A Survey of Historical and Current Agricultural Pesticide Use in Arizona

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by

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EXECUTIVE SUMMARY

INTRODUCTION

The controversy over the growing awareness of the adverse effects of toxic substances and their increasingly essential role in our modern lifestyle is an issue of widespread concern. Agriculture in the United States is an excellent example. While pesticides have become indispensable to current operations, certain specific substances and application/disposal technologies are recognized as having the potential to impair the overall quality of air, land and water supplies. As knowledge of the environmental fate of pesticides grows, the importance of better information on the scope, nature and potential threats of pesticide-related contamination also increases.

Arizona agricultural pesticide issues have focused largely on groundwater quality, because of the arid climate and limited water supplies. To express their concern, Arizona legislators passed the 1986 Environmental Quality Act and created the new Department of Environmental Quality (DEQ). One of DEQ's major functions is to define pesticide-related groundwater problems, gauge the nature and scope of the current situation, and develop regulations and legislative recommendations for protecting the environment and human health.

As part of its investigative effort, DEQ commissioned the State Pesticide Coordinator's Office of the University of Arizona Cooperative Extension to study agricultural pesticide use patterns in the state. Research procedures involved two primary sources, the Annual University of Arizona Pesticide Sales Survey and the Pesticide Applicator Reports (Form 1080) filed with the Arizona Commission of Agriculture and Horticulture; these were correlated with other available compilations and supplemental information from bulletins, questionnaires and personal consultations to develop historical pesticide data and a land use profile. Future trends which might affect pesticide use are also described. Selected information is summarized for chemicals of environmental concern, as a basis for guidelines to aid in selection of areas for focusing monitoring for pesticides with potential to leach into groundwater. Recommendations for improving pesticide use information and appendices of additional data are included in the report.

PRINCIPAL FINDINGS AND RECOMMENDATIONS

Evidence is clear that agricultural pesticides have been steadily sold and applied in Arizona at a rate reflecting the importance of this business in the state's economy. Certain compounds, such as chlordimeform, methyl parathion and sulfur, consistently appear in different types of pesticide use records in the state. Persistent chemicals like DDT, toxaphene and DBCP are known to have been applied for long periods and often at increasing rates of active ingredient per acre before their cancellation.

Examination of land use in Arizona reveals that traditionally the same areas, located near principal waterways in various counties, constitute the major part of agricultural acreage. This distribution occurs because irrigation for most crops is essential in the state's arid environment. Cropping patterns indicate that certain commodities have been grown for many years, although overall acreage has increased. Large farms, often devoted to a single crop, intensify the economic impact of pest infestations.

Major agricultural counties are Maricopa, Pinal and Yuma; other counties with significant plantings include La Paz and, to a lesser extent, Cochise and Graham. Pesticide use data reflect the mix of crops which occupy the principal farming areas in different counties. The state agricultural production scene has been and still is dominated by cotton and cattle. Cotton accounts for approximately 40 percent of cropland and 70 to 75% of the insecticides used by custom applicators. Certain crops (like lettuce) require intensive pesticide use for high quality production; others, like alfalfa, are of concern because of the high acreage involved. Some commodities, including cattle, wheat and barley, either need minimal treatment or use application patterns which result in little environmental residue. Specialty crops (like safflower, sesame and jojoba) often have few or no pesticides registered.

Although chemicals are an indispensable part of modern agriculture, the risks and benefits of any pesticide must be evaluated to determine whether cancellation or continued use under amended conditions would be of greater value. Newer products which are less environmentally persistent and applied at lower rates have been and are being developed; their use in Arizona agriculture has already reduced the total pesticide load and averted some potential environmental impacts on air, land, water and wildlife. Trends toward biological products and Integrated Pest Management practices project less overall use of chemicals and shifting from those which are environmentally harmful.

As stated earlier, however, Arizona environmental issues focus primarily on water quality, especially groundwater. Since this is also a national concern, the Environmental Protection Agency had by May 1986 identified 17 pesticides in the groundwater of 23 states, from normal land applications. Nine are herbicides and nine soil incorporated insecticides or fumigants. While herbicides are not sold in Arizona as extensively as in states with large corn and soybean plantings, three of the reported pesticides have been found in our groundwater: the soil fumigants/nematicides aldicarb, DBCP and EDB. DBCP and EDB are cancelled, and little aldicarb is sold in the state; but many Arizona areas experience a continuing need for soil fumigation and nematode control.

