AN ECONOMIC INVESTIGATION OF THE IMPACT OF ALTERNATIVE INSECTICIDE STRATEGIES ON COTTON PRODUCTION IN THE SUNFLOWER RIVER BASIN, MISSISSIPPI

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CHAPTER I

INTRODUCTION

> Modern man has achieved, through the miracles of science and technology, benefits for human life that our ancestors could not even have dreamed of. We have stamped out most of the contagious diseases. We have achieved an unparalleled abundance of food and consumer goods for an ever-growing population. In our own country, and in most of the developed countries of the world, people live longer and are healthier, better nourished, and better off by almost every measure of ease, comfort, convenience, and security, than ever before in the history of man (31, p. 1).

Relationships Between Insecticide Use in Agriculture and Environmental Quality

Since World War II, synthetic organic substances have dominated the chemical insecticide market. Two classes of organic insecticides, the chlorinated hydrocarbons (organochlorines) and organophosphates, are intensively used to control insect pests at the present time. The chlorinated hydrocarbons such as DDT, aldrin, chlordane, dieldrin, heptachlor, and toxaphene, are insecticides containing molecules of chlorine, hydrogen, carbon, and occasionally oxygen. This group of insecticides are known as persistent or hard insecticides because their residues remain active in the environment for long periods of time. Their persistency is due to their being insoluble in water, having a very low vapor pressure, and resistance to destruction by light and oxidation (54, p. 276). In addition to having a long residual life, they are relatively safe to handle and are effective against a wide range of insects.

The organophosphates and carbamate compounds such as malathion, parathion, methyl parathion, azinphosmethyl, disulfoton, bidrin, phorate, trichlorfon, and carbaryl contain phosphorus in their molecules. They are more soluble in water and are not classed as persistent insecticides. They are more hazardous to the people who handle and apply them. They also have a greater tendency to suppress natural insect parasites and predators, necessitating an even more widespread use of insecticides.

The term pesticides includes herbicides which are substances toxic to plant life, fungicides which inhibit the growth of fungi, and insecticides which are chemicals that are toxic to insects and other small animals. The emphasis for this research was on insecticides only.

Insecticides, when properly used, are valuable tools in agricultural production and are expected to continue to be used by agricultural producers in the foreseeable future. They are responsible for higher yields, lower production costs, and improved product quality, all of which results in the consumer spending less of his income for food. It has been estimated that food prices would rise 50 to 75 percent if pesticides were eliminated (14, p. 5).

Pollution of the environment by insecticides is a problem of major concern both regionally and nationally. Sixty-five percent of the total insecticides applied in 1964 were directly related to agriculture and forestry (24, p. 28). The quantities and kinds of insecticides employed by producers have continued to expand in recent years. Increased usage of insecticides adds to the problems of dissemination by natural and artificial means, residue accumulations, and harmful effects on nontarget biological entities. Improved methods for monitoring the presence of a greater variety of insecticides, and their degradation products, and an increased awareness of observable and suspected harmful effects on the environment have added to the present clamor.

Concern over the social costs of using chlorinated hydrocarbon insecticides is increasing. However, from the viewpoint of both private and social costs, the substitute organophosphate insecticides increase production costs from three aspects: they are usually higher priced; larger quantities must be used; and, they are more toxic to humans and require more elaborate facilities and greater care in handling to prevent contamination (41).

Although DDT is one of organochlorines, it is usually dealt with separately. DDT was the first of this group of insecticides to be put into general use, hence it is better known than many of the others. Also, it is more effective in the control of a wide variety of insect pests than some of the other organochlorines. It has a lower cost per pound and less is required per application than other persistent insecticides. It has been widely used for the control of vectors of human diseases as well as crop and animal pests. DDT has become a household word and has been singled out by those who desire to prevent the use of all insecticides. It is quite possible that the use of DDT may be completely restricted in the future, while producers are allowed to continue using other organochlorines. Therefore, DDT has been analyzed separately in this study.

If the agricultural sector is to maintain public confidence in its practices, and observe an appropriate and responsible regard for public health and the quality of the environment, it is quite clear that changes will need to be made in future pest control practices and in some cases the nature of insecticide chemicals themselves. For example, Federal and state governments have recently taken steps to selectively restrict the use of certain insecticides by farmers. For example, on August 28, 1970, the U.S. Department of Agriculture cancelled registered use of DDT for many classes of livestock, lumber, buildings, forest trees and more than 50 vegetable crops. This restriction does not apply, however, to the use of DDT for control of insects on cotton and citrus crops (43, p. 10).

More and more people are becoming concerned about the third party effects of all insecticides. Past studies have tended to take either the benefits side or the hazards side with little regard for the other. A few survey-type studies have also been conducted to determine the value of insecticides in the production process. A comprehensive evaluation is needed to place this problem more clearly in perspective. Such an evaluation should consider technical, economic, social, and political questions and their ramifications.

An in-depth evaluation of all of the questions raised above is beyond the scope of this study. This study is primarily concerned with the economic and social aspects of different strategies of insecticide use or nonuse in crop production with primary emphasis on a single crop.

Many of the crops grown in the United States are treated with insecticides to combat insect pests. To study the effects of alternative insecticide strategies, the selected crop should be one of major importance in terms of acres, value per acre, and kinds and quantities of insecticides used. A crop that meets all these requirements is cotton. Application of insecticides on cotton accounts for the major agricultural use of insecticides in the United States.

Cotton is an important crop in all of the southern states from Florida to California. Because many cultural practices and insect pests vary from one cotton-producing region to another, it was necessary to limit the area of investigation. The area selected for study was the Sunflower River Basin in Mississippi, a part of the

Mississippi Delta. This is an important cotton-producing area that uses large quantities of insecticides.

Cotton's Importance to the Economy

Cotton is the fifth most valuable crop in the United States. The 1970 crop was valued at $1.5 billion and was produced on 11.2 million acres (26, p. 121).

Cotton is one of the crops subject to acreage allotments. The Federal Government controls the number of acres a producer can use for cotton production which in most cases is less than the producer would prefer to devote to the production of cotton. Combined with the fact that cotton is a high value per acre crop, allotments result in producers using insecticides and other production practices that will remove as many of the risks of low yields and crop failures as possible.

Acreage allotments on cotton have caused producers to continue to produce cotton in some cases when perhaps they would have realized a net return as great or greater from some other crop. They have maintained their historical acreage of cotton production to remain qualified for a cotton allotment. This practice has resulted in a sluggish responsiveness to the comparative advantage of one cotton producing area to another.

Area Suited for Cotton Production

Cotton is best suited to an area that has a long warm growing season. It requires fertile soils and sufficient moisture to provide the water needed by a relatively large plant. When producers are required to provide supplemental irrigation, they have higher costs and lower net returns compared to producers who can achieve the same yield per acre without irrigating. Similarly, producers in an area subject to high insect pest control costs would have lower net returns. The climatic characteristics of the study area are described in a later section. Suffice it for now to say that the Sunflower Basin in Mississippi is well suited to the production of cotton.

Insecticides in Cotton Production

Insect control for cotton production in the Mississippi Delta represents approximately 20 percent of the total production cost. Approximately 80 percent of the cotton grown in the Mississippi Delta is treated with insecticides and about three-fourths of the insecticides used are organochlorines (19, p. 11). The best control of cotton insect pests, measured in terms of increased yields per acre is from a combination of toxaphene, DDT, and methyl parathion (32, p. 1249).

Insecticides have become increasingly important in cotton production since World War II. Increased specialization of production has been made possible in part by the use of insecticides. There is a favorable cost-benefit ratio for producers. However, the effects of insecticides do not end with their initial application. Insecticides that remain in the air, water, or soil result in external or spillover effects beyond the farm boundary. As a result, conflicting objectives exist and decisions must be made that concern individual farmers and other interest groups including total society.

Future Agricultural Production

In 1966, the Federal Water Resources Council directed the development of projections of economic activity in the agricultural, forestry, and related sectors of the United States. This council was created by the Water Resources Planning Act of 1965 (PL 89-90). It includes representatives from the Departments of Agriculture, Interior, Army, Transportation, Health, Education and Welfare, and the Federal Power Commission. The projections were made by the Economic Research Service of USDA through a cooperative agreement with the Water Resources Council.

These projections, which include agricultural production, land use, employment and income, are known as the National Food and Fiber Requirements. The projections are based upon historical trends, analysis of current relationships, and an evaluation of foreseeable developments with respect to domestic consumption, industrial use, and import-export balances of agricultural goods. The national food and fiber requirements (products demanded) for 1980, 2000, and 2020 have been allocated to the 17 water resource regions in the United States. The Lower Mississippi Water Resource Region is one of the 17 major regions and encompasses the Sunflower River Basin. The Lower Mississippi Water Resource Region food and fiber requirements were further allocated to the various subregions within it.

This allocation of the 1980 food and fiber production requirements provided basic data for the minimum cost linear programming model used in this study. The 1966 base year and projected 1980 food and fiber requirements for the major crops are presented in Table I. In the case of cotton, production will need to increase 57 percent by 1980 in the Sunflower River Basin to meet the projected requirements as established by national policy. This large increase can be explained on the basis of increase in population by 1980 and the fact that the Sunflower River Basin historical base for cotton has been trending upward. Other areas have lost some of their production base, part of which has been allocated to the study area.

Specific Problem and Objectives

The specific problem for this research was to quantify the economic impact of alternative insecticide strategies on cotton production in the Sunflower River Basin of Mississippi. Related to this problem was the determination of social impacts and externalities associated with alternative insecticide situations.

The specific objectives of this study were to:

1. Determine the cost per acre of producing the 1980 projected cotton requirements with DDT (Strategy I), without the benefit of DDT (Strategy II), without other chlorinated hydrocarbon insecticides (Strategy III), and without chemical insecticides (Strategy IV).
2. Determine the effect on net returns to the cotton producer with each of the four insecticide strategies.
3. Determine the effect on alternative crops and idle cropland to maintain the 1980 projected cotton production requirements, with each of the four strategies.
4. Identify and discuss some of the externalities associated with the alternative insecticide strategies.

The major economic effects to be determined were changes in production levels and costs, changes in land resource use, and impacts on agricultural producers and non-agricultural groups resulting from alternative insecticide strategies.

Institutional constraints such as restriction on persistent insecticides will cause producers to re-examine their farming operations and make the necessary adjustments to the changed conditions. This research effort attempted to examine the effect of such restrictions. Information gained from this study should be useful to cotton producers, insecticide producers, policy makers, and others.

TABLE I

1966 FOOD AND FIBER PRODUCTION IN THE SUNFLOWER RIVER BASIN AND 1980 PROJECTED PRODUCTION REQUIREMENTS

Crop	Unit	1966 Base Production	1980 Projected Production
		Thousands	Thousands
Corn	Bushels	379	276
Sorghum	Bushels	29	42
Cotton	Bales	640	1,005
Soybeans	Bushels	20,470	32,032
Rice	Bushels	3,429	5,940
Wheat	Bushels	3,926	4,403
Oats	Bushels	1,904	711
Hay	Tons	58	74

Source: Adapted from Preliminary Projections of Economic Activity in the Agricultural, Forestry, and Related Economic Sectors of the United States and its Water Resource Regions, 1980, 2000, 2020, Washington: U.S. Department of Agriculture, August, 1967.

Characteristics of the Study Area

The Sunflower River Basin is in the northwestern part of the state of Mississippi and is shown in perspective to the surrounding area in Figure 1. This basin is a part of

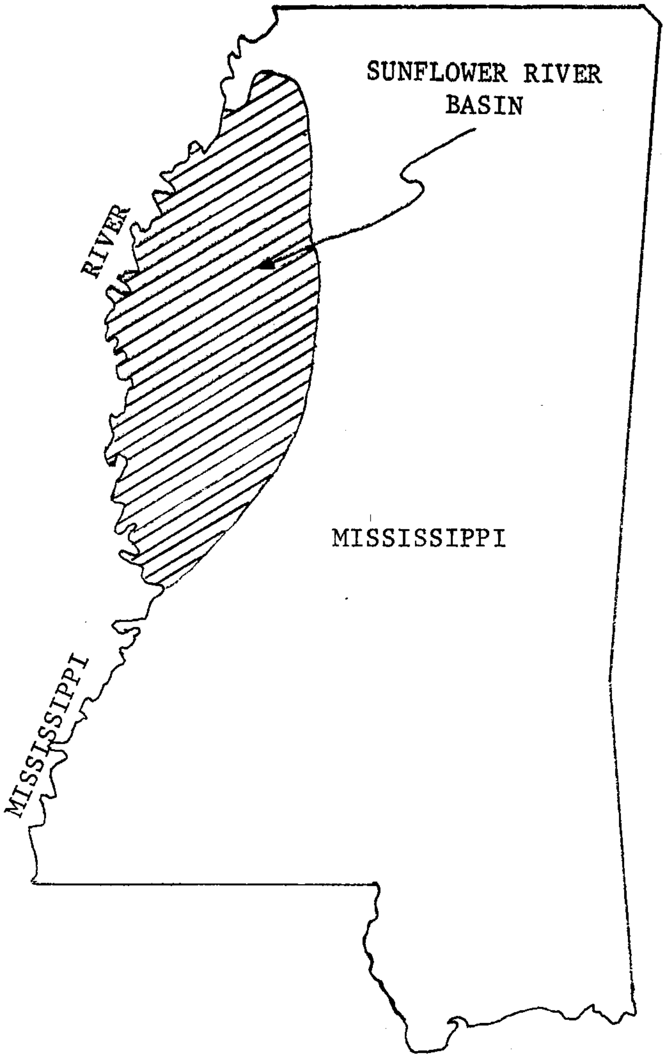

Figure 1. Location of Sunflower River Basin Study Area in Mississippi

the Alluvial Valley of the Lower Mississippi River. Clearing and development of this fertile valley has been going on for over two hundred years and is an important part of the agricultural production in the South. The reclamation is not completed, but sufficient progress has been made in flood control, land drainage, and land clearing to demonstrate the potentialities of the area for agriculture, forestry, and industry (27).

