; and, (3) to examine various incentives that may encourage adoption of alternative pest control measures.

The need for the study arose from the pesticide paradox. Without pesticides the increase in weeds and insects would cause farm output to decrease thus causing the cost of food to increase. With pesticides the possibility exists for adverse effects on non-target humans, plants, animals, soil and water. This possibility of adverse effects has prompted environmental groups to lobby for legislation to restrict such use. A major effort of this study was to determine the extent of pesticide benefits and costs on selected crops in Oklahoma based on various restrictions in agricultural pesticide use, and on alternative methods of control.

Benefits to consumers from pesticide use on selected crops were estimated by demand analysis. Changes in consumers' surplus due to added farm output were estimated from elasticities of demand and average output and prices. Alternative methods for controlling pests on selected crops were analyzed with an environmental impact matrix. The impact of each alternative method of control on environmental quality, social well-being and economic parameters was determined by use of an environmental impact matrix. Both qualitative and quantitative data were estimated and analyzed for each alternative. The parameters in the matrix were developed specifically to fit this study of pesticide use. Weights were assigned to each parameter according to its value in the decision making process from a policy standpoint.

Cotton and rangeland were selected as the study crops. Cotton was selected because Oklahoma farmers have used more insecticides on cotton than on any other crop and DDT had been used to control insects on cotton. DDT was under review by EPA at the time the crops were selected and has since been restricted. Rangeland was selected because 500,000 acres of rangeland in Oklahoma have been treated annually for brush and weeds, and the herbicide (2,4,5-T) used was under review by EPA for possible registration cancellation when this study was initiated. Four cotton producing counties, Jackson, Harmon, Tillman and Washita, were selected as one study area. The counties selected for the rangeland study area, Woodward, Osage, and Pittsburg Counties, were selected on the basis of the type of brush controlled.

Information on the extent of pesticide use, application rates and the effect of pesticide use on the environment was obtained by surveying farmers, technical advisers, and licensed applicators who had treated the selected crops in the study areas. Information concerning environmental damage was also obtained from reports made by the State Board of Agriculture fieldmen, who are charged with investigating all reported cases of pesticide damage or misuse. Other data sources were: Oklahoma State Health Department, Oklahoma Poison Control Center, Oklahoma Pollution Control Board, Oklahoma Geological Survey and the Environmental Protection Agency.

Results

Extent of Pesticide Use. Over the past twenty years the practice of controlling weeds and brush on rangeland in Oklahoma has grown from 20,000 acres treated annually to over 500,000 acres treated annually. The number of rangeland acres in Woodward County treated for brush quadrupled between 1961 and 1972; the number of acres treated in Osage County doubled in the same period. Brush control on rangeland in Pittsburg County increased by 50 percent between 1961 and 1972. Ranchers and licensed applicators controlling brush and weeds on rangeland reportedly used application rates that were less than or equal to the rates recommended by the Department of Agronomy at Oklahoma State University.

The extent of insecticide use on cotton farms is a function of the harmful insect population which, in turn, is dependent upon the vigor of the cotton. Vigorously growing cotton attracts harmful insects which require treatment. Since cotton grows more vigorously in wet years or with irrigation, chemical treatment is greatest in wet years or in years with sufficient water for irrigation. For this same reason dryland cotton in Oklahoma seldom has been treated with insecticides.

Farmers in the study area treated more cotton for insects in 1970 than in 1971 because 1970 was a much wetter year. The number of acres of cotton treated with herbicides was relatively constant between years. Cotton farmers generally applied herbicides before planting to help control weeds. Herbicide use is not a function of rainfall in the growing season.

Cotton farmers in the study area that have used herbicides and insecticides to control pests generally applied pesticides at rates that were less than or equal to the recommended rates. Cotton farmers have been substituting toxaphene and methyl-parathion for DDT. Over the period studied (1961-1971), cotton farmers in the study area decreased the use of DDT as much as 100 percent in Jackson County and by about 22 percent in Harmon County. The reason given for this substitution was that the bollworm complex has become resistant to DDT.