Chemicals of Potential Environmental Concern

Various indicators in the report were synthesized to provide a summary chart of 43 chemicals which can offer guidelines for further groundwater research on chemicals of environmental concern. The table provides information on the following criteria: 1) total sales volume over 100,000 pounds reported from 1966 -1980; 2) average annual sales volume greater than 25,000 pounds between 1982 and 1986; 3) noted on custom applicator reports during 1985 and 1986; 4) recommended by pest control advisors and other experienced agricultural personnel; 5) registered on selected Arizona crops; 6) found in other states' groundwater; and 7) found in Arizona groundwater.

Also provided is information on specific counties where the chemicals have recently been used in custom applications and registrations for certain Arizona crops. Five chemicals which have been banned are also included, because of high sales and/or environmental persistence. This list can serve as a preliminary basis for further research on characteristics like solubility, soil adsorption, vapor pressure and dissipation, which may affect their potential to leach below crop root zones and into groundwater.

Pesticide/Land Use Trends

Certain trends have been emerging and are expected to continue in the future. For example, soil fumigants/nematicides have been found in Arizona groundwater; certain areas of the state (where DBCP and EDB were previously used) also have a continuing need to use nematicides, known to be highly water soluble. Existing data cannot be employed to estimate nematicide use. Further monitoring of these pesticides is very important.

Both nationally and in the state, the overall agricultural pesticide load is decreasing. Contributing factors include use of materials with lower application rates, shifts to Integrated Pest Management techniques, regulation of certain compounds, and improved delivery systems. Arizona sales survey figures show that in the last 21 years the pesticide load for agricultural commodities declined (especially during the last eight years). Custom applications are exhibiting the following patterns: less use of chlorinated hydrocarbons; more use of combinations of organophosphates, carbamates and synthetic pyrethroids; and frequent additions of sex attractants (pheromones).

Pesticide use will also be affected by increased government regulation, shifts in land use, improved technologies and increasing resistance to pyrethroids. Land use patterns will be affected by commodity prices, urbanization, regulation and irrigation costs (causing shifts to areas where water is more affordable).

Recommendations

Because of serious limitations in available data resources (Pesticide Application Reports and Annual Pesticide Sales Survey) and the expense of groundwater monitoring for specific pesticides, recommendations focus on ways of developing a more reliable, site-specific pesticide use database:

1. At present, compiling data from the 1080 Forms is both difficult and time-consuming. An initiative to computerize the information on these forms would make available a database of pesticide applications conducted by custom agricultural applicators in different counties.

2. DEQ will require certain types of mandatory reporting under the Environmental Quality Act. Since the Annual Arizona Pesticide Sales Survey provides a voluntary accounting of activities from 1966, requiring distributors to report all sales of pesticides within the state would permit compilation of a reliable data source and eliminate the drawbacks of the current system.

3. Additional data gaps exist in the lack of records for pesticides applied by private applicators and ground equipment, as well as for nonagricultural purposes (i.e., structural, homeowner and other urban uses). Legislation which would enable collection of this data would significantly complement available knowledge of pesticide use patterns in the state.

4. Sufficient time must be allotted to collect and synthesize an accurate database; other states have taken one to four years to accomplish this goal. Many productive avenues of research presented themselves during this project, but the five-month time limit for conducting this particular research precluded their pursuit.

TABLE OF CONTENTS

TABLES AND FIGURES

TABLES PAGE

FIGURES

ACKNOWLEDGEMENTS

We would like to thank the Pest Control Advisors, County Directors, Extension Specialists, and retired entomologists for providing information used in this report. We are especially indebted to Stuart Evans, J. N. Roney, Leon Moore, Stan Heathman, George Ware, David Byrne, Lowell True, and our office staff Kevin Taylor and Trisha Cooper for their cooperation and support. In addition, we owe a debt of gratitude to our editor, Helen DeVries, for her effort, time, and patience in the preparation and completion of this report.