The Sunflower River Basin comprises approximately 4,100 square miles, is approximately 140 miles long, averages 30 miles in width, and extends from Clarksdale on the north to near Vicksburg on the south.

The basin's climate is characterized by fairly mild winters, alternately subjected to warm tropical air and cold continental air usually in three or four-day cycles, and warm hot summers with frequent afternoon thundershowers. The average annual rainfall is about 51 inches and occurs at the rate of about 16 inches in the winter, 15 inches in the spring, and 10 inches each in the summer and fall. There are periods of excess rainfall as well as periods of deficient rainfall throughout the year. The average annual temperature is about 65 degrees and is fairly constant throughout the basin. The length of the average growing season is 235 days.

Prior to the construction of the Mississippi River levee system, the Sunflower River was a natural overflow channel for the Mississippi River. Also, many small creeks and bayous that previously drained into the Mississippi River have been diverted into the Sunflower River and add to the land area that must be drained by natural or improved channels within the basin.

A Corps of Engineers authorized improvement project is essentially completed in the study area. Improvements consist of channel clearing, channel enlargement and realignment, channel cut-offs, and weir construction for low water level control. The project has not been as effective in controlling flooding and surface runoff as anticipated. This is due to a tremendous amount of clearing and the intensive cropping operations that has increased the runoff from the field. Recent studies made by the Corps of Engineers indicate that out-of-bank flooding could still be expected over much of the area once every three to five years during the growing season (38, p. 7). The Corps is working on a flood prevention project that would enlarge drainage channels by more than a third over the currently authorized project.

Soil Conservation Districts have been organized in all of the counties that are wholly or partially within the basin. All of the Districts are actively engaged in carrying out soil and water conservation programs with individual land owners.

Detailed soil surveys have been completed on all of the agricultural land. Conservation practices carried out include such items as conservation cropping systems, crop residue management, farm drainage measures, irrigation, land leveling, pasture planting and management, wildlife habitat development and management, recreation area improvement and woodland measures.

Over the past 35 years the forested acres have decreased approximately 34 percent, or an average of one percent per year. This trend is expected to continue in the near future, thus making more land available for crop production and adding to the drainage and insect control problems.

Environment problems caused by insecticides are intensified in the study area because more applications of insecticides are needed with a longer growing season. The humid and hot climatic conditions favor insect populations. Also, the Sunflower River Basin has a higher average annual rainfall per year, 51 inches, than most other cotton growing areas in the United States. This increases the problem of surface runoff and may cause contamination of streams and bayous with silt and insecticide residues.

The Sunflower River Basin is an area of intensive insecticide usage. This is primarily due to the production of cotton. Fifteen years ago one chemical application was used in conjunction with six to ten mechanical cultivations and 25 hours of hand weed control to control pests and weeds in cotton. Today, three to six chemicals (including herbicide applications) and four to six mechanical cultivations are being used. Some producers follow a rigid schedule of insecticide application from May through September, during which time 15 to 20 applications may be required. Other producers apply insecticides when field conditions indicate the need, usually making eight to ten applications during the growing season. Those who spray according to infestation have the added expense of scouting the fields to determine when and for what particular pest to spray.

Organization of Remainder of Dissertation

The remainder of this dissertation is divided into four chapters. Chapter II develops the institutional framework and background pertinent to the problem. The procedures used for data collection and analyzing the effect of restricting insecticides are discussed in Chapter III. The results of restricting insecticides for cotton production are presented in Chapter IV. Chapter V discusses the social impacts and externalities related to insecticides. The results of the analysis and conclusions of the study are presented in Chapter VI.

CHAPTER II

INSTITUTIONAL FRAMEWORK AND PROBLEM SETTING

The purpose of this chapter is to establish the framework for the analysis. The intent is to show how man's actions affect his environment and to indicate how man has attempted to control insect pests in the past and at the present time. Today's cotton producer is faced with many institutional and legal restrictions pertaining to the use of insecticides. The major Federal and State regulations are discussed. Finally, an introduction to the concept of externalities is presented.

Man and the Environment

Everything man does affects the environment. In the struggle for survival, man and other creatures have modified the "spaceship" earth. The extent of the modification and the extent of the side effects have in some cases become important issues. As early as 1860, Dr. Hilgard warned that the Mississippi loess hills could not sustain row crops, such as cotton, for a very long period of time (15, p. 22). He was ignored, and Mississippi paid the price of severe erosion. Later, in the 1930's, Hugh Bennett, the first Soil Conservation Service Administrator, traveled the country decrying erosion. People listened and he had a tremendous impact.

According to Jan van Schilfgaarde, man has a task to modify his environment in a knowing manner. "The question is not to leave nature as we find it or as our grandparents found it, but to modify it to man's benefit" (15, p. 22). This does not imply that man has license to abuse nature by contaminating the natural resources. Rather it suggests that man should make wise use of his surroundings and give consideration to future generations.

Environmental quality has been defined as the condition of our air, water, soil, and general surroundings (19, p. 1). Pollution has been defined as the situation that occurs when materials accumulate where they are not wanted (19, p. 9). Pollution that reduces environmental quality can, in many cases, be prevented. One approach to the problem is to identify the polluting agents, determine the nature and extent of their contribution, and evolve an acceptable means of control.

Pollution of the environment can result when cotton producers apply chemical insecticides to their cotton. Some of the insecticide remains in the air and some adheres to soil and water molecules. To the extent that insecticides are not efficiently used in the manner intended and then broken down into harmless components so as not to accumulate where they are not wanted, environmental quality is adversely affected.

Controversy not only develops over the causes and effects of pollution, but on methods of control and costs to society of maintaining a "clean" environment. Adverse environmental side effects from the application of insecticides on cotton can be reduced. For example, restricting the use of all insecticides or restricting the use of persistent insecticides would reduce the amount of polluting material released into the environment. Also, technological development could result in more of the insecticide adhering to the cotton plant thus creating less drift. These and other changes are possible, but at a cost. The cost of a "clean" environment in this case would be reflected in less cotton being produced and/or higher prices for the cotton products.

Insecticide Development

There has been a long evolutionary period culminating in modern insect control measures coincident with growing single crops, such as cotton, on large acreages with improved crop management practices. Historically, cultural practices have aided in the control of insects and are still used today. However, the desire to obtain more dependable insect control has resulted in growers relying more and more on chemicals to control undesirable insects. Beginning in the 1940's, organic chemical insecticides were developed that were inexpensive and effective. Cotton producers have been heavy users of these insecticides and have contributed significantly to the annual increase in organic insecticides used by farmers. The latest data available indicate that 44 percent of all insecticides and 60 percent of the organochlorines used on crops are applied to cotton (19, p. 10).

The development of non-persistent insecticides has been emphasized for several years. Many of the less persistent insecticides developed to date are more toxic and thus can have a greater immediate effect on insecticide handlers and nontarget organisms. The fact that they remain in the environment for shorter periods of time reduces their possible entrance and retention in ecological systems (57, p. 4).

Integrated Control

A rather new approach to the problem of controlling insects is called Integrated Control. This is a unified program which manages pest population in such a way that economic damage is avoided and adverse effects are minimized. The objective is to control insect populations without necessarily having a 100 percent kill. A combination of chemical and nonchemical methods may be employed. The Integrated Control method relies on a greater knowledge of field conditions and specific treatments for particular pests at the proper time. This approach may use chemical insecticides when needed but the number of applications is minimized. In the case of cotton, yields have been maintained with no chemical insecticides being used until the level of insect infestation in the squares (bud stage) reaches 20 percent (47, p. 284).

Federal Laws and Agencies Regulating Insecticide Use

> Acts and councils seldom have much impact unless there is a sincere and persistent implementation of their intent in later executive and legislative decisions. . . Both executive and legislative levels of the federal government are now as clearly on record against permitting further environmental deterioration as words can make them. Let deeds follow (17).

Prior to 1970, most state and federal regulations to control the use of insecticides were indirect. Control was essentially accomplished by labeling laws and restrictions on residues permissible on raw agricultural products for marketing. The Environmental Policy Act of 1970 established a new principle of unified action at the federal level.

> It not only defines our purpose of maintaining environmental harmony but authorized establishment of a new Council on Environmental Quality in the White House and required that all Federal activities be subject to review as to their impact on the environment (15, p. 5).

The law sets forth a broad national policy of environmental protection proclaiming that "Congress recognized that each person should enjoy a healthful environment" (2, p. 2).

The development and sale of insecticides are controlled by state and federal regulations. In fact, regulations of insecticides in the United States has set a standard of excellence that is recognized throughout the world. An insecticide cannot be sold in the United States until it has received the approval of the Food and Drug Administration, the U.S. Department of Interior, and the U.S. Department of Agriculture.

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) of 1947 has been modified and strengthened periodically since it was first enacted. Under this law and the Miller Amendment to the Federal Pure Food Laws, an insecticide manufacturer is required to spend an average of six years in research and testing before the marketing of a new product is permitted. These laws further require that toxicological studies be run by independent accredited organizations. Also, tests must be made by accredited State and Federal Experiment Stations to determine the effectiveness of the material, the quantities required, methods of application, insects controlled, etc.

After all the legally required information has been submitted to the Pure Food and Drug Authorities, they inform the manufacturer of the permitted uses of the insecticide. The Pure Food and Drug Administration also insures that certain information is included on the label of the container, such as: the quantities to be used, the method or methods of application, and the crop or crops on which it may be used including timing. Each year a summary of these permitted uses is published and circulated by USDA (33, p. 8, 9). An insecticide which fails to comply with the labeling requirement, or which cannot be rendered safe by any labeling, is misbranded, and the Secretary of Agriculture must, as the Administrator of FIFRA, refuse or cancel its registration as an economic poison approved for shipment in interstate commerce (25, p. 137).

Any application to USDA to register an insecticide must be accompanied by scientific data on residues that will remain on the crop at marketing time. The FDA is required to establish residue tolerances for all insecticide treated products designed for use on or in human or animal food. The FDA must establish the residue tolerance for a particular use before USDA grants the registration. The law provides for seizure and destruction of commodities that contain insecticide residues in excess of established tolerances (20, p. 7).

The Federal government has no direct regulatory control over the application of insecticides, except on Federally owned or controlled property. However, the Department of Transportation is responsible for licensing aerial applicators and, in this capacity, has an important role in regulating non-Federal applications of insecticides. The Federal regulations related to aerial applications are the only Federal controls over non-Federal uses of insecticides at the present time (25, p. 137).

Several significant efforts to control insecticides have come about during the past two years. In July of 1969, all USDA operated pest control programs involving persistent insecticides were suspended for 30 days to review their contamination of the environment. One outcome of this suspension was the placing of restrictions on certain insecticides for certain uses. DDT was one of the first to have restrictions placed upon its use. Further study has resulted in the accumulation of more evidence that has resulted in additional restrictions being placed on the use of DDT. Legislation is pending to further restrict its use at the present time.

In November of 1969, the Cabinet Committee on Environmental Quality established a subcommittee on pesticides. Two months later, in January of 1970, a new inter-departmental agreement designed to strengthen the review of insecticide regulations was signed by Secretaries of the departments involved. The new agreement emphasized the protection of human health and the environment (25, p. 138).

The Pesticide Subcommittee is chaired by the Secretary of Agriculture. Other members are the Secretary of Health, Education and Welfare and the Secretary of the Department of the Interior. Observer status is given to the Departments of Defense, Transportation, and State. This rule committee has a Working Group which, through frequent meetings of its agency members, acts as an inter-agency mechanism to facilitate day-by-day coordination, review, and evaluation of matters related to insecticides. Should the Working Group, composed of departmental representatives, fail to reach agreement after exhausting all procedures designed to facilitate and expedite resolution of differences, the dispute would be referred to the Pesticide Subcommittee of the

Cabinet Environmental Committee (20, p. 4). The final responsibility on insecticide matters that was previously the responsibility of the Secretary of Agriculture has been assigned to the relatively new Environmental Protection Agency (EPA). Many of the duties and responsibilities pertaining to the regulation of insecticides that have been under FDA and USDA have been consolidated into this one Federal agency. The USDA has, however, retained its pesticide committee.

The Federal Environmental Pesticide Control Act of 1971 is currently awaiting debate in the House of Representatives. This bill contains a series of amendments to the FIFRA statute to change it from a labeling law into a comprehensive regulatory statute that will more carefully control the manufacture, distribution, and use of pesticides. The pending legislation contains three main provisions. First, pesticides would be classified into "General Use" and "Restricted Use". The latter can only be applied by or under the direct supervision of licensed pesticide applicators or under other restrictions set by the Environmental Protection Agency, such as research organizations. Second, applicators will be of two types--commercial and private. All applicators will be licensed and required to exhibit a satisfactory knowledge of and ability to safely apply pesticides. Most of the private applicators are expected to be farmers. Third, EPA is given enforcement powers to impose civil penalities and bring criminal charges when such action is warranted (53, p. 2).

Mississippi Laws and Agencies Regulating Insecticide Use

Nearly all states have or are in the process of enacting lesiglation to establish air and water quality standards. This is usually accomplished by the State Legislature. This body makes provisions for the establishment of a State Department of Pollution Control with a Board empowered to prescribe air and/or water quality criteria and enforce compliance with the adopted standards. Insecticides can be responsible for both air and water pollution if improperly handled.

Most states have laws, patterned on Federal law, which govern the marketing of insecticides. These state laws are in addition to those laws affecting interstate commerce required by Federal agencies.

Nearly all states require that pesticides be registered in the states, and some states restrict the marketing of certain insecticides that have Federal clearance for use. Most states rely on an informed and conscientious user as the primary security for the proper use of insecticides according to the laws and registration specifications pertaining to them. State and local governments do have police authority to see that the laws are obeyed, but for the most part, compliance is voluntary rather than enforced.