It was estimated that 50 percent of the chemical <u>weed</u> control in the rangeland survey area was done by ranchers who either owned or leased spray equipment. However, the majority of the <u>brush</u> control in the study area was done by licensed applicators. In 1971 and 1972 licensed applicators treated 75 percent of the total acreage treated for chemical brush control in Woodward County, about 60 percent in Pittsburg County, and about 95 percent in Osage County. The extent of brush control practiced by farmers was a function of the type of brush (short sand sage or large post or blackjack oak) and the terrain (rough and broken or sandy and rolling).

All cotton farmers interviewed in the study area reported owning spray equipment and most of the farmers did their own herbicide spraying, but few reported doing their own insecticide spraying. In 1970 and 1971 licensed applicators did about 25 percent of the chemical weed control and all of the chemical insect control in the cotton study area.

Economics of Pesticide Use. The carrying capacity of native rangeland has been doubled and even tripled after chemical brush and weed control. The increse depends upon the type and density of the brush and the amount of grass that was originally in the field. Chemical insect control on cotton has been responsible for increases in yield ranging from 50 to 150 pounds of lint per acre, depending upon water consumption. Chemically controlling weeds on cotton resulted in an additional 20 pounds of lint per acre on the average.

Ranchers' net returns to land, labor, capital and management have increased as a result of brush and weed control. In Woodward County the increase in net returns was estimated at $5.62 per acre, and in Osage and Pittsburg Counties the estimated increase was $2.44 per acre. Net returns have been increased as insects have been controlled chemically. On dryland cotton, in a heavy rainfall year, insecticide treatments added an estimated $22.00 per acre in net returns (Table XIV). Irrigated cotton growers indicated they would not plant cotton if they could not use insecticides. Thus, the positive difference in net returns between cotton and the next best alternative crop was their net return from pesticide use.

No evidence was found to support the hypothesis that herbicides used on rangeland adversely affected the quality of beef produced. Several research studies have indicated that little possibility exists of the herbicide reaching consumers in the market place through beef produced on treated rangeland. The use of insecticides on cotton has not deteriorated the quality of fiber produced or adversely affected the price received for cotton.

The number of acres used for grazing cattle remained constant whether or not ranchers used herbicides to control brush. However, if brush was not controlled, the amount of soil erosion likely would increase and the quality of lakes, rivers and rangeland would decrease. The number of acres of farmland used for cotton production in Oklahoma was dependent in part upon pesticide use to control insects. Without the benefit of pesticides in 1972, farmers would have had to plant an additional 130,000 acres, to produce the same amount of cotton that was produced in 1972.

When pesticides were used to control brush and weeds on rangeland and insects and weeds on cotton, the resulting increase in yields caused output to increase. The increase in output of beef and cotton in Oklahoma has increased consumers' surplus, i.e., has provided consumers a net savings. Increased beef production in Oklahoma resulted in a net savings of $15,880,000 in 1971 and added cotton produced in 1971 resulted in a savings of about $1,300,000 to consumers. These were direct benefits to consumers of pesticide use on selected crops in Oklahoma

Environmental Quality and Pesticide Use. The effects of 2,4-D and 2,4,5-T on livestock and wildlife was of little consequence in Oklahoma. There were no reported deaths of livestock or humans from these herbicides in the study area. Research by others has indicated that these herbicides are rapidly eliminated from animals thus reducing the change of humans contracting the chemical in meats. The herbicides used on cotton (Treflan, Planavin, and others) have not caused any livestock or wildlife deaths or human sickness in the cotton study area.

The major insecticides used on cotton in the study area (toxaphene, DDT, methyl-parathion) have caused minor damage to man, livestock and wildlife. Some environmental damage from these insecticides was reported in each of the cotton survey counties. A total of 54 beehives were killed in the study area by toxaphene and methyl-parathion over the study period (1961-1971). Several farm ponds have had fish killed by toxaphene drift. The largest such incident was a fish kill of about 100 carp in Skull Creek (Jackson County) in 1968. A farmer's misuse of methyl-parathion resulted in the death of 16 of his own cows; he sprayed them with a spray rig that had not been cleaned out thoroughly.

Phenoxy herbicides used on rangeland have been responsible for light damage to non-target vegetation in the study area. The majority of the damage was to cotton and small gardens. In Osage County cash settlements of about $1,600 were made by licensed applicators in 1972 for damage to gardens, pecan trees and cotton. In 1972 no damage in Woodward County was reported to the State Board of Agriculture; in Pittsburg County one settlement of $50 was made in 1972. Whenever one rancher damaged another, no settlements were made and the resulting externalities likely were not investigated unless a licensed applicator was accused for the damage. There have been some external benefits from phenoxy herbicides used on rangeland: reduced tick populations, reduced soil erosion, increased soil moisture, increased palatability of grasses and weeds, and an increase in wildlife numbers.