INTRODUCTION

The controversy over the growing awareness of the adverse effects of toxic substances and their increasingly essential role in our modern lifestyle has become an area of worldwide concern. The issue of toxic substance control has spawned workshops, seminars and public meetings aimed at identifying solutions to this dilemna. Political and scientific leadership, in both international and national arenas, have responded by creating government and state agencies assigned a mandate similar to that of the US Environmental Protection Agency -- administering the laws intended to establish a more healthful and cleaner environment.

In this country the debate over the negative impacts of toxic substances versus the benefits of their use continues to receive widespread attention. An excellent example is the area of agriculture. While pesticides have become an indispensable part of current operating practices, certain specific substances and application/disposal technologies are recognized as having the potential to impair the overall quality of air, land and water supplies.

Arizona agricultural pesticide concerns focus largely on water quality. Because of this state's unique climate and environment, the development of population, agriculture, mining and other industries has historically been associated with availability of suitable water. Until the recent past, this association has been mutually beneficial. Steady increases in population, however, have placed rising demands on natural resources. Given Arizona's combination of an arid climate and limited water supplies, protecting the quality of available hydrological resources has become a major concern.

BACKGROUND

In the early 1970's, scientists were able to detect traces of pollutants in parts per million. With the development of increasingly sensitive analytical equipment, certain substances can now be monitored in parts per trillion and even parts per quadrillion. Measurement of pollutants such as tetrachlorodioxin has thus improved 100 million-fold in the last 15 years. This extended capability has created not only a greater awareness of pesticide residues but also an increased demand for more precise identification and quantification of their potential health effects on humans and wildlife.

As knowledge of the environmental fate of pesticides grows, the importance of understanding and realistically interpreting these data also becomes greater. To protect human health and the environment but at the same time maintain a viable climate for agriculture and other industries, federal and state regulatory agencies need better information on the scope and nature of pesticide-related contamination and the potential threats posed by such contamination.

Both nationally and in Arizona, political and scientific leadership is in the process of addressing significant pesticide-pollutant issues. Strict and far-reaching legislation has been promulgated, and federal and state agencies have initiated long-term scientific studies on the potential effects of pesticides as environmental pollutants. As an expression of their concern, Arizona elected officials passed the 1986 Environmental Quality Act, which created the new Department of Environmental Quality (DEQ). One of DEQ's major functions is to define pesticide-related groundwater problems, gauge the nature and scope of the current situation, and develop regulations and legislative recommendations for protecting the environment and human health.

In carrying out this responsibility, DEQ recognizes the critical need to compile the best possible information about in-state patterns of pesticide application and handling which may impact on groundwater quality. As part of its investigative effort, the Department commissioned the State Pesticide Coordinator's Office of the University of Arizona Cooperative Extension to conduct this study intended to provide an overview of Arizona's historical and current pesticide use in agriculture. The information in this study can serve as a basis for developing guidelines to aid in the selection of areas in which to focus monitoring for pesticides that have the potential to leach into the groundwater.

FOCUS OF THE STUDY

Statistics on historical pesticide use for Arizona are severely limited and scattered; the existing sources also provide no indication of specific application patterns by geographical area. The focus of the study therefore was to correlate available data with other resources, for the purpose of developing an agricultural historical pesticide use profile (directed toward the underlying theme of potential environmental impacts to water supplies).

The primary sources of available information are the Annual Pesticide Sales Survey, published since 1966 by the University of Arizona to provide estimated volumes of pesticides sold in the state, and the Pesticide Applicator Reports (Form 1080). The severe limitations in their overall content and reliability necessitated compilation of supplemental information from technical bulletins, Economic Research Service surveys, pesticide use questionnaires and consultations with people experienced in agricultural pest control. These data were synthesized to develop land use data and a historical picture of in-state agricultural pesticide use.

Future trends in national and Arizona agriculture and pesticide usage are also presented for consideration as to their potential influence on patterns in the state. Major findings, including a section on chemicals of environmental concern, as identified from recurrence of certain selected criteria, are presented. The report concludes with recommendations for improving available information mechanisms to provide a clearer picture of pesticide use within Arizona. Appendices of additional information are included for more intensive review.