Mississippi's current air and water pollution control act was last amended in March 1968. This act is similar to the 1970 Federal Environmental Policy Act in that it recognizes the need to protect the health and general welfare of the people. A statement of policy follows:

> Whereas, the pollution of the air and waters of the State constitutes a menace to public health and welfare, creates a public nuisance. . .impairs domestic, agricultural, industrial, recreational and other legitimate beneficial uses of air and water; . . .it is hereby declared to be the public policy of this State to conserve the air and waters of the State and to protect, maintain, and improve the quality thereof for public use. . .to maintain such a reasonable degree of quality of the air resources of the State to protect the health, general welfare and physical property of the people; . . . to provide for the prevention, abatement and control of a new or existing air or water pollution; and to cooperate with other agencies of the State, agencies of other States, and the Federal Government in carrying out these objectives (50, p. 1).

The laws and regulations pertaining to the marketing and application of insecticides in Mississippi are discussed in Appendix A.

Externalities

An externality may be defined as any condition resulting in a difference between marginal private benefits and costs and marginal social benefits and costs. When marginal private effects and marginal social effects are not the same, externalities occur in the form of external benefits and/or external costs.

The concept of externalities is one of the most elusive concepts that confronts economists because it is difficult to determine the true effect of a particular course of action. For example, a farmer could apply an insecticide to his crop to control insects. If his neighbor has the same crop, the effect of insecticide drift might control the insects in his crop, thus creating an external benefit. If the neighbor has a crop with a low or zero tolerance for the insecticide, the drift may cause damage to the crop, thus resulting in an external cost. A specific action can be beneficial or harmful to a "third" or outside party depending upon the time, place, or other factors.

Traditional economic theory is primarily keyed to internal benefits and costs as they are reflected in the market place. "But economic theory does not provide an adequate means of empirically analyzing the external benefits and costs, and economists have devoted relatively little study to them through the years" (20, p. 64). Recently, economists and others have begun to give the spill-over or "third party" effects more attention. The usual approach, if externalities are considered, is to incorporate the external costs and benefits into a measure of social welfare or a consumers' plus producers' surplus approach such as Edward's work in Florida (23).

The general public's primary concern over insecticides is the possible hazards to environmental quality and the consequential effects they may have upon animal life, including mankind. Problems dealing with environmental quality inevitably pose conflicts of interest.

Environmentalists have repeatedly assailed insecticides in their efforts to preserve environmental quality. In some cases, the arguments and decisions have been emotionally, rather than factually, oriented. The environmentalists claim agriculturalists have been over zealous in the application of new insecticides and techniques without knowing their effect on the environment. Agriculturalists counter that the use of insecticides often represents the margin between crop production and crop failure and between economic profit and economic loss.

Economic models need to be developed to more adequately handle the externalities concept. Also, specific models should be aimed at evaluating the effects of insecticides on the environment as well as handling the direct effects on producers. This kind of information is essential for sound policy decision making. Research in this area should assist policymakers to sponsor programs and propose legislation that is consistent with established goals. Externality models should be useful in analyzing alternative regulatory policies on insecticide use. They could be structured to deal with a specific insecticide such as DDT or a group of insecticides such as the organochlorine group.

Persistent Insecticides

Externalities associated with insecticides are due primarily to their persistency traits. Persistent insecticides may move about in the environment by adsorption to soil particles, particularly the fine silt and organic fractions. This type of sorption occurs both at the site of application and in the aquatic environment. The normal process of erosion may transport the insecticide laden soil particles into streams, rivers, estuaries and eventually the ocean. This is a particular problem in the Mississippi Delta. The heavy rains cause soil erosion that carries impregnated soil particles into the bayous and lakes, causing an insecticide buildup in the water.

Insecticide particles may drift considerable distances before they are adsorbed to some surface or they may vaporize and be carried away in atmospheric currents. In either event, they are transported from the target area and released somewhere else in the environment. It is difficult to pinpoint the cause of pollution when the pollutants enter the ecosystem from many sources.

Persistency in and of itself is not necessarily bad or harmful. Insecticides that remain biologically active have economic advantages to the cotton producer because they continue to destroy the target organisms over an extended period of time. Persistency of insecticides has resulted in the development of new agricultural techniques, such as pre-emergent soil insecticides and seed treatments. Also, certain persistent insecticides have been found to be generally safe to the persons handling them and there is less likelihood of immediate harm to nontarget organisms in the treated area (17, p. 15).

Persistency also has some disadvantages. Residues of a persistent insecticide may remain in the soil for a considerable length of time after the crop to which it was applied has been harvested. A persistent insecticide may also become quite mobile as it degrades and may contaminate other elements of the environment for a considerable period of time and distance from the site of initial use.

Degradation rates differ widely with the different persistent insecticides and a particular environment. The original compound or a toxic metabolite may be highly resistant to degradation elements of the environment. A persistent chemical may be relatively long-lived in one habitat, but much less persistent in another. The degradation may only be partial or may involve extensive breakdown of the molecule. While the degradation rate may change as the insecticide moves from one part of the ecosystem to another, the process continues, although the rate may vary.

Water pollution from the use of agricultural insecticides is perhaps not as intensive as some reports have indicated. Even in areas where sizeable quantities of chlorinated hydrocarbons have been used on large acreages, only traces of insecticides have been found in the runoff water. This conclusion was from a study at Greenville, Mississippi, which is in the Sunflower River Basin. Approximately 22.5 pounds per acre of insecticides had been applied to cotton over a period of nine years. Residues in the soil at the end of the period amounted to approximately one part per million in the surface three inches. This is equivalent to 0.3 pound per acre or the amount applied in a single application. Water from the area which had accumulated in a nearby slough was sampled 19 different times and measurable residues were found on only six occasions. The residue ranged in amounts from 0.07 to 1.49 parts per billion (55, p. 30). Although the results of this study did not indicate severe contamination, slough-water contamination did occur. The significance to cotton producers of these substances in the water and in terms of long-run environmental impact on the ecosystem is not known.

Charges that insecticides have caused fish kills are common. Of the total fish killed by various pollutants (municipal, industrial, transportation wastes and other operations) in 1968, only 2.2 percent were caused by insecticides and other poisons (14, p. 6). Sublethal doses of chlorinated hydrocarbons absorbed or ingested by fish, birds, or mammals are, for the most part, excreted. Some insecticide material may be stored in fatty tissue. Continued ingestion of chlorinated hydrocarbons tends to increase the amount stored until a certain level, varying from specie to specie, is reached, beyond which no more will be stored. If an animal with insecticide stored in fatty tissue is eaten by a larger animal in the food chain, part of the stored material can be passed up the line in the food chain. There are no indications that this stored organochlorine material causes any damage to mammals (14, p. 6).

Non-persistent Insecticides

Body storage is not a factor with the non-organochlorine insecticides because the body does not store phosphate and carbamate compounds. These non-persistent insecticides are effective in controlling most of the insect pests attacking crops and they degrate quickly with no apparent residue problem. However, one of their primary disadvantages is that they are toxic to warm blooded animals, including man. They are more hazardous to handle and have caused numerous poisonings, some fatal, in man. Even though some chemicals in this group that are relatively harmless to man, they are very toxic to bees and other insects. Resistance of insects to non-persistent insecticides currently developed may result in the application of greater quantities of currently developed insecticides, the development of more potent insecticides for which the environmental impact is not known, or the possibility of re--verting back to the use of organochlorines.

The Dilemma

There are positive as well as negative effects associated with the use of insecticides. It has been estimated that the harm man has done to wildlife by felling forests, tilling fields, draining wet places, non-insecticide water pollution and urbanization is, collectively, of much greater consequence than the relatively small and temporary losses that have occured from the externalities of insecticide use. Of the total land and water area of the United States, only 5 percent receive insecticides in a typical year. The wildlands make up about 75 percent of the total area and 99 percent of this area receives no insecticides (16, p. 2). As insecticides are currently used in routine operations to control pests of our farms and forests, the hazards to wildlife are generally considered to be small.

The advent in 1959 of gas-liquid chromotography, and other developments in instrumental analysis, made possible the first detailed evaluation of water contamination by insecticides (23, p. 871). Advances in instrumentation during the last six to eight years have demonstrated that minute quantities of chlorinated hydrocarbon insecticides may contaminate our food and possibly make it harmful to eat (39, p. 1109).

The consequences of prolonged exposure on human health is not fully known, nor is the effect of insecticide accumulation in human tissues known. Studies by the World Health Organization and U.S. Public Health Service have not as yet revealed a casual relationship between the presence of these residues and human disease (57, p. 2).

Insecticides, by necessity, are poisons; however, the toxic hazards of the different compounds vary greatly. Scientists have been actively studying whether or not through exposure there is a gradual build-up of the residues of insecticides in the body tissues, and if so, how this may affect our own and succeeding generations. This extensive research by industry, universities, research institutes and government has provided a basis for establishing effective controls to assure the safety of presently recommended compounds and uses. However, continued surveillance is necessary to assure the safety of new compounds and to protect against possible hard-to-detect effects of older insecticides.

The complexity of the problem is illustrated in the case of DDT. This illustration also points out that all decisions on environmental quality are not based on economics. DDT was first used to protect mankind from insects. It was responsible for saving many lives and eliminated many diseases. Later, it became an input in producing food and fiber. Still later, it was recognized as possibly having adverse effects on other parts of the ecosystem. Then restrictions were imposed upon its use. Monetary values on the saving of lives, or the reduction of illness, or the reduced costs of and higher quality of food and fiber have not been established. Just as it is difficult to measure these external benefits, so it is difficult to measure the external costs or adverse effects such as the loss of wildlife and contamination of the food chain.

Another aspect of the dilemma is the effect on agricultural production of restricting the use of insecticides. Lower yields can be expected if insecticides are not permitted to be used in the production of most crops. The problem then becomes one of deciding whether to devote more acres to the production of food and fiber or having smaller quantities produced. If the decision is to increase the cropland base, there is a limit to the amount of land suited to the growing of crops. When that limit is reached, a reordering of priorities would again have to be made to decide how to increase production from the addition of non-soil resources at the cost of other goods and services which may have to be given up to maintain the desired agricultural production.

Agricultural producers in the Sunflower River Basin are operating within the framework of having cropland that is not being intensively farmed at the present time. Some of the land not currently used for crops is being used for conservation purposes. That is, grasses and certain other crops may be growing on the land but are not harvested or pastured. All open acreage diverted from other crops under Federal programs is also included in the conservation use category. Certain low areas that are subject to flooding that have been formerly cropped and are not purposely being converted to another use could be brought back into production if necessary.

CHAPTER III

PROCEDURE

The procedure is discussed in two parts in this chapter: (1) the procedure or analytical technique used to make the analysis; and (2) the procedures used to obtain the input data for the analysis.

A recent USDA study of the Sunflower River Basin developed data on land use and cropping patterns, crop yields, and budgets for the major crops for 1966 (the base year) and for future time periods (1). A comparison of "with" and "without" resource development was made. The "with" resource development results of that study were used to provide the base data used in the analysis of alternative production strategies associated with the restricted use of certain insecticides. Cotton yields and budgets associated with the USDA study were adjusted to depict the different insecticide situations. Details of how this was done are given in the next chapter.

The four alternative insecticide strategies for this analysis were identified as follows:

Strategy I	Non-restricted use of insecticides-- a combination of DDT, toxaphene, and methyl parathion.

Strategy II Without DDT--a combination of toxaphene and methyl parathion.

Strategy III Without organochlorines--methyl parathion and other organophosphates.

Strategy IV Without insecticides--non-chemical insect control.

The future time period of 1980 was selected because some of the resource development projects that have been authorized have not been constructed and put into operation at the present time. Some of the 1966 crop relationships would perhaps be modified by the completion of all of the approved projects. The assumption was made that all improvements for drainage and flood protection would be completed by 1980. Also, the USDA study was keyed to 1980 for one of its future target years which facilitated the establishment of certain food and fiber relationships used for the analysis.

The Analytical Technique

Linear programming is an analytical technique utilizing a systematic method for evaluating simultaneously the relative contribution of a number of measures toward stated objectives, and then checking a selected combination of measures against a number of restrictions placed on achieving the objectives. Linear programming was used in this study to simulate resource managers expected response to the different insecticide strategies. The output from this analytical tool is the optimum combination of resources subject to the specified constraints. This analytical tool requires the use of a high speed computer and in this sense linear programming may be thought of as the computer counterpart of the economic budgeting model. The budgeting model can be set up in either of two ways on the computer: (1) maximize profits from a given set of resources assuming an unlimited demand or requirement for food and fiber at given product prices; or (2) start with a given demand or requirement for food and fiber, and determine the most efficient, i.e., the most profitable way of producing the given amount of product. The second or "minimum cost" linear programming model was used in this study.

Minimum Cost Linear Programming Model

The model was set up in a minimum cost formulation in what is sometimes called the requirements approach. A minimum cost resource use pattern was derived to produce a given level of food and fiber requirements under constraints of land availability, yields per acre, costs per acre and other restraints. The minimum cost model can be generalized as follows:

$$\text{Min } Z = P_1X_1 + P_2X_2 + \ldots + P_nX_n$$

subject to:

$$X_{1,2,} \ldots n \geq 0$$

$$A_{11}X_1 + A_{12}X_2 + \ldots + A_{1n}X_n = C_1$$

$$A_{21}X_1 + A_{22}X_2 + \ldots + A_{2n}X_n = C_2$$

$$\cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot$$

$$A_{m1}X_1 + A_{m2}X_2 + \ldots + A_{mn}X_n = C_m$$

$$D_{11}X_1 + D_{12}X_2 + \ldots + D_{1n}X_n \leq R_1$$

$$D_{21}X_1 + D_{22}X_2 + \ldots + D_{2n}X_n \leq R_2$$

$$\cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot\ \cdot$$

$$D_{s1}X_1 + D_{s2}X_2 + \ldots + D_{sn}X_n \leq R_s$$

Where z = total production cost excluding payments to land and management:

$P_1 \ldots P_n$ = cost of production per acre excluding land costs for the various crops,

$X_1 \ldots X_n$ = acres of various land uses (activities),

$A_{11} \ldots A_{mn}$ = amount of product requirement used in a unit of activity,

$D_{11} \ldots D_{sn}$ = amount of land resource used in a unit of activity,

$C_1 \ldots C_m$ = product requirements for various commodities specified exogenously, and

$R_1 \ldots R_s$ = amounts of land resources (soil productivity groups) available.