Proof?

Herbicides used on cotton for weed control reportedly did no damage to non-target vegetation. However, desiccants and defoliants have caused minor damages. Arsenic acid occasionally burned the tops of forage crops adjacent to cotton fields, preventing their being grazed. The damage from this herbicide was less than $500 annually in Washita and Tillman Counties over the study period.

Acute poisoning of humans (resulting in death) in Oklahoma from agricultural pesticides has been low relative to the state's population. Between 1962 and 1970 twenty persons were killed by agricultural pesticides, and only eight of these cases were farm residents. Six of the eight farm persons killed were from accidents while two were suicides. No farm children were killed by pesticides during the period, even though pesticides were widely used. Practicing physicians in Oklahoma reported that the number of pesticide poison cases treated were relatively constant during 1971 and 1972 as compared to other years.

The extent of pesticide poisoning that resulted in sickness has been relatively constant. For the past six years the number of emergency calls at the Oklahoma Poison Control Center has fluctuated between 2,200 and 3,000. The number of calls related to agricultural pesticides has been about five percent of the total calls between 1966 and 1972. Of the 47 licensed applicators interviewed, only one reported having missed any work due to pesticide poisoning. None of the cotton farmers reported sickness or loss of work from using pesticides on cotton and only one rancher reported being sick. He was reportedly poisoned by a cattle spray.

The possibility of water supply contamination with agricultural pesticides has been discussed widely. In Oklahoma five years of water sampling and analysis have failed to show any accumulation of phenoxy herbicides, DDT, toxaphene, methyl-parathion, or other pesticides used on selected crops in Oklahoma. Pesticide residues in the water samples never were greater than the maximum levels established by the federal government for water quality.

Alternative Methods of Pest Control

Several alternative methods of brush and insect control on selected crops were analyzed: (1) present method of control; (2) reduced herbicide application rates; (3) deep plow and establish love grass; or (4) reduced cattle numbers. Sand sage has also been controlled by dormant season mowing. Based on an environmental impact matrix analysis of these alternatives, the best alternative from an economic and environmental standpoint was reduced application rate. This was also the best alternative, assuming society preferred the alternative method of control that resulted in the greatest positive overall impact on the environment, economic parameters and social well-being.

The alternative methods to control post and blackjack oak analyzed in the thesis were: (1) clear brush mechanically and plant the land to bermuda grass; (2) establish fescue to supplement bermuda established on cleared land; or (3) reduce cattle numbers and not control brush. The preferred alternative for society was to establish fescue to supplement bermuda grass. Several alternative methods to control insects on cotton were analyzed: (1) non-persistent insecticides; (2) insect scouting programs; (3) strip cropping cotton; and, (4) no chemical or biological insect controls. From the analysis of the environmental impact matrix, the strip cropping alternative had the largest positive impact on the economic parameters, environmental quality and social well-being.

Assuming that society wanted pests on selected crops controlled by the alternative that resulted in the largest positive net impact, various incentives could be used to encourage adoption. Incentives that have been used in the past were analyzed in this thesis.

The profit motive was sufficient to insure adoption of reduced application rates to control sand sage and schinnery oak. The adoption process could be shortened by using an educational program to advise ranchers of the benefits of this alternative.

Incentives to encourage adoption of the alternative of establishing fescue and bermuda grass to control brush on rangeland depended upon the present method of brush control. If no brush control had been used in the past, a 50 percent cost-sharing incentive (on the $30 per acre cost of establishing bermuda grass) by the federal government was estimated to be sufficient to insure adoption. If brush had been controlled with 2,4,5-T in the past, a 75 percent cost-sharing program (on all fixed costs) by the federal government was considered necessary to insure adoption. Since the total cost of establishing bermuda and fescue under this alternative was an estimated $130 per acre, the federal government initially would need to pay about $97.50 per acre of the fixed costs to insure adoption. This is more expensive than most programs used to date. An educational program also was considered to be a necessary part of the incentives to encourage adoption.