PESTICIDE USE INDICATORS

HISTORICAL BACKGROUND

The use of pesticides dates back to Biblical times, when brine, sulfur, and botanicals like hellebore were recorded as being applied for pest control. (A time line showing significant developments in pesticide history is provided in Appendix A.) A wide variety of compounds have been used through the years for pest control; popular materials before development of synthetic organic materials included arsenicals (mercuric chloride, lead arsenate, copper sulfate, calcium arsenate, zinc arsenite, sodium arsenate); botanicals (pyrethrum, rotenone, nicotine sulfate, sabadilla, ryania); and other substances like cryolite, soap, oils, turpentine and kerosene emulsions.

In 1930, only 30 pesticides were registered for use in the United States. A major breakthrough occurred when Paul Muller of Switzerland discovered in 1939 that DDT had insecticidal properties. Chemical research during and after World War II led to the development and registration of thousands of products available for pest control in the US.

The first compounds widely used after WW II were the chlorinated hydrocarbons (sometimes referred to as "hard chemicals"). These substances, which included DDT, endrin, aldrin, dieldrin, chlordane, heptachlor, and toxaphene, were very persistent in the environment and toxic to nontarget organisms.

Increasing adverse impacts and resulting regulation of the chlorinated hydrocarbons encouraged the development of less environmentally persistent compounds, such as the organophosphates, carbamates and synthetic pyrethoids. Later advances in pest control strategies included use of Integrated Pest Management (IPM) technologies, sex attractants (pheromones), microbials and insect growth regulators.

ARIZONA ANNUAL PESTICIDE SALES DATA

Since 1966, the Council for Environmental Studies at the University of Arizona has published a yearly summary of the estimated volume of pesticides sold in the state. These data appear to be the only historical record of pesticide sales within the state. Certain limitations need to be noted, however, in any use of these figures:

1. The sales data cannot be directly correlated with usage data because the pesticides may be taken out of the state or used in a later crop year; in addition, compounds purchased somewhere else may be applied.

2. Since information for the sales survey is provided by distributors on a voluntary basis, a different number of respondents may reply in various years. In 1979, for example, 97% of the surveys sent to pesticide distributors were returned; 84% replied in 1981; only 34% responded in 1983. Reasons for not replying may include new management, limited personnel time or business closings. The results may therefore be seriously skewed.

Even though the sales records do not provide use data, they do offer an indication of the pesticides being purchased for application purposes. In addition, they provide a 21-year history of recorded sales in the state. An overall evaluation of the data indicates that the pesticide type sold in the largest volume (pounds of active ingredient) is insecticides; following in descending order are herbicides (which includes defoliants, desiccants and growth regulators), fungicides/bactericides, and fumigants.

In this 21-year period, the overall pesticide load for agricultural commodities in Arizona decreased (Figure 1). As the graph demonstrates, insecticide use declined significantly; herbicide use (including defoliants) generally declined; but fumigants and fungicide/bactericide use increased slightly. A closer look at just the eight years (Table 1) shows a corresponding decrease in pesticide load. (Additional sales data are provided in Appendix B.)

The data also reveal that certain compounds have been sold in the state in large volumes since 1966 and are being still extensively used in Arizona agriculture today. Good examples of these are chlordimeform, DEF, dichloropropene, dinoseb (registration cancelled 1986), endosulfan, malathion, methyl parathion, methomyl, mevinphos, monocrotophos, MSMA, parathion and sulfur.