The two basic sets of constraints in the model are: first, product requirements, i.e., the maount of food and fiber to be produced in the basin; and second, land resources, the amount of land resource available to produce the required products. Both sets of constraints are inputs that must be exogenously determined. That is, the quantity of food and fiber to be produced in the basin and the amount of the different soils in the agricultural base, must be known. Also, for each soil productivity group, projected yields and production costs for each potential crop must be developed.

The land resource, including idle cropland and various cropland reserve and retirement programs, was not sufficient to meet the 1980 production requirement goal for all crops when no insecticides were used. Therefore, the land resource constraints for Strategy IV were relaxed to permit a solution consisting of production less than the projected quantities of food and fiber, except for cotton. The constraints on product requirements were changed from "equal to" to "less than or equal to" production requirements on all crops except cotton.

The ADE Computer Program

A computer program designed to analyze agricultural development possibilities for a base year and for future time periods has been developed. The Analyze Development Effects (ADE) system allocates a basin's land resources to required production of specified crops; thus, it is a "minimum cost" format. This allocation minimizes the cost of meeting crop production requirements and provides guidelines by which an economic analysis of the need for and value of future resource development projects such as drainage and flood protection can be made. A diagramatic representation of the inputs required, the constraints, and the output to be obtained from the ADE computer routine is presented in Figure 2.

The constraints associated with the ADE program may be of two types. Physical restraints on the agricultural base may be in the form of a limiting amount of soils suited for the production of one or more of the specified crops. A flooding hazard could restrict the crops that can be grown in certain areas. Inadequate drainage may prevent the farmer from growing a long season crop such as cotton.

Rather than allowing only for the optimal allocation of crop enterprises among the various soil resources, a limit to the amount of acreage change of each crop was specified. This was done to account for the fixity aspect of resources committed to the production of a particular agricultural commodity. The acreage devoted to a particular crop was not allowed to change more than 25 percent from the 1966 base year to the 1980 crop production requirements. However, an additional adjustment was made in the ADE program for Strategy IV since a greater than 25 percent acreage change was necessary to allow the solution for Strategy IV sufficient acreage to meet the 1980 cotton requirement.

The second type of constraint is institutional in nature. These restraints may be in the form of acreage

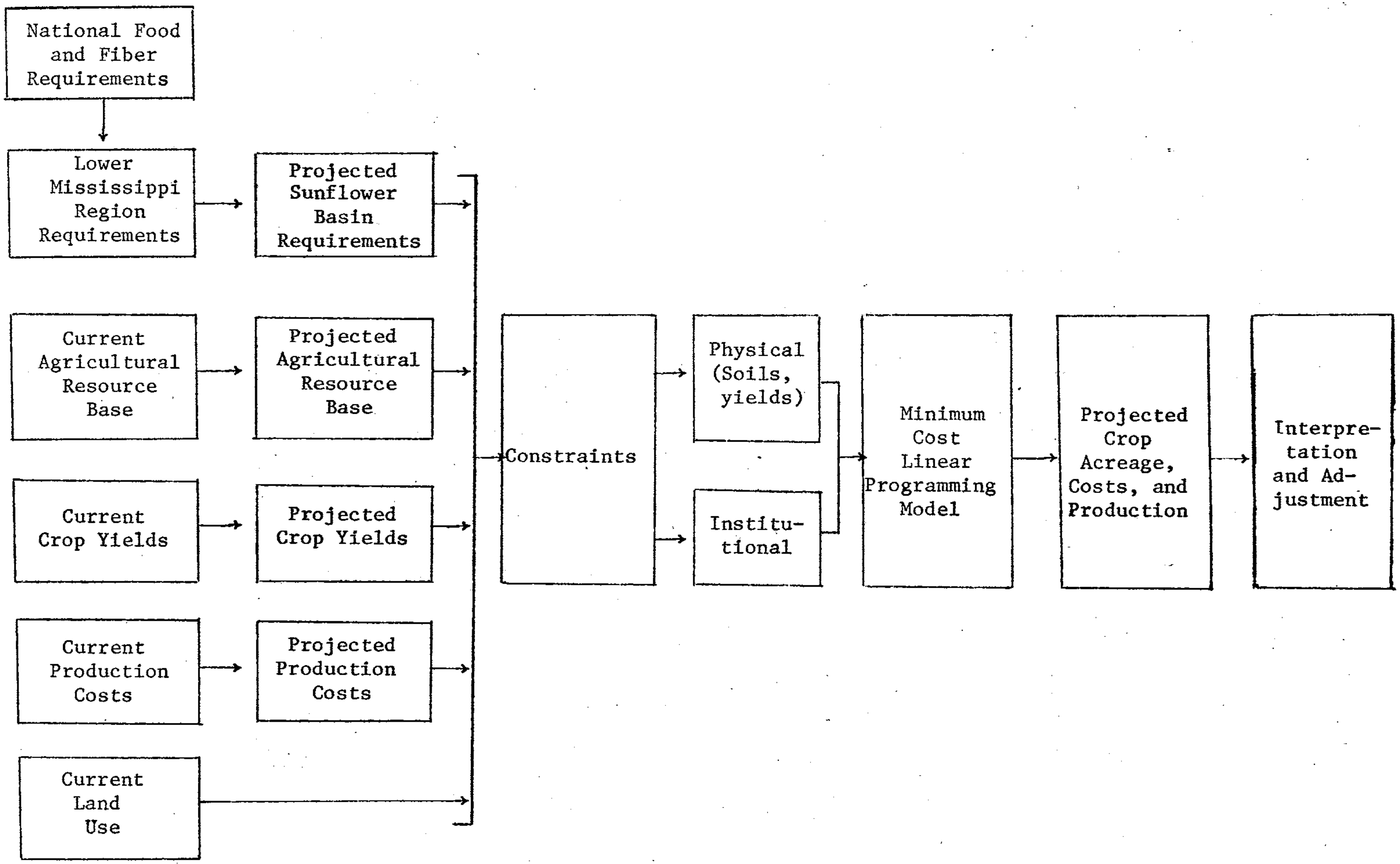

Figure 2. Diagramatic Representation of the ADE Computer Program.

allotments or marketing quotas. For example, if the cotton acreage allotment was greatly reduced, as it was in 1966, the required quantity of cotton may be impossible to produce. Conversely, if the allotment was greatly increased the basin may not have the ability to produce the given quantities of the various crops as determined from a historical base. Marketing quotas could result in the same kind of an effect if they adversely modified the production requirements associated with the basin.

One institutional constraint associated with this study was the acreage allotments for cotton and rice production. These restrictions were incorporated into the basin's share of food and fiber requirements. Therefore, since these values were exogenously determined, they do not directly restrict the model. One constraint that can affect the minimum cost solution is the provision that, in the event the basin is not capable of meeting the required production of all the crops, the production of cotton will have priority over the other crops. This stipulation was placed on cotton production to provide a constant cotton production base to determine the effects of restricting the use of certain insecticides.

By having a constant base for cotton, the effect on acres of land required to produce the given amount could be determined. Also, the added cost in terms of inputs and possible loss of production of some of the other crops could be established.

By adjusting the cotton yield and cost input data related to the four different insecticide strategies, the ADE program output gave the projected acres, costs, and production for each of the four insecticide use situations. The means of establishing the required input values and the basis for making the cotton adjustments are discussed in the following section.

Input Data and Procedures

Several types of input data were required to analyze the restricted use of insecticides. The procedures used in obtaining the different types of data depended upon the nature of the data required. Secondary sources were used in some cases and field data were obtained in others. The types of data collected, the procedures used in the collection process, and the values established are discussed below.

Sunflower Basin Agricultural Land Base

The ADE program requires the various kinds and quantities of soils be identified if a cost of production or yield differential exists. All of the soils in the basin are basically alluvial deposits and although yield differentials do exist, the production practices are essentially the same throughout the basin. No production cost differentials could be established except for variable harvest costs which change with yield differentials. Soil scientists familiar with the soils in the basin were consulted and upon their recommendation each soil series occurring in the basin was placed in one of four soil productivity groups (SPG) that are fairly homogeneous with respect to physical characteristics and yields (See Appendix B). The four soil productivity groups are:

SPG I	Poorly drained heavy soils,
SPG II	Medium texture, somewhat poorly drained,
SPG III	Moderately well to well drained sandy loam, and
SPG IV	Well drained somewhat droughty soils.

The distribution and acreage of each soil productivity group are presented in Table II.

The supply of agricultural land available to meet future production requirements is affected by several forces which are permanently reducing the agricultural resource base. Shifts of farm land to residential, industrial, commercial, recreation, and transportation uses contribute to urban and other built-up areas. Additional land has been used for water supply and flood control areas, national defense, wildlife refuges, and other uses. It is quite possible that land in the basin that is suitable for certain crops will be further restricted by institutional restraints related to the prohibiting of the application of insecticides in certain areas.

While land is being removed from crop production for various purposes, additional land is being added to the base from the clearing of forested areas. A sizeable amount of clearing of forested lands is projected to occur over the projection period. It was assumed that all land cleared would be suitable for agricultural production and would be added to the agricultural base.

TABLE II

LAND RESOURCE AND SOIL PRODUCTIVITY GROUP DISTRIBUTION IN THE SUNFLOWER RIVER BASIN, MISSISSIPPI, 1966

Land Resources	Acres	Percent
Agricultural land		
SPG I	1,370,897	52.3
SPG II	473,515	18.1
SPG III	476,616	18.2
SPG IV	10,011	0.4
Non-agricultural land[1]	288,961	11.0
Total	2,620,000	100.0

[1] Non-agricultural land consists of urban built-up areas, Federal land, and water areas less than 40 acres.

Source: Expanded CNI Data, U.S. Department of Agriculture.

Sunflower Basin Crop Yields

Yield data for each soil series were obtained from soil survey reports, experiment station reports, and other publications. Yields for each of the four soil productivity groups were established by weighting the soil series in each group. The projected yield values are the result of a cooperative effort by several USDA agencies. Historical data, trends, projections, and the professional judgment of several knowledgeable individuals experienced in soil management and crop production in the Delta were incorporated in this basic yield table. Per acre yields for each of the major crops grown in the basin are presented in Table III.

TABLE III

PROJECTED PER ACRE YIELDS BY SOIL GROUPS, SUNFLOWER RIVER BASIN, MISSISSIPPI, 1980

Crop	Unit	Yield per acre by SPG				Weighted Average all SPG's
		I	II	III	IV	
Corn	Bu.	54	66	96	36	68
Sorghum	Bu.	61	74	109	41	77
Cotton	Lbs.	850	900	1125	715	980
Soybeans	Bu.	36	36	44	30	40
Rice	Bu.	117	99	111	-	111
Wheat	Bu.	34	40	45	26	40
Oats	Bu.	51	62	74	45	62
Hay	Ton	2.8	3.2	3.5	2.6	3.2

Yield Adjustments for Each Insecticide Strategy

The cotton yields used for Strategy I were the same as those developed for the Sunflower Study with resource development. Yields for the other strategies were derived by reducing the Strategy I yields on the basis of Texas and Mississippi Delta studies which indicated the percentage yield reductions from restricting certain insecticides and combinations of insecticides (32, 16).

These studies indicated that when DDT was deleted and only toxaphene and methyl parathion used, cotton yields were reduced almost four percent. Strategy II yields for cotton were derived by reducing the Strategy I yields 3.89 percent.

Cotton yields were reduced more than 15 percent when no organochlorine insecticides were permitted. Methyl parathion is more effective in controlling insects when used in combination with an organochlorine insecticide, either DDT or toxaphene, than when used alone. Strategy III yields were derived by reducing the base yield values 15.45 percent.

Insecticide infestations would undoubtedly be much greater if none of the producers sprayed. Therefore, the yields for the no insecticide situation are perhaps higher than they would actually be if all spraying were to stop. Based upon research at the Stoneville Experiment Station, the yields for Strategy IV were reduced 35 percent from Strategy I.

The cotton yield input values for the four different insecticide strategies are presented in Table IV. The yields per acre for all other crops remained the same.

TABLE IV

PROJECTED COTTON YIELDS FOR SOIL GROUPS AND INSECTICIDE STRATEGIES, SUNFLOWER RIVER BASIN, MISSISSIPPI, 1980

Insecticide situation	Yield per acre by SPG				Weighted average all SPG's
	I	II	III	IV	
					Pounds
Strategy I	850	900	1125	715	980
Strategy II	820	865	1080	685	940
Strategy III	720	760	950	605	830
Strategy IV	550	585	730	465	635

Sunflower Basin Production Costs

The production cost data for the crops grown were developed primarily from two Mississippi State Experiment Station publications (11, 12). The budgets in these publications were developed specifically for use in the Delta phase of Regional Project S-42 "An Economic Appraisal of Farming Adjustment Opportunities in the Southern Region to Meet Changing Conditions". The budgets were considered to be current and accurate in terms of inputs by agricultural workers in the field. The general format of the Mississippi reports was followed in developing the budgets for this study. The budgets were based on "advanced technology" level of management, medium to large farms, and mixed soils.

The advanced technology implies the budgets represent input-output relationships on farms using proved new production techniques that are known to be more profitable than the old methods. Delta farmers have been quick to adopt new technology. Thus the advanced technology at the time the reports were published was assumed to be the general practice by 1980.

The medium to large farms represent more than 100 acres of cropland and the use of four-row equipment. The typical cotton farmer in the Sunflower Basin has several hundred acres of cotton and would be classed as having a large farm.

The mixed soils group is made up of the silt loams, silty clay loams, and similar soil types having poor to fair internal drainage. These characteristics represent the soils found in the four soil productivity groups of this study.

Preharvest expenses include seed, fertilizer, insecticide, herbicide, tractor operation, equipment operation, interest on operating capital, labor and miscellaneous. The nature of the soils in the study area is such that the preharvest cost of producing a crop on one soil as compared to another could not be distinguished. That is, inputs for the different soils were essentially the same.

Harvest costs could not be conveniently grouped due to the nature of the different crops. Certain costs, such as investment in harvesting equipment, are incurred regardless of the amount of yield and were designated as fixed harvest costs. Costs that vary with the quantity produced were identified as variable harvest costs and were associated with a unit of production. All other costs were developed on a per acre basis. The preharvest and harvest costs are presented in Table V.