A federal or private insurance program to insure farmers against decreased yields due to insect damage was a possible incentive to gain adoption of strip cropping cotton, as an alternative to insecticide treatments. This alternative required drastic changes in cultural practices, thus even though it increased net returns per acre, farmers were not likely to adopt this practice without a guarantee against possible loss of yield. Such an incentive simply insured cotton yields against damage by harmful insects if cotton was planted according to recommendations of this alternative method of control.

Conclusions and Recommendations

The restriction of DDT by the Environmental Protection Agency is not going to reduce cotton farmers' ability to control insects in the study area. Farmers have been substituting methyl-parathion and toxaphene for DDT for the past six years. However, this substitution most likely will increase the number of pesticide poisonings of humans because methyl-parathion is more toxic than DDT.

The alternative method of pest control that provides the greatest positive overall impact on society was assumed to be the preferred alternative. The preferred method to control sand sage is reduced application rate; to control post and blackjack oak, the ideal method is to establish fescue and bermuda grass after mechanically and chemically controlling brush; to control insects on cotton, the best method is to strip crop cotton with grain sorghum. By definition the preferred alternatives improve the overall social well-being of the region and nation. Incentives needed to insure or speed up the adoption process for the preferred alternative methods of control depend upon the change in farmers' net returns and the change in farming practices required by the alternative.

Each of the preferred alternatives have similar implications on farmers, consumers and environmental quality. Farmers' net returns per acre are greater under the preferred method of control than the present system. Farm output is estimated to increase under the preferred alternatives. The increase in output results in an estimated increase in consumers' surplus so consumers receive a net savings in food expenditures as a result of farmers adopting the preferred alternative.

The reduction in pesticide use, decrease in soil erosion, and change in wildlife feed and cover are the primary benefits to environmental quality from the preferred alternatives. The decreased use of pesticides also reduces the possibilities of pesticide poisonings of people, either acute or chronic, as well as reducing pesticide drift damage, air pollution and residues in the environment.

Farmer adoption of the preferred alternatives will result in a reduction in the use of pesticides and thus reduce the licensed applicators' incomes. However, these businessmen could use their equipment to treat other crops or treat the selected crops according to the requirements of the preferred alternative. Also, applicators could move to other regions or nations where these pesticides are still being used as Oklahoma farmers' have in the past.

Future Research Needs

Additional research is needed in the area of farmer externalities created by pesticide use and non-use. Farmers generally are not being sued or held responsible for off-site damage done by their spraying.

Also they are not compensated for off-site benefits to others created by spraying. The problem should be approached by surveying all farmers in a study area to determine the extent of use and non-use of pesticides and the value of benefits and costs created. In such a project, the researcher should be careful not to use the term "pesticides" because farmers' definition of this term is a chemical that kills insects. Many do not consider herbicides for weed and brush control to be a pesticide.

The increased farm output and decreased production costs associated with the preferred alternative methods of pest control could change Oklahoma's competitive position in the market. Since the preferred alternatives reduce the cost of producing a given amount of output, Oklahoma ranchers may gain an absolute advantage in beef production over other regions of the United States. Cotton farmers likewise, may increase their comparative advantage in the market. Such a shift in regional specialization has many policy implications for agricultural production and input use and needs to be researched further to determine the impact on farm size, farm income and other regions of the nation.

An in-depth analysis is needed of the impact on rural communities of adopting preferred alternative methods of pest control. The impact on licensed applicators and other input suppliers needs to be determined before we can understand the full impact on rural communities and private and social well-being. Input-output analysis is a tool that could be used in such an analysis.

Additional research also is needed in the area of timeliness in pesticide applications. The current economic thresholds are based purely on physical relationships without regard to prices of inputs, price of insect control, and the price of outputs. A threshold based on these parameters would be more useful and possibly provide better timing of pesticide treatments than current measures.

These additional areas of research were beyond the scope of study of this research project. However, the results of such research are vitally needed if personnel of the Agricultural Experiment Station and Extension Service are to provide the guidelines and recommendations needed by farmers and society. We must continue to improve quality and quantity of food and fiber production to meet increasing needs of society, while at the same time take the appropriate steps to minimize or reduce the adverse environmental impacts on society of such production.