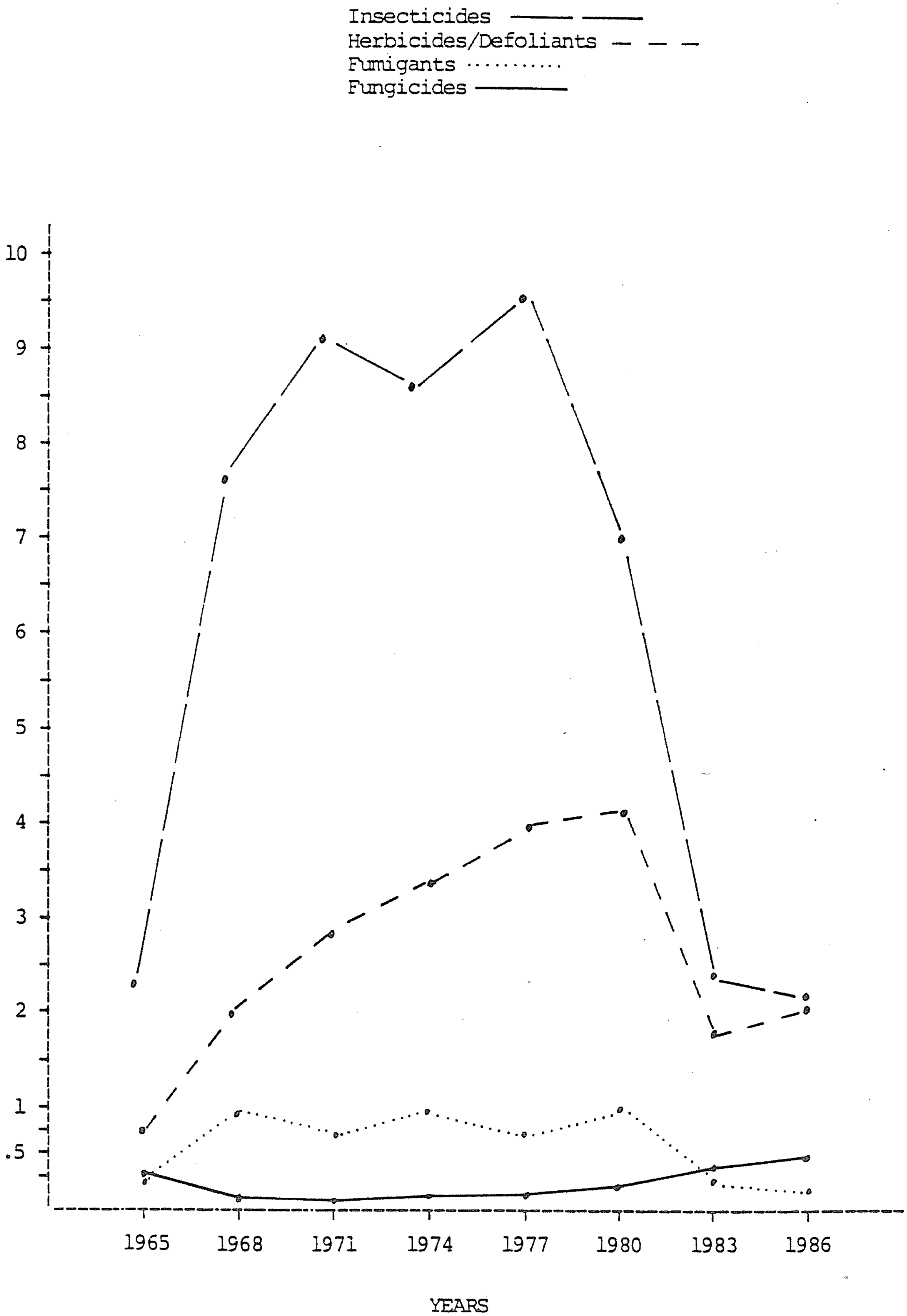
The pesticide load applied to acreage in any given year fluctuates according to several factors, including pest population dynamics, crops, pesticide formulations and weather. As pests are introduced and become established, new products may be required for control; as a result, changes in rates, formulations and equipment may occur.

TABLE 1. PESTICIDES SOLD IN ARIZONA 1979 THROUGH 1986 BY TYPE IN THOUSANDS OF POUNDS OF ACTIVE INGREDIENT

Year	Defoliants, Desiccants, & Growth Regulators	Fungicides/ Bactericides	Fumigants	Herbicides	Insecticides	Total
1979	1758.2	367.0	1062.5	2249.8	4168.9	9606.4
1980	2341.1	270.5	921.5	1820.6	6332.5	11686.2
1981	1238.6	208.0	645.9	1414.3	15128.3	18635.1
1982	1643.0	560.4	300.3	1214.4	5034.5	8752.6
1983	781.0	296.8	131.7	812.5	2528.1	4550.1
1984	999.0	202.6	249.2	900.7	3464.5	5816.0
1985	1924.5	565.3	27.7	667.5	2356.0	5541.0
1986	1014.5	436.9	130.3	1109.8	2311.6	5003.1

(Source: Sales Survey, University of Arizona)

FIGURE 1. PESTICIDE SALES DATA FOR ARIZONA 1965 - 1986



PESTICIDE APPLICATION REPORTS

The Pesticide Applications Reports (Form 1080), filled out each time a custom applicator uses an agricultural pesticide on a designated area, also serve as another source of information for estimating Arizona pesticide use. From 29,000 to 35,000 forms are annually submitted to the Commission of Agriculture and Horticulture, which stores them in boxes alphabetically by applicator. Some custom applicator files can hold as many as 1,100 reports for one year, while others may not contain any in a specific year. The reports are submitted weekly and are therefore a helpful reflection of seasonal pest control practices. Most applicators work only in one county, although several work across county lines. The 1080 forms are retained for five years before they are discarded.