Cost Adjustments for Each Insecticide Strategy

Strategy I represents the same combination of insecticides used in the USDA Study. Therefore, the original budgets were applicable and no adjustments were made. This strategy was included to provide a basis for comparison with the restricted insecticide strategies. The budgets were adjusted for each of the other strategies by the cost of the insecticides. The fixed harvest costs remained the same, but the variable harvest costs differed due to the changed yield per acre.

For Strategy II (no DDT) preharvest costs per acre were increased $3.90. This figure was obtained from a recently published report by Davis and others in which cotton producers throughout the United States were interviewed and the data analyzed by production regions. The Mississippi Delta

TABLE V

PREHARVEST AND HARVEST COSTS OF PRODUCTION BY CROP, SUNFLOWER RIVER BASIN, MISSISSIPPI

Crop	Item	Unit	Cost
			Dollars
Cotton	Preharvest	Acre	75.89
	Harvest		
	Fixed	Acre	33.91
	Variable	Lb.	.0341
Soybeans	Preharvest	Acre	17.12
	Harvest		
	Fixed	Acre	3.90
	Variable	Bu.	.2755
Corn	Preharvest	Acre	24.85
	Harvest		
	Fixed	Acre	5.59
	Variable	Bu.	.1524
Grain Sorghum	Preharvest	Acre	20.27
	Harvest		
	Fixed	Acre	4.30
	Variable	Bu.	.3482
Rice	Preharvest	Acre	75.47
	Harvest		
	Fixed	Acre	11.94
	Variable	Bu.	.7881
Wheat	Preharvest	Acre	22.20
	Harvest		
	Fixed	Acre	11.33
	Variable	Bu.	.1503
Oats	Preharvest	Acre	22.04
	Harvest		
	Fixed	Acre	3.95
	Variable	Bu.	.1404
Hay	Preharvest	Acre	23.05
	Harvest		
	Fixed	Acre	10.48
	Variable	Ton	-

region had the highest additional costs for restricted use of organochlorines (19, p. 10).

In Strategy III, which used no organochlorines, preharvest costs increased by $7.05 per acre. This value was determined from Cooke's work at the Delta Experiment Station (18). This cost increase is due to additional quantities of more expensive spray materials and additional applications.

The no insecticide situation, Strategy IV, reduced preharvest costs $15.33 per acre. The development of non-chemical insect control, such as biological control, could possibly permit cotton production to continue as a profitable farm enterprise. In the event this did happen, the yields would likely be comparable to those associated with Strategy I rather than being so drastically reduced as for this study.

The variable harvest costs change due to added costs associated with higher yields. For example, a high yielding crop will require the cotton picker to travel slower or go over the field more times. The hauling and ginning costs are also more with higher yields.

The cotton costs for the different insecticide strategies are summarized in Table VI. The budget values for all other crops were not adjusted since the insecticide restrictions were only applicable to cotton.

TABLE VI

PREHARVEST AND HARVEST COSTS OF COTTON PRODUCTION FOR FOUR INSECTICIDE STRATEGIES, SUNFLOWER RIVER BASIN, MISSISSIPPI

Insecticide Situation	Item	Unit	Cost
			Dollars
Strategy I	Preharvest	Acre	75.89
	Harvest		
	Fixed	Acre	33.91
	Variable	Lb.	.0341
Strategy II	Preharvest	Acre	79.79
	Harvest		
	Fixed	Acre	33.91
	Variable	Lb.	.0341
Strategy III	Preharvest	Acre	82.84
	Harvest		
	Fixed	Acre	33.91
	Variable	Lb.	.0341
Strategy IV	Preharvest	Acre	60.56
	Harvest		
	Fixed	Acre	33.91
	Variable	Lb.	.0341

CHAPTER IV

PROGRAMMING RESULTS FOR ALTERNATIVE INSECTICIDE STRATEGIES

The objective function of the linear programming model used in this study was to minimize the costs of producing a given set of product requirements, given a specific set of restraints on the production process for the basin. The cost and yield restraints associated with cotton production were modified for each of the insecticide strategies. The programming results are given for each insecticide strategy separately. This is followed by a summary of all four strategies with respect to acres, production, costs, and costs per unit. The final section analyzes the effect on cotton producers of restricting insecticides.

Non-restricted Insecticide Use Strategy

Strategy I, the non-restricted insecticide condition, has the same acreage, production, and cost relationships as the USDA study for 1980 with resource development. The data on acres, production, and costs for the eight competing crops are presented in Table VII. Under these conditions, 656,842 acres of land would be required to produce the required amount of cotton. The total cost would be

$72,292,608 for an average cost of $110 per acre. The total cropland for the eight competing crops would be 1,720,242 acres with a total production cost of $113,443,762.

TABLE VII

PROJECTED ACRES, PRODUCTION, COSTS, AND COST PER UNIT OF CROPS WITH NON-RESTRICTED USE OF INSECTICIDES (STRATEGY I), SUNFLOWER RIVER BASIN, MISSISSIPPI, 1980

Crop	Acreage	Production	Cost	Cost/Unit[a]
	Acres	Bushels	Dollars	Dollars
Corn	3,866	275,981	159,745	.58
Sorghum	670	42,350	31,209	.74
Cotton	656,842	1,005,018[b]	72,292,608	71.93
Soybeans	862,853	32,031,831	26,962,648	.84
Rice	50,850	5,940,000	9,125,400	1.54
Wheat	107,047	4,402,620	3,583,660	.81
Oats	11,827	711,054	407,205	.57
Hay	26,287	74,002[c]	881,287	11.91
Total	1,720,242		113,443,762	

[a] All costs are in dollars per bushel with the exception of cotton and hay, which are measured in bales and tons, respectively.

[b] Bales

[c] Tons

The acres of idle cropland amount to 123,273 or 7 percent of the total cropland. This quantity of cropland remaining idle appears large, but a large amount of unused cropland is characteristic of the basin. The idle cropland in 1966 was estimated to be over 200,000 acres (49). The large amount of idle cropland is due to much of the area being subject to flooding. This was particularly true prior to resource development in the form of major drainage channels and small watershed projects that were assumed to be completed by 1980. Resource development is not expected to prevent all flooding, but it does reduce the frequency and extent of flooding, thus reducing the risk of a flood in certain areas and permitting producers to more intensively farm some of the land that had been subject to flooding prior to resource development.

The programming procedure used in this analysis stops production when the food and fiber requirements have been fulfilled whether the land resource has been fully utilized or not. The idle cropland associated with the solution for Strategies I and II would undoubtedly be used for agricultural production in reality. The effect of this added production on the economy of the area and surrounding areas is subject to speculation. The added production could adversely affect the price of certain commodities in the local area. This in turn could affect the production of some of the crops in future years.

No DDT Insecticide Use Strategy

Strategy II, which restricted the use of DDT, resulted in an increase in the number of acres needed to produce the cotton requirement. The additional land required for cotton also resulted in acreage shifts among some of the other crops. This is due to crop yield differentials for the different soil productivity groups and by cotton requirements having priority. The other crops shifted to soils with lower yields per acre than for Strategy I except for corn. Cotton yields are highest on one soil productivity group and corn yields are highest on another SPG. Also, there is a certain amount of random selection by the computer as to the order of crop selection where the costs are equal.

Without DDT, 22,188 more acres were required for cotton, 5,550 more acres for soybeans, and 357 more acres for wheat. More acres were required for soybeans and wheat crops because they were produced on lower yielding soils due to the added acreage used for cotton production. The land for corn decreased 334 acres. Corn shifted to soils that have a higher yield for corn and a lower yield for cotton. The cropland in production increased 27,314 acres over Strategy I. Total costs increased due to more acres being used for crop production. Per acre cotton production costs increased from more expensive insecticides being used. The average cost per acre was $114. The cost per bale increased $5.01 as compared to Strategy I because the yield per acre was lower due to a less effective insecticide and some of the additional acres needed to produce the required quantity of cotton had lower yields.

Each increase in crop acreage over Strategy I indicates a higher cost per acre (due to lower yields) unless there is some unused portion of a particular soil productivity group that can be brought into production before the computer selects from the next highest yielding soil group. The cost to produce the required amount of cotton increased $5,027,596, whereas the cost to produce corn decreased $10,513. The total cost for all crops increased $5,148,338.

The extent to which additional cotton acreage, at lower yields and higher costs, can be added is limited by the cropland available. The acres, production and costs associated with Strategy II are presented in Table VIII. It can be seen from this table that even with restricted use of DDT insecticides, the basin would be able to meet the food and fiber requirement by using some of the idle cropland.

No Organochlorine Insecticide Use Strategy

Results of Strategy III, which did not use organochlorine insecticides, indicate that practically all of the idle cropland would be brought into production to produce the required quantities of the various crops. These values indicate very closely the production capacity of the basin under the stated conditions.

The two crops having the largest acreage increase were cotton and soybeans. Cotton production required an

TABLE VIII

PROJECTED ACRES, PRODUCTION, COSTS, AND COSTS PER UNIT OF CROPS WITHOUT DDT INSECTICIDE (STRATEGY II), SUNFLOWER RIVER BASIN, MISSISSIPPI, 1980

Crop	Acreage	Production	Cost	Cost/Unit[a]
	Acres	Bushels	Dollars	Dollars
Corn	3,532	275,989	149,592	.54
Sorghum	675	42,500	31,440	.74
Cotton	678,530	1,994,950[b]	77,320,204	76.94
Soybeans	868,403	32,032,946	27,078,534	.84
Rice	50,850	5,939,990	9,125,390	1.54
Wheat	107,404	4,402,890	3,592,700	.81
Oats	11,827	711,004	407,165	.57
Hay	26,335	74,000[c]	883,075	11.93
Total	1,047,556		118,592,100	

[a] All costs are in dollars per bushel with the exception of cotton and hay, which are measured in bales and tons, respectively.

[b] Bales

[c] Tons

additional 83,873 acres, an increase of 12 percent. Soybeans were grown on 12,279 more acres than with Strategy II, an increase of nearly two percent. Again this increased acreage requirement for soybeans and some other crops was due to the forced shift of higher yielding soils to cotton.

The total cost increase for cotton was $11,861,701. This is an average cost of $117 per acre. The cost per bale increased $11.80 over Strategy II and $16.81 over Strategy I. The increased cost to produce soybeans was $67,667. The acres, production, costs, and cost per unit for all the crops are presented in Table IX for Strategy III.

No Insecticide Use Strategy

The basin does not have sufficient land resources to produce the required quantities of the major crops when no insecticides are used, as required by Strategy IV. The effect of not using chemical insecticides to produce cotton was a reduction in the acres and production of all crops except cotton. Although cotton production remained the same, 272,233 additional acres were required and the cost increased $8,731,514 over Strategy III. The additional acreage of cotton caused the production of the other crops to be reduced approximately one-third.

The additional land used for cotton production resulted in an increase in the average yield per acre of the other crops that were produced. This is explained by the fact that after the cotton requirement had been met, some of the

TABLE IX

PROJECTED ACRES, PRODUCTION, COSTS, AND COSTS PER UNIT OF CROPS WITHOUT ORGANOCHLORINE INSECTICIDE (STRATEGY III), SUNFLOWER RIVER BASIN, MISSISSIPPI, 1980

Crop	Acreage	Production	Cost	Cost/Unit[a]
	Acres	Bushels	Dollars	Dollars
Corn	3,324	275,985	143,265	.52
Sorghum	670	42,350	31,209	.74
Cotton	762,403	1,005,013[b]	89,181,905	88.74
Soybeans	880,682	32,031,970	27,346,203	.85
Rice	51,033	5,940,000	9,141,460	1.54
Wheat	107,137	4,403,210	3,585,440	.81
Oats	11,497	711,040	398,629	.56
Hay	26,441	73,997[c]	886,469	11.98
Total	1,843,187		130,714,580	

[a] All costs are in dollars per bushel with the exception of cotton and hay, which are measured in bales and tons, respectively.

[b] Bales

[c] Tons

remaining soils had higher yields for certain crops than some of the soils previously used for the production of those crops. The costs per unit were lower except for cotton and wheat. Cotton costs increased $8.68 a bale and yields per acre decreased 26 percent as compared to Strategy III. The total acres, production, and costs associated with this strategy are presented in Table X.

Practically all of the cropland would be used, but the total cost for all crops is $1,762,109 less than in Strategy III. This decrease in cost is due to two factors; no insecticides used on cotton and smaller production of all other crops due to the land limitation.

Comparisons of the four insecticide situations with respect to acres, production, total costs, and cost per unit are presented in Tables XI, XII, XIII, and XIV. The total cropland used in Strategies III and IV was almost the same (Table XI). Cotton production costs increased approximately ten percent from one strategy to the next (Table XIII). The data in Tables XII and XIV remain nearly the same for the first three strategies but vary considerably with Strategy IV due to the shortage of the land resource.

Effect on Cotton Producers of Restricting Insecticides

If the same quantity of cotton is to be produced with restricted insecticides as before restrictions are invoked, producers must allocate more resources to the production of

TABLE X

PROJECTED ACRES, PRODUCTION, COSTS, AND COSTS PER UNIT OF CROPS WITHOUT INSECTICIDE, (STRATEGY IV), SUNFLOWER RIVER BASIN, MISSISSIPPI, 1980

Crop	Acreage	Production	Cost	Cost/Unit[a]
	Acres	Bushels	Dollars	Dollars
Corn	2,304	209,150	101,993	.49
Sorghum	225	23,492	13,720	.58
Cotton	1,034,636	1,005,022[b]	97,913,419	97.42
Soybeans	657,222	24,274,000	20,503,015	.84
Rice	38,473	4,501,500	6,909,700	1.53
Wheat	82,740	3,337,100	2,759,220	.83
Oats	8,121	538,814	286,715	.53
Hay	19,629	56,200[c]	658,159	11.71
Total	1,843,350		128,952,471	

[a] All costs are in dollars per bushel with the exception of cotton and hay, which are measured in bales and tons, respectively.