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APPENDIX

SCHEDULE A
FARMERS SURVEY

CONFIDENTIAL

ECONOMIC ANALYSIS OF PESTICIDE USE

Department of Agricultural Economics
Agricultural Experiment Station
Oklahoma State University
Summer 1972

1. Name: ______________________________

   Address: ______________________________

   ____

2. County: ______________________________

3. Age: ____________________

4. Acres Cropland Owned ____________ Acres Cropland Rented ____________

5. Acres Pasture Owned ____________ Acres Pasture Rented ____________

6. Total Acres Owned ____________ Total Acres Rented ____________

7. Crop: ______________________________

	1961 or Base Year	1966	1971	1972
8. Acres Planted				
9. Acres Harvested				
10. Yield				
a. Cotton, bales/acre				
b. Pasture, acres/AUY				
c. Size of Animals				
11. Total Production				

Insect, Brush, and Weed Control	1961 or Base Year	1966	1971	1972
12. Chemical:				
a. What chemical(s) used				
b. How much applied/application (lbs./acre)				
1. Average application				
2. Heaviest application				
c. How many applications/season				
d. Chemical application equipment used (ground rig, aerial)				
13. Mechanical:				
a. How many mowings (on pasture)				
b. How many cultivations per season (on cotton)				
c. Caterpillar				
d. Other (burnings, etc.)				
14. Fungus Control:				
a. What chemical(s) used				
b. How much applied/application (lbs./acre)				
c. How many applications/season				
d. Chemical application equipment used (ground rig, aerial)				
15. Insect Control:				
a. What chemical(s) used				
b. How much applied/application (lbs./acre)				
1. Average application				
2. Heaviest application				
c. How many applications/season				
d. Chemical application equipment used (ground, rig, aerial)				

	1961	1966	1971	1972
16. Other Uses of Pesticides:				
a. Desiccants (lbs./acre; no. of acres)				
b. Cattle Sprays				
c. Other _________ (specify)				
Chemical Application Equipment:				
17. Owned:				
a. Type of equipment (tractor, plane)				
b. Powered by what (self propelled or pulled)				
c. Size (rows, gallons)				
d. When purchased				
e. Cost of equipment new or used				
f. Time required per acre per application				
18. Leased:				
a. Cost of airplane to spray per acre				
b. Cost of ground to spray per acre				

19. What are your estimates of direct benefits from using pesticides (how do you estimate this)?

(approximately 15 lines for response)

20. Do you have evidence of any benefits in the last ten years from your neighbors' use of pesticides? Yes_____ No_____. Please explain how you determine this:

(approximately 10 lines for response)

21. Do you have any evidence of problems in the last ten years on your farm from your own use of pesticides? Yes_____ No_____. Please explain how you determined this:

(approximately 10 lines for response)

22. Do you have any evidence of damages in the last ten years from your neighbors' use of pesticides? Yes_____ No_____. If yes, please explain how you determine this:

(approximately 10 lines for response)

23. How would you change your farming practices if you could no longer use: "________________" (pesticides) on this crop (more men, wider rows, change crops, etc.)?

"________________________": (approximately 10 lines for response)

24. How would these changes in your farming practices affect:

a. Yield:____

b. Production costs:________________________________

c. Acres farmed:___________________________________

25. Do you rotate this crop with other crops? Yes_____ No_____. If yes, please explain rotation:

(approximately 10 lines for response)

26. From whom do you currently buy:

a. insecticides ______________ ______________

b. fungicides ______________ ______________

c. herbicides ____________________ ____________________

d. desiccants ____________________ ____________________

e. __________ ____________________ ____________________
(other)

27. Have you changed your source of supply for the above in the last three years? Yes_____ No_____. If yes, please explain:

_____________(approximately 8 lines for response)_____________

SCHEDULE B
APPLICATORS SURVEY

CONFIDENTIAL

ECONOMIC ANALYSIS OF PESTICIDE USE

Department of Agricultural Economics
Agricultural Experiment Station
Oklahoma State University
Summer 1972

1. Applicator Name: ____________________

   Address: ____________________

   ____

2. Type of Equipment:

   a. No. of planes: __________ Size Tank: __________

   b. No. of ground sprayers: ______ Size Tank: __________

3. Counties you treat:

   a. __________ b. __________

   c. __________ d. __________

	1961 or Base Year	1966	1971	1972
4. How many acres did you spray in "_______________" county each year for this pest?				
5. What pesticide did you use on this pest each year?				
6. How much pesticide did you apply per acre for each application, in each of these years?				
7. How many applications did you have to make for this pest each year?				
8. <u>Breakdown of Custom Spray Fees per Acre</u>: a. What did you charge farmers for the chemical you applied each year?				
b. What did you charge for application of the chemical each year?				

(Three pages were included in each questionnaire.)

11. What percent of your spraying business is treating agricultural crops?

____

12. Would you have to go out of business if there was a ban on farmers' use of "______________________" pesticides? Yes_____ No_____ If no, please explain:

(approximately 10 lines were provided)

13. Do you know of instances where pesticides have been used in such a way that adverse effects have occurred, either to the user, or to others? Yes_____ No_____ Please explain:

(approximately 10 lines were provided)

14. Have you had any damage suits? Yes_____ No_____. If yes, what was the cause (mechanical, wind drift, etc.)?

____

What was the outcome ($)? (approximately 10 lines for response)

SCHEDULE C
TECHNICAL ADVISERS SURVEY

CONFIDENTIAL

ECONOMIC ANALYSIS OF PESTICIDE USE

Department of Agricultural Economics
Agricultural Experiment Station
Oklahoma State University
Summer 1972

1. Name: ______________________________

   Address: ______________________________

   ____

2. County(s):

   a. ______________ b. ______________

   c. ______________ d. ______________

	1961 or Base Year	1966	1971	1972
3. What percent of farms in "______" county were infested with this pest each of these years?				
4. What percent of the infested farms sprayed for the pest each of these years?				
5. How many acres were treated for the pest each of these years?				
6. What particular pesticide did they use?				
7. What was the rate of pesticide used per acre each year?				
8. How many applications did they have to make for this pest each of these years?				
On Success of Treatment: 9. How successful were they in controlling damage each of these years?				
a. Acres lost completely				
b. Yield/acre lost				
c. List source on how estimated				

(Three copies were included in each survey.)

10. Do you know of any damage suits that have developed from pesticide use or misuse: Yes_____ No_____

    If yes, Who: ______________________________

    When: ______________________________

    How: ______________________________

    How much damage: ______________________________

    Results: ______________________________

11. Do you know of any other instances where pesticides have been used in such a way that adverse effects have occurred, either to the user, or to others (human poisonings, fish kills, injured crops, etc.)?

    Yes_____ No_____ Explain (approximately 10 lines were provided)

12. How would farmers in "_______________" county have to change their farming practices if they could no longer use "___________" (pesticides) on this crop?

    (approximately 5 lines were provided)

    What about mechanical substitutes?

    (approximately 5 lines were provided)

13. How would this change in farming practices affect:

    Yield: (approximately 3 lines were provided)

    Production Costs: (approximately 3 lines were provided)

    Number of acres farmed: (approximately 3 lines were provided)

14. Could you name ten to twenty farmers in your area using pesticides, that I could interview?

    (approximately 10 lines were provided)

VITA

James W. Richardson

Candidate for the Degree of

Master of Science

Thesis: ENVIRO-ECONOMIC ANALYSIS OF PRESENT AND ALTERNATIVE METHODS OF PEST MANAGEMENT FOR SELECTED OKLAHOMA CROPS

Major Field: Agricultural Economics

Biographical:

Personal Data: Born in Reserve, New Mexico, March 17, 1949, the son of Mr. Herbert Richardson Mrs. Della McKinney.

Education: Graduated from Las Cruces High School, Las Cruces, New Mexico, in May, 1967; received the Bachelor of Science degree from New Mexico State University with a major in Agricultural Economics in May, 1971; completed the requirements for the Master of Science degree from Oklahoma State University with a major in Agricultural Economics in July, 1973.

Professional Experience: Student Aid, Department of Agricultural Economics and Agricultural Business, New Mexico State University, September - August of 1967 - 1971; Agricultural Management Trainee, Farmers Home Administration, June - August, 1969 and 1970; Research Assistant, Department of Agricultural Economics, Oklahoma State University, September, 1971 to present.

Professional Organizations: Member of American Agricultural Economics Association, Southern Agricultural Economics Association, Alpha Zeta, and Phi Gamma Mu.