[b] Bales

[c] Tons

the cotton crop. The more acres and other inputs used for cotton, the less there will be available for other crops in the basin. The comparative cotton acreage data in Table XI indicates that the required number of acres to produce the specified quantity of cotton would increase 377,794 acres with the no insecticides strategy, an increase of 58 percent.

TABLE XI

PROJECTED CROP ACREAGE FOR DIFFERENT INSECTICIDE STRATEGIES, SUNFLOWER RIVER BASIN, MISSISSIPPI, 1980

Crop	Strategy I	Strategy II	Strategy III	Strategy IV
	Acres	Acres	Acres	Acres
Corn	3,866	3,532	3,324	2,304
Sorghum	670	675	670	225
Cotton	656,842	678,530	762,403	1,034,636
Soybeans	862,853	868,403	880,682	657,222
Rice	50,850	50,850	51,033	38,473
Wheat	107,047	107,404	107,137	82,740
Oats	11,827	11,827	11,497	8,121
Hay	26,287	26,335	26,441	19,629
Total	1,720,242	1,747,556	1,843,187	1,843,350

TABLE XII

PROJECTED CROP PRODUCTION FOR DIFFERENT INSECTICIDE STRATEGIES, SUNFLOWER RIVER BASIN MISSISSIPPI, 1980

Crop	Strategy I	Strategy II	Strategy III	Strategy IV[a]
	Bushels	Bushels	Bushels	Bushels
Corn	275,981	275,989	275,985	209,150
Sorghum	42,350	42,500	42,350	23,492
Cotton	1,005,018[b]	1,004,950[b]	1,005,013[b]	1,005,022[b]
Soybeans	32,031,831	32,032,946	32,031,970	24,274,000
Rice	5,940,000	5,939,990	5,940,000	4,501,500
Wheat	4,402,620	4,402,890	4,403,210	3,337,100
Oats	711,054	711,004	711,040	538,814
Hay	74,002[c]	74,000[c]	73,997[c]	56,200[c]

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[a] The projected food and fiber requirements were not met for any of these crops except cotton. This was due to the fact that cotton required an additional 272,233 acres.

[b] Bales

[c] Tons

TABLE XIII

PROJECTED CROP PRODUCTION COSTS FOR DIFFERENT INSECTICIDE STRATEGIES, SUNFLOWER RIVER BASIN, MISSISSIPPI, 1980

Crop	Strategy I	Strategy II	Strategy III	Strategy IV
	Dollars	Dollars	Dollars	Dollars
Corn	159,745	149,592	143,265	101,993
Sorghum	31,209	31,440	31,201	13,720
Cotton	72,292,608	77,320,204	89,181,905	97,913,419
Soybeans	26,962,648	27,078,534	27,346,203	20,503,015
Rice	9,125,400	9,125,390	9,141,460	6,909,700
Wheat	3,583,660	3,592,700	3,585,440	2,759,220
Oats	407,205	407,165	398,629	286,715
Hay	881,287	883,075	886,469	658,159
Total	113,443,762	118,592,100	130,714,580	128,952,471

Net Returns

Cotton producers realize lower net returns when insecticides are restricted because the cost per acre is greater and more acres are required for the same amount of product.

The cost figures in Table XIII indicate an increase in costs to produce cotton without insecticides of $25,620,811 or 35 percent. The cost of producing a bale of cotton increased $25.49 with no insecticides as compared to using DDT and other insecticides.

TABLE XIV

PROJECTED CROP COST PER UNIT FOR DIFFERENT INSECTICIDE STRATEGIES, SUNFLOWER RIVER BASIN, MISSISSIPPI, 1980

Crop	Unit	Strategy I	Strategy II	Strategy III	Strategy IV
		Dollars	Dollars	Dollars	Dollars
Corn	Bu.	.58	.54	.52	.49
Sorghum	Bu.	.74	.74	.74	.58
Cotton	Bale	71.93	76.94	88.74	97.42
Soybeans	Bu.	.84	.84	.85	.84
Rice	Bu.	1.54	1.54	1.54	1.53
Wheat	Bu.	.81	.81	.81	.83
Oats	Bu.	.57	.57	.56	.53
Hay	Ton	11.91	11.93	11.98	11.71

Assuming a cotton price of 22 cents per pound of lint, 2½ cents per pound of cottonseed, the average yield per acre for each insecticide strategy, and the average per acre cost for each insecticide strategy as developed in this analysis, the net returns per acre are presented in Table XV.

TABLE XV

PROJECTED COTTON NET RETURNS PER ACRE FOR DIFFERENT INSECTICIDE STRATEGIES, SUNFLOWER RIVER BASIN, MISSISSIPPI, 1980

Insecticide Situation	Cotton Net Returns Per Acre[a]
	Dollars
Strategy I	91.89
Strategy II	81.40
Strategy III	57.28
Strategy IV	33.42

[a] Based on 1970 Mississippi average price for cotton.

Applying 1971 Mississippi average prices to the other crops and using the average yield per acre, the net returns for the crops grown were also calculated. Rice is the most competitive crop with cotton in terms of net returns. However, due to the particular soil requirements of the crop and the fact that it is an allotment crop, rice is not expected to have a substantial increase in acreage. The only crop that has net returns high enough to be competitive with cotton is soybeans. Net returns from soybeans, based on an average yield of 37 bushels per acre and a price of $2.50 per bushel, are $62.29 per acre.

The net return figures for cotton and soybeans are only approximate because they are based on average values. Even so, they indicate that cotton producers could continue to produce cotton in the basin when certain insecticides could not be used. Restricting the use of DDT will increase producers' costs and lower their net returns, but they can still compete with other crops grown in the basin. Cotton producers that have higher than average yields can realize as large a net return with cotton as with soybeans with Strategy III production practices. When all insecticides are restricted, soybeans replace cotton as the most profitable crop.

Minimum Cotton Yields to be Competitive

There is a different cost and yield relationship associated with each of the four insecticide strategies. Therefore, the minimum yield per acre that is necessary to permit the producer to be competitive with the net returns that can be realized from other crops, will vary with each insecticide situation. Assuming the same cost and product prices used in the previous analysis, a producer would be required to have a yield of 655 pounds of cotton per acre with Strategy I to have a net return comparable to that which could be obtained from soybeans, the next most profitable crop.

Restricting the use of DDT (Strategy II) will increase costs and require a higher yield for cotton to become competitive with soybeans. A yield of 670 pounds per acre would be necessary. Per acre costs for cotton are the highest of any of the strategies with Strategy III. The minimum yield producers would be required to achieve is 680 pounds per acre.

The average yield for Strategy IV would eliminate the production of cotton without the use of insecticides. A producer would need to have a yield of approximately 595 pounds to be competitive. Producers with high yielding soils may be able to achieve yields of this magnitude or more without insecticides, particularly if the producers around them use insecticides. Producers who are unable to achieve this high a yield without insecticides will find it more profitable to use insecticides or produce other crops.

An increase in the cost of growing an acre of cotton due to added insecticide expenses will result in those crops not requiring the restricted insecticides to be in a more favorable competitive position. The added costs to produce cotton, however, may not be sufficient to cause the net returns per acre of cotton to be as low or lower than the next most competitive crop. A decrease in the price of cotton or an increase in either the yield or price of soybeans could change the competitive position of the two crops. In those situations where cotton is no longer the most profitable crop, other crops with higher net returns would be substituted for cotton to maximize profits.

CHAPTER V

SOCIAL IMPACTS AND EXTERNALITIES OF INSECTICIDE USE

Uncompensated costs and returns associated with the use of insecticides may take different forms. When society considers ways and means of restricting producers from using insecticides, it is really saying that the social costs (hazards to health and the environment) of using current insecticides have exceeded the social benefits (large supplies of high quality food and fiber). In other words, it is no longer acceptable to society for producers to use insecticides with little or no regard for the effect on the environment. The social benefits and social costs of insecticide use, particularly as they relate to the production of cotton are summarized in Table XVI. A complete ban on all insecticides would result in a reversal of most of the positive and negative effects listed.

Positive Insecticide Effects

Insecticides used on farms have contributed to a relatively stable and inexpensive supply of high quality food and fiber. These chemicals have improved human health and made life more pleasant by controlling insect pests.

TABLE XVI

EXTERNALITIES OF INSECTICIDE USE

Positive Effects	Negative Effects
Higher crop yields	Destroying nontarget organisms
Higher quality products	Accumulation in the food chain
Healthier environment	Lowered reproductive potential
Persistency	Resistance to insecticides
	Chemical migration or drift
	Persistency

Cotton producers in the Sunflower River Basin have achieved and are continuing to achieve high yields by keeping insect pests under control. Improved plant varities, commercial fertilizer, and improved cultural practices have also contributed to higher yields.

Perhaps no single factor has contributed more to the high quality of cotton produced than insecticides. Early insect infestations prevent the cotton boll from developing properly and result in lower yields. Later infestations may affect the quality of the cotton that is produced.

Spraying with DDT and other organochlorines in the basin has reduced the problem of insect-related diseases such as malaria. While cotton is the main consideration, rice is an important crop in the area and wherever rice is grown a mosquito problem exists. Insecticides are used to combat them, thus reducing the hazard of insect vectors to residents in the area.

Persistency has a positive effect due to the length of time certain insecticides remain active in the control of insects. The lasting residuals provide control of pests over relatively long periods of time and decrease the need for reapplication. The use of more specific insecticides requires a different pesticide for almost every different pest that attacks a given crop.

Negative Insecticide Effects

In most spray operations, many nontarget insects are killed, some of which may be predators on the very organisms being sprayed to control. The more selective the insecticide the less of this problem there is to contend with. The organophosphates and carbamates have an advantage in this respect because they are more selective in the insects they will control.

The persistent nature of certain insecticides permits them to be carried from one area or organism to another. This permits them to accumulate in the food chain. Studies conducted by the Mississippi Game and Fish Commission in the study area found that DDT and toxaphene were the prevalent insecticides in lake waters and fish flesh. Also that insecticides were responsible for a decline in the number of fish in certain lakes. "Bass and crappie are virtually absent in many waters where they flourished previous to the advent and widespread intensive use of long-lived insecticides" (2, p. 4).

There is conclusive evidence that DDT does cause thin egg shells and other reproductive problems in certain species of birds. The study area has several recreational preserves for hunting and fishing that have been developed in recent years by private groups of individuals. Apparently the ducks and other species hunted in the basin have not been adversely affected by insecticides. These preserves are usually developed in wooded areas. Thus, the potential contamination from drift and surface run-off from cotton fields is not as great as it is in more open areas in the basin.

Insects have a remarkable ability to develop a resistance to certain types and/or levels of insecticides. As higher levels of insecticides are applied, the potential for causing environmental problems increase. Perhaps one reason a problem of insect resistance has not developed in the Mississippi Delta is because producers have not relied on a particular insecticide to control the insect pests of cotton over a period of years. As new products have been put on the market, the cotton growers have been quick to use them. Although it has not developed at this point in time, insect resistance could still become a problem in the basin.

Effect of Restricting Organochlorine Insecticides

The previous section discussed the effects, both positive and negative, of using all classes of insecticides to produce cotton. Similarly, there are social costs and social benefits associated with persistent insecticides (DDT and other organochlorines) as compared to the nonpersistent insecticides (organophosphates and carbamates). A summary of these relationships is presented in Table XVII.

TABLE XVII

EXTERNALITIES OF RESTRICTING DDT AND OTHER ORGANOCHLORINES

Positive Effects	Negative Effects
Substitute insecticides are not as persistent	Substitutes are more expensive
Increased sales of substitute insecticides	Substitutes are more toxic to warm blood animals
No long-term residue problem	May discourage development of new and better insecticides
Degrade rapidly	Increased costs may reduce the supply of farm products
Environmental pollution reduced	Potential hazard for those who handle and apply them
	More frequent applications required
	Higher loss of pollinating insects

The results of this study indicate that the required amount of cotton could be produced in the basin without the use of DDT. Although, the social costs of restricting the use of DDT and other organochlorines has not been precisely measured, certain values and relationships are apparent. For example, use of substitute insecticides result in a higher cost per acre to produce cotton, thus committing resources that would otherwise be available for production and/or consumption of other commodities. Not only is more land area required, but the inputs per acre are greater. The cost to society in this case is the value of other goods that could be produced on the additional land used for cotton production and the additional costs per acre to produce cotton in a less efficient way.

Efficiency to the producer refers to the amount of cotton that can be obtained from the least input cost per acre. Efficiency to society includes the effect on the environment and the health of society. In other words, environmental pollution is a social cost that must be added to the regular production costs. The persistency aspects of the organochlorine insecticides have caused society to consider a less efficient cotton production process for a cleaner environment.

It should also be recognized that cotton prices, exclusive of government programs, would rise if these adjustments in production practices result in decreased total output because of higher prices or inability to maintain production with the restricted use of insecticides. Ideally public regulations or restrictions attempt to guide the use of insecticides and other chemicals to produce food and fiber with a minimum level of social and private costs. The only condition when the private and social costs would be the same is when there are no externalities or spillover effects.

Effect on the Economy of the Study Area

Increased local employment and added volume of sales are anticipated market effects. The basis for anticipating increased economic activity are discussed below. First, the additional quantities of insecticides needed to produce the 1980 cotton requirement (57 percent increase over 1966) would be substantial with present insecticides and application rates. A substantial increase in the quantity of insecticides used will be required on the additional acreage, even for Strategy I. This would stimulate sales for suppliers of insecticides and insecticide application equipment.

Second, the added volume of sales would require additional personnel to handle and apply the insecticides. The added volume may result in the expansion of present suppliers or the establishment of new businesses.

Third, if persistent insecticides are restricted, the quantities of non-persistent insecticides applied would be even greater than the quantities of the persistent insecticides used because larger quantities are required per acre for effective control. This, plus the fact that more total acres are required for cotton production under Strategies II and III, add up to a substantial increase in insecticide sales in the basin.

An insecticide firm could be adversely affected by the amount of the restricted insecticide in inventory when a restriction goes into effect. In reality this is not a serious problem because legislative action usually provides a time lag of one to several years before a restriction goes into effect. The current insecticide bill pending before the Congress has a four-year adjustment period.

The costs of controlling insects for the three strategies using insecticides are presented in Table XVIII. With the use of DDT, the cost is two cents per pound of lint and a total cost of a little more than $10,000,000. Restricting the use of DDT increased costs by almost $3,000,000 or 20 percent. Restricting all organochlorines increased costs nearly $7,000,000 or 69 percent. These figures not only indicate the expenditures by producers in the basin to control insects, but they also indicate the increased volume of business that would be associated with restricting the use of certain insecticides.

A fourth effect is the fact that other inputs in addition to insecticides would be required on the additional cotton acreage. Seed and machinery inputs would increase as the acreage increased, thus creating additional sales

TABLE XVIII

PROJECTED COST OF INSECT CONTROL IN THE SUNFLOWER RIVER BASIN, MISSISSIPPI, 1980

Strategy	Insect Control cost per Acre	Cotton Acreage	Average Yield	Cost per pound of Lint	Total Cost to Control	Increase In Cost Without DDT	Increase in Cost Without Organochlorines
	Dollars	Acres	lbs/Acre	Dollars	Dollars	Dollars	Dollars
I	15.33	656,842	765	.020	10,069.388	-	-
II	19.23	678,530	740	.026	13,048,132	2,978,744	-
III	22.38	762,403	660	.034	17,062,579	6,993,191	4,014,447
IV	-	1,034,636	485	-	-	-	-

volume and more employment.

Additional ginning facilities would probably not be required since the quantity of cotton produced would not change. A possible exception might be if a gin needed to be located closer to where the additional cotton is being produced. This becomes a location problem rather than a capacity problem.

Restricting only DDT would have little noticeable effect on the sales of specialized cotton equipment as only 22,000 additional acres would be involved. Restricting all organochlorine insecticides would have a much greater effect. The additional acreage would be increased 16 percent, or 105,500 acres. A complete ban on all insecticides would increase the cotton acreage more than 50 percent if producers continued to grow cotton.

As a means of measuring the impact on farm machinery sales of growing cotton on more acres, the investment in farm tractors and equipment per acre of cotton was calculated. Data of this nature were not readily available. Mississippi sales tax information was used to get an indication of machinery expenditures. Gross sales by selected industrial groups for each county in the basin were obtained. The two groups of primary interest were farm tractor and farm equipment dealers. Historical data were compiled for 1960, 1965, and annually from 1968 through 1970.

Since cotton is not the only crop grown in each of the counties, it was necessary to determine what proportion of total sales pertained to cotton production. This was accomplished in a series of steps. The first step was to determine what proportion of total agricultural commodity receipts cotton represented. The percentage for the most recent 10 year period, for which these data are available, 1960-69, gave an average of 31.7 percent. From 1960 through 1965, the percentage remained nearly constant at approximately 40 percent. After 1965 the percentage decreased quite rapidly. This was caused by the tremendous increase in soybean production. The cash receipts from cotton remained about the same during this period but total commodity receipts increased.

The next step was to determine the acreage of cotton in the Sunflower Basin for the years that sales tax data were available. The county acreage was obtained from Mississippi Agricultural Statistics (37). The county acreage of cotton was used to be consistent with the sales tax data. It should be kept in mind that the boundary of the Sunflower Basin is on a hydrologic basis, thus, parts of several counties are in the Basin. Consequently, the county acreage of cotton is larger than the Sunflower Basin acreage.

The third step consisted of dividing the basin's shares of the gross sales by the acreage of cotton for the selected years. This value represents the producer's expenditure for tractors and farm equipment per acre of cotton (Table XIX).

TABLE XIX

GROSS, COTTON, AND PER ACRE OF COTTON FARM TRACTOR AND EQUIPMENT SALES FOR SELECTED YEARS, SUNFLOWER RIVER BASIN, MISSISSIPPI

Year	Farm Tractor and Equipment Sales	Farm Tractor and Equipment Sales for Cotton	County Cotton Acreage (Sunflower Basin)	Farm Tractor and Equipment Sales per Acre of Cotton
	Dollars	Dollars	Acres	Dollars
1960	26,042,025	8,255,323	737,400	11.20
1965	42,777,269	13,560,394	660,950	20.52
1968	48,313,102	15,315,253	581,150	26.36
1969	46,985,663	14,894,455	621,300	23.98
1970	32,762,841	10,385,821	623,910	16.65

The impact on farm machinery sales of an increased acreage of cotton was calculated by using the average tractor and machinery cost per acre, for the five selected years; and relating it to the four insecticide situations. The average investment per acre was $19.74. The increased sales due to restricting DDT amounted to only $428,121. As explained earlier, the acreage change going from Strategy I to Strategy II is not great. Increased sales associated with Strategy III are $2,083,774 more than with no restrictions on the use of insecticides. Strategy IV would increase sales $7,457,655. These values are presented in Table XX.

Agribusiness sales related to the increased acreage of cotton are limited by the amount of idle cropland (including conservation and acreage reserves) brought into production and the other cropland that was less intensively farmed. Land previously used for other crops with comparable non-farm inputs, would not increase the volume of business to the supplier. Rather it would be a change of inventory items.

Of all the crops grown in the Sunflower Basin, cotton requires the greatest "dollar" outlay. Therefore, agribusiness sales would increase. The exact amount would vary, depending on the crops replaced by cotton.

Non-market effects are primarily related to human health and the environment. Improved application techniques may reduce the amount of insecticide released in the air

TABLE XX

PROJECTED FARM TRACTOR AND EQUIPMENT SALES FOR ALTERNATIVE INSECTICIDE STRATEGIES, SUNFLOWER RIVER BASIN, MISSISSIPPI, 1980

Insecticide Situation	1980 Acreage	Farm Tractor and Equipment Sales	Increase over Strategy I	Increase over Strategy II	Increase over Strategy III
		Dollars	Dollars	Dollars	Dollars
Strategy I	656,842	12,966,061	-	-	-
Strategy II	678,530	13,394,182	428,121	-	-
Strategy III	762,403	15,049,835	2,083,774	1,655,653	-
Strategy IV	1,034,636	20,423,716	7,457,655	7,029,534	5,373,881

which may come in contact with nontarget organisms. The development of new insecticides that are biodegradable may reduce or eliminate the undesirable characteristics of the present persistent insecticides. In spite of these possible improvements in the application of and type of insecticide used, added quantities of insecticides applied to cotton in the area may have some adverse effects on certain organisms.

Restricting the persistent organochlorines as a means of reducing the hazard to birds and other wildlife may result in a greater hazard to humans. The more toxic organophosphates currently being substituted for the organochlorines are thought to be responsible for the death of several crop duster pilots and others working directly with the more toxic substitute insecticides.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Summary

Insecticides are valuable tools in agricultural production when properly used. They are responsible for higher yields, lower production costs, and improved product quality. Two classes of organic insecticides, the organochlorines and the organophosphates are the most widely used. There are advantages and disadvantages to both. The organochlorines are more persistent but the organophosphates are more toxic to man.

The general objective of the study was to estimate the economic effects of restricting the use of insecticides in the production of cotton. Specific objectives were: (1) to determine the cost per acre of producing cotton without the use of DDT, without other chlorinated hydrocarbon insecticides, and without chemical insecticides in the study area; (2) to determine the effect on net returns to the cotton producer of alternative insecticide strategies; (3) to determine the effect on the production of other crops and idle cropland of maintaining a constant cotton production with the alternative insecticide strategies; and (4) to identify, discuss, and summarize the externalties associated with insecticide use for cotton production.

The economic effects analyzed were changes in production levels and costs, changes in land resource use, and impacts on agricultural producers and non-agricultural groups of persistent versus non-persistent insecticides.

The objective of Integrated Control of insect pests is to control insect populations without having a 100 percent kill. A combination of non-chemical (mechanical, cultural, and biological) and chemical (insecticides) may be used. Such integrated control requires a greater knowledge of field conditions and specific treatments for a particular pest at the proper time rather than an extensive use of insecticides applied on a predetermined schedule whether actually needed or not.

The lessons learned from DDT should encourage a broader sense of economic and social responsibility; an increased awareness of the short-run and long-run implications of man's actions; and an attempt to determine if such actions and technology are in harmony with biological, social, and economic objectives.

The development and sale of insecticides is controlled by state and federal regulations. An insecticide cannot be sold in the United States until it has been approved by the Food and Drug Administration, the U.S. Department of Agriculture, and the U.S. Department of Interior. Pending legislation (the Pesticide Control Act of 1971) has three main provisions: (1) pesticides would be classified into "General Use" and "Restricted" with the latter requiring a licensed applicator; (2) all applicators would be licensed and required to exhibit a satisfactory knowledge of and ability to safely apply pesticides; and (3) the Environmental Protection Agency is given enforcement powers to impose civil penalties and bring criminal charges when such action is warranted.

Externalities may occur in the form of external benefits and/or external costs. Externalities associated with insecticides are due primarily to their persistency and/or toxicity to man. Persistency has several advantages in addition to its disadvantages.

A U.S. Department of Agriculture study of the Sunflower River Basin in Mississippi was used as the starting point for this analysis. This study used the projected 1980 "with" resource development results as a base from which to modify the cotton yields and budgets as depicted by the alternative insecticide situations. Four insecticide strategies were identified as follows: Strategy I, non-restricted use of insecticides; Strategy II, without DDT; Strategy III, without all organochlorines; and Strategy IV, without chemical insecticides. The analysis was made using a minimum cost linear programming model in which cotton cost and yield values were adjusted for the different insecticide strategies.

Alternative Insecticide Strategies

Analysis

The objective function of the linear programming model minimizes the cost of producing a given set of product requirements, given a specific set of restraints on the production process. The optimum solution for Strategy I required 656,842 acres to produce cotton. The total cropland required was 1,702,242, leaving approximately seven percent of the total cropland idle. The cost per acre for cotton was $110, the total cost for production of cotton was $72,292,608, and the total cost for all crops was $113,443,762.

With Strategy II (without DDT), 22,188 more acres of cropland were required to produce the required amount of cotton. Total cropland in production increased 27,314 acres. More acres were required for some of the other crops because cotton production had priority, thus resulting in shifts of other crops to lower yielding soils. The cost to produce cotton increased $5,027,596 and the total cost increase for all crops was $5,148,338. Cotton cost increases were due to higher priced insecticides and more total acres of cotton. Restricting DDT brought some idle cropland into production but did not use all of the idle cropland available in the basin.

Results of Strategy III, without organochlorine insecticides, provide an indication of the production capacity of the basin under the stated conditions as practically all of the idle cropland was brought into production. Cotton production required an additional 83,873 acres and the total cost of cotton production increased $11,861,701. The cost per bale increased $11.80 over Strategy II and $16,81 over Strategy I.

Restricting all insecticides resulted in the study area failing to meet the 1980 projected production requirements. Cotton production remained the same but 271,933 additional acres were required. This caused the other crops to be reduced to approximately two-thirds the acreage needed to produce the required quantities. Cotton production costs increased $8,731,514.

Externalities Analysis

The primary concern of the general public about insecticides is the possible hazard to environmental quality and the possible effect or effects on humans and other forms of animal life. When society considers restricting the use of insecticides, it is really saying that the social costs (health and environmental hazards) of using insecticides have exceeded the social benefits (quantity and quality of food and fiber).

There are positive and negative spillover or external effects from using insecticides. Similarly, there are positive and negative effects of substituting the less persistent insecticides for the more persistent ones.

Social costs increase as the more efficient (from a producer's point of view) insecticides are restricted due to their undesirable spillover effects on the environment. The less persistent insecticides increase the total quantity of insecticides used per acre, increasing cost of cotton production. Also, they are more toxic to man. In other words, the reduction of environmental pollution does have social costs. Public regulations or restrictions are used to govern the use of insecticides and other chemicals in the production of food and fiber with a minimum of social and private costs.

Conclusions

The effect of restricting certain insecticides can be estimated using the procedures presented in this study. Cotton producers can and undoubtedly would continue to produce cotton in the study area even if certain insecticides are restricted because producers would realize a greater net return than if they produced other crops under the yield and cost data used in this analysis.

An increase in the cost of growing an acre of cotton due to added insecticide expenditure may not be sufficient to cause net returns per acre to be as low or lower than for soybeans, the next most competitive crop. A small decrease in the price of cotton, an increase in the price of soybeans, or an increased yield per acre of soybeans could change the competitive position of the two crops.

Restricting the use of certain insecticides, but still maintaining a set level of cotton production, would increase the volume and sales of cotton related businesses. Additional cotton acreage would increase the sale of specialized cotton equipment used for production but not for processing. Also, more seed, insecticide, and certain other supplies would be required. Agriculture related businesses would gain from these sales only to the extent they did not lose sales from inputs used in the production of other crops grown in the basin. Since the available cropland is fixed, the increased sales due to more acres of cotton production are no more than the idle cropland available, plus the added inputs associated with cotton as compared to the crop cotton replaces.

Cotton producers can reduce the amount and kind of insecticides used to produce cotton. By using integrated control, the joint utilization of several techniques to manage pest population levels, the amount of insecticide entering the ecosystem can be reduced.

Suggestions for Further Research

Additional research is needed to evaluate the cost of restricting the use of specific insecticides under assumptions other than maintaining a predetermined production level. Further studies might consider alternatives other than insecticides to control pests. Land, labor, and machinery have been replaced by insecticides and herbicides.

If pesticides are banned, can substitution of production inputs be reversed? If so what are the consequences?

The basic model and techniques developed in this study need to be expanded and refined. Collection of basic data on insecticides to determine more accurately the response with different crops and different insecticide combinations is essential to accomplish this task. This study dealt primarily with cotton. Information is needed on other crops to determine their yield and quality response to various types of insecticides. Also, in the case of persistent insecticides, especially, the effect on subsequent crops grown in rotation needs to be known.

The procedures used in this study could be expanded to include not only insecticides but herbicides and fungicides. Cost and yield differentials associated with the major crops grown in an area as they are affected by alternative pesticide situations would provide a more realistic approach to the production and environmental problems that are involved.

The integrated control approach to controlling insect pests is relatively new. Improved technology and managerial strategies can be used to not only control the pests but to control some of the undesirable external effects of spraying toxic compounds into the environment. An objective of future research in this area would be to determine economic "threshold" level of infestation before insecticides or other control procedures are employed.

Finally, research is needed to better estimate the costs and benefits to society of using insecticides. The specific problem is to determine the optimum level of insecticides insofar as society is concerned as compared to the optimum level for the individual producer. Research in this area would require the establishment of some sort of quantitative values pertaining to such things as aesthetics, recreation, fish and wildlife, and human health and well-being. This kind of research will require a cooperative effort from several disciplines. Better communications among sociologists, biologists, and economists will go a long way toward bringing all the factual pieces together to better understand the effects of given insecticide treatments on the environment.

Although there are limitations to the methodology and perhaps some of the input data used, this study does contribute significantly to the quantification of economic impacts of alternative insecticide strategies on cotton production.

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APPENDIXES

APPENDIX A

MISSISSIPPI INSECTICIDE LAWS AND REGULATIONS

The Mississippi Economic Poisons Act of 1950, as amended, is the basis for controlling insecticides in the State. This Act relates to the distribution, sale, or transportation of adulterated or misbranded insecticides and other economic poisons. The term "insecticide", as it relates to this Act, means any substance or mixture of substances intended for preventing, destroying, repelling, mitigating, or attracting any insects which may be present in the environment whatsoever (47, p. 1).

The Act states that it is unlawful for any person to distribute, sell or offer for sale, or transport any insecticide which has not been registered according to the provisions of this same Act. Also, the insecticide must bear a label giving the name and address of the manufacturer, registrant, or person for whom manufactured; the name brand or trade-mark under which said article is sold; the net weight or measure of the contents; and the batch number from which the date of packaging can be determined.

The Act also protects the manufacturer by making it illegal for any State Plant Board official or other State employee to disclose the exact formula of an insecticide except to qualified persons, such as physicians or pharmacists, for the preparation of antidotes.

Registration requirements are essentially the same as those required by federal law. Every insecticide must be registered in the office of the State Plant Board and must be renewed annually. The registration requires a complete copy of the labeling and a statement of all claims to be made for it including directions for use. State regulations are minimized and uniformity with other states and the Federal Government is maintained by the following provisions of the Act:

> In order to avoid confusion endangering the public health, resulting from diverse requirements, particularly as to the labeling and coloring of economic poisons, and to avoid increased costs to the people of this state due to the necessity of complying with such diverse requirements in the manufacture and sale of such poisons, it is desirable that there should be uniformity between the requirements of the several states and the Federal government relating to such poisons. To this end the State Plant Board ia authorized, after due public hearing, to adopt by regulation such regulations, applicable to and in conformity with the primary standards established by this Act, as have been or may be prescribed in the United States Department of Agriculture with respect to economic poisons (51, p. 7).

Enforcement of the Act is provided by granting the State Plant Board or its employees free access to all places of business, factories, buildings, carriages, cars, stores, warehouses, and other places where insecticides are offered for sale, or kept for sale or distribution. They have authority to open any parcel or package and to take a sample for the purpose of examination and analysis.

The penalty for someone not complying is perhaps the weakest point of the Act. A person violating this Act is guilty of a misdemeanor and upon conviction shall be fined not more than five hundred dollars.

The Act was amended in 1970 to establish requirements for bulk handling facilities. The term bulk container means a container larger than 55 gallons for liquids and larger than 100 pounds for dry material.

The State Entomologist, a member of the State Plant Board, may refuse to allow the dispensing of certain insecticides in bulk containers if in his opinion such dispensing would create an undue hazard. A bulk handler must conform to the regular requirements for registration and in addition must agree in writing to the following:

1. All containers to be dispensed from shall be plainly marked by painting or stenciling in large letters showing the name and address of the applicant, and a phrase similar to "Warning - Contains Economic Poison".

2. All containers shall be provided with suitable sample points to permit withdrawal of samples by personnel of the State Plant Board, such samples to be accepted without reservation as being representative of the material therein and described on the label attached.

3. When containers are charged or recharged, the filling inlet shall be sealed in such a manner so as to prevent tampering with the contents.

4. The pesticide shall be diluted or otherwise formulated in a "final mix ready for application" on the immediate premises where withdrawn.

5. Adequate provisions shall be made for handling to prevent contamination or injury to persons, livestock, crops and wildlife (44, p. 1).

The Mississippi Pest Control Law, amended in 1969, establishes regulations governing pest control operators. No person shall advertise in any manner to render professional services or solicit business without first obtaining a license. No application for a license shall be accepted unless the applicant meets one of the following requirements: (1) Must be graduated from a recognized college or university with at least 15 semester hours or the equivalent in the field for which he is requesting a license; (2) Must have not less than two years college or university training with special training in the field for which he is requesting a license; (3) Must be at least a high school graduate, and have had, in addition, at least one year's experience with a licensed operator; (4) Must be able to furnish proof that he has had at least two years experience with a licensed operator.

The applicant shall take an examination which may be oral, written or both, as may be determined by the Board and in general, cover the subject of the professional services designated in the application. At the discretion of the Board, the examination may be waived if the applicant is already licensed to perform the same professional services in a state with standards equal to those of Mississippi, and provided further that said State recognizes such examinations given by Mississippi.

If the qualifications and other requirements of the applicant are satisfactory, the Board shall then require that the applicant submit a detailed statement of the methods he will employ and such typed or printed forms or contracts which will be used in the conduct of the professional services for which the application for license is made. After all requirements have been met by the applicant, the Board shall then issue a license which shall be valid for an indefinite period unless suspended or revoked for cause (45, p. 1,2).

A further protection to the public was provided in the amendment that requires each employee of an operator, who solicits business or otherwise represents the operator in dealings with the public, to have an identification card with a permanently attached recent picture of the employee.

The purpose of the Agricultural Aviation Licensing Act of 1966 is to supervise and regulate for the public good all commercial agricultural aerial application within the State of Mississippi and to establish and promote a close working relationship between agricultural aerial applicators and the Mississippi Plant Board by the licensing of all persons engaged in the aerial application of pesticides, poisons, seeds, and chemicals and the registration of all such commercial agricultural aircraft (3, p. 1).

This Act provided for the creation of the State Board of Agricultural Aviation. The board is vested with the authority to adopt such rules and regulations as may be necessary to regulate the application of chemicals and pesticides according to the time of year, manner, form and area of application, wind velocity, and may restrict the use of certain chemicals and pesticides which create an unusual hazard to the health, safety and welfare of the public. The board also sets professional standards for aerial applicators in the interest of the safety, welfare, and general well being of the public of Mississippi.

APPENDIX B

YAZOO-MISSISSIPPI DELTA SOILS

The soil survey legend for the Yazoo-Mississippi Delta, which was used on the Mississippi River and Tributaries Study, consists of 13 soil groups (38). These are virtually soil associations at a low level of generalization. Each of these soil groups has a descriptive title that states the important characteristics and qualities. Soils for the Delta portion of Mississippi along with a description are as follows:

Soil Group 1 (Sharkey and Alligator Soils; fine textured, very slowly permeable, poorly drained soils) The Sharkey series comprises dark, poorly drained, slightly acid alkaline, alluvial soils of the Mississippi River floodplain. These soils are derived from fine textured slackwater deposit and are usually subject to overflow except where protected by levees.

Soil Group 2 (Tunica and Dundee; moderately fine textured, somewhat poorly to moderately well drained soils) Tunica soils are somewhat poorly to moderately well drained soils on bottomlands and low terraces. The upper 36 inches of the profile is silty clay loam, below which is coarser textured materials. Tunica soils are better drained than the Sharkey. They are somewhat less plastic and occupy the slightly higher positions in the slackwater areas.

Soil Group 2 has a nearly level to undulating surface. A great part of the acreage is well suited for cultivation. It is productive of cotton, oats, alfalfa, corn and soybeans.

Soil Group 3 (Sharkey and Crevasse Soils; fine textured very slowly permeable, poorly drained soils and coarse textured, excessively drained sands in bottomlands of Mississippi River) The Sharkey-Crevasse complex of alternate strips of Sharkey Crevasse soils, the separate areas of these two soils being so small or intricately associated as to make their separation impractical on detailed maps.

Most of this soil group is cleared and used for cotton and soybeans. The wide variation in the texture and drainage of the Sharkey-Crevasse complex causes its productivity to vary.

Soil Group 4 (Dundee, Dubbs, Bosket soils; medium textured, moderately well to well-drained, medium to strongly acid soils on natural levees and low terraces) Many of the areas of this soil group consist chiefly of Dundee and Dubbs soils with smaller amounts of Bosket intermixed. The areas are on the natural levees or terraces adjacent to old channels. They are higher than Sharkey soils and soils of the bottomlands such as Mhoon and Commerce.

A small amount is mapped as strongly undulating, good tilth. A great part is cleared and is productive of cotton corn, and soybeans.

Soil Group 5 (Commerce and Robinsville; medium textured moderately well and well-drained, predominately slightly acid to slightly alkaline soils on bottomlands) This group is similar to Group 4 in drainage, texture, permeability, and general suitability to crops and management requirements. It occupies first bottom areas adjacent to present channels rather than the older, somewhat higher positions occupied by Soil Group 4. The profiles of Group 5 soils are not as well developed and their reaction is more nearly slightly acid to slightly alkaline.

A great part of the acreage of this group is cleared and Group 4 includes some of the most desirable land for the production of crops. Much of the acreage is well suited to corn, cotton, alfalfa, soybeans, and truck crops. The areas of Group 5 are widely distributed throughout the bottomlands.

Soil Group 6 (Forrestdale and Sharkey soils; medium and moderately fine textured, overwash on poorly to moderately well drained soils of the bottomlands and natural levees of the Mississippi River) Much of this soil group is cleared and produces cotton, corn, oats and soybeans. All areas require artificial drainage for high yields.

Soil Group 7 (Collins, Falaya, Hymon and Ina soils; medium textured, somewhat poorly and moderately well drained soils on bottomlands of tributary streams) Areas of this group are nearly level and subject to overflow by the tributary streams. The soils are moderately fertile and medium acid. They are permeable, have good tilth and have a moderately high capacity for available water. Much of the better drained parts (Collins and Hymon soils) are cleared and used for crops, chief of which are corn, soybeans, sorghum, cotton and pasture. Although some of the somewhat poorly drained soils are cleared and used for soybeans, corn, and pasture, much is under cutover deciduous forest. The somewhat poorly drained soils are the more extensive, are a little lower-lying, and more subject to overflow than the moderately well drained soils. Most of this soil group responds favorably to adequate water control and good management.

Soil Group 8 (Waverly, Falaya, Brittain and Ina soils; medium and moderately fine textured, poorly and somewhat poorly drained soils of the bottomlands of tributary streams) These soils consist chiefly of loessial material deposited as alluvium by streams flowing from loessial uplands.

A small part of the Falaya and Ina soils is cleared and used for corn, soybeans and pastures. Much of the remainder is still under cutover deciduous forest due to wetness and the great hazard of overflow. Drainage and control of overflow is necessary if areas of this soil group are to be cultivated or to be productive of improved pastures.

Soil Group 9 (Richland, Freeland and Pearson; medium textured, moderately well drained soils of loess terraces)

This group is on stream terraces consisting chiefly of loessial alluvium that originated in the upland areas consisting of Memphis, Loring and Grenada, and associated soils.

All of these soils have good tilth and a moderately high capacity for supplying water to plants. They are moderately fertile and they respond well to good management. A great part of the acreage is cleared and cultivated. It is well suited to a wide variety of crops, including cotton, corn, small grains, soybeans, hay crops and pasture.

Soil Group 11 (Beulah and Robinsville soils; medium and moderately coarse textured, well drained soils) This group is distinguished for its adequate soil drainage. Drainage is rapid; the sandier part being somewhat excessively drained. The slope ranges from nearly level to gently sloping. Much of the acreage is mapped as slightly sloping and strongly undulating.

Nearly all of this soil group is cleared and cultivated. Corn, cotton, and soybeans are usually grown on them. They respond well to management and give good yields.

Soil Group 12 (Crevasse soils; coarse, textured, excessively drained soils of the bottomlands and natural levees) This group represents sandy areas that are low in water supply capacity and plant nutrients. In general, they are on the higher parts of natural levees.

This soil group is not extensive, most of it is open and used for pasture, cotton, corn, and soybeans. These soils do not need drainage, they have a low water supplying capacity, and are low in fertility.

Soil Group 13 (Sandy alluvial land; very sandy alluvial deposits) This soil group consists of coarse, sterile sands dumped during high water. Many deposits resulted from breaks in main line levees, and most of them buried otherwise productive soils. Where these deposits are but a few feet thick, farmers may spread the sand so as to get the underlying soil near enough to the surface to mix it with the sandy material by deep plowing. Some of the areas are fairly productive of such crops as watermelons, even though not mixed with the underlying soil. Some areas, however, are of very little or no value for growing crops and are a decided hazard as they may move into adjacent areas of productive soils by blowing. The total area of this soil group is small.

Soil Group 14 (Swamp; very wet and poorly drained land covered with water most of the time) These are the permanently wet wooded areas. The water table, most of the time is above the surface and the areas are not considered reclaimable for crops or pasture. The total area of this soil group is small.

The Mississippi River and Tributaries grouping of the soils in the Yazoo-Mississippi Delta was aggregated into the four Soil Productivity Groups for the Yazoo-Sunflower Basin Study as follows:

Soil Productivity Group	Mississippi River and Tributaries Group
I	1
II	2, 3, 6, 8,
III	4, 5, 7, 9,
IV	11, 12, 13, 14

These groups were developed by Mississippi Soil Conservation Service soil scientists.

VITA

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Candidate for the Degree of

Doctor of Philosophy

Thesis: AN ECONOMIC INVESTIGATION OF THE IMPACT OF ALTERNATIVE INSECTICIDE STRATEGIES ON COTTON PRODUCTION IN THE SUNFLOWER RIVER BASIN, MISSISSIPPI

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