The information on these records is neither entered into a data base nor analyzed to produce usage calculations. For this report, a sampling format was therefore devised in consultation with a statistician from the University of Arizona Agricultural Economics Department. Samples consisted of nearly 500 forms, from which the following information was obtained: county where pesticide material was applied, trade and common names, application rate, total acreage treated, active ingredient per acre and total load. Biological control agents such as pheromones or microbials, however, were not included.

Application data from the 1080 forms for 1985, 1986, and up to September first of 1987 were collected, entered into a computer and summarized. The figures for total pounds of active ingredient were derived by multiplying the result obtained from the sample interval by the appropriate factor. (This factor was calculated from the number of 1080 forms submitted in that particular year. During 1986, for example, 30,337 forms were turned in; sample size was 494 forms, or 1.63% of all available records. Totals for the sample were therefore multiplied by a factor of 98.37.) The 1987 calculations took into account the fact that only partial data (up to September 1) were available. For more information on calculations, see Appendix C.

Calculated total quantity of pesticides applied during the three years for which computations were done from the Form 1080 submissions were as follows:

1985	10,856,253 lbs	34,191 forms
1986	8,309,609 lbs	30,337 forms
Jan-Aug 1987	9,341,544 lbs	24,538 forms

Insecticides usually constituted 30 - 60% of the pesticide load in any year. Methyl parathion, sulfur and chlordimeform were consistently among the five most highly used materials.

Calculated totals derived from the 1080 form sampling show that pesticide use patterns differ between the seven counties represented (Table 2); this was to be expected, as these areas have differing agriculture and crop systems. Counties receiving the highest pesticide load over the three year period (in decreasing order) were Maricopa, Pinal, Yuma, La Paz, Cochise, Pima and Graham.

Within each county, however, the total pesticide load was fairly consistent from year to year (except Graham and Pima). On the average, as indicated by the calculations, the five pesticides used most often in custom applications accounted for over three-quarters of the entire county load. (Mean of comparisons of total annual county load with sum of reported county use of the five primary pesticides for the same year was 77 percent; range was from 40%-96%.)

TABLE 2. FIVE HIGHEST USE COMPOUNDS IN SELECTED COUNTIES. VOLUME OF USE AND TOTAL QUANTITY OF ALL PESTICIDES REPORTED BY CUSTOM APPLICATORS ON ARIZONA 1080 FORMS, 1985, 1986, 1987. (1987 sampling includes only forms received by September 1)

COCHISE

1985		1986		1987	
All Pesticides					
204,430		110,961		209,285	
Five Highest Use Pesticides					
Parathion	93,544	Sodium chlorate	39,348	Mancozeb	111,166
Dimethoate	21,632	Malathion	18,985	Methyl parathion	36,285
Methyl parathion	17,325	Mancozeb	14,854	Fluazifop-butyl	10,974
Methomyl	11,176	Mevinphos	14,362	Acephate	10,896
Glyphosate	9,609	Acephate	5,214	Methomyl	8,371

GRAHAM

1985		1986		1987	
All Pesticides					
56,977		115,093		18,812	
Five Highest Use Pesticides					
Disulfoton	19,720	Sodium chlorate	80,270	Mancozeb	18,812
Sodium chlorate	19,710	Azinphos-methyl	19,674	(no record)	
Methyl parathion	8,151	Fenvalerate	4,525	(no record)	
Fenvalerate	2,564	Trifluralin	3,935	(no record)	
Dimethoate	2,217	Methyl parathion	3,646	(no record)	

LA PAZ

1985		1986		1987	
All Pesticides					
1,059,878		758,728		1,627,605	
Five Highest Use Pesticides					
Methyl parathion	277,714	Azinphos-methyl	71,810	Sulfur	250,481
Malathion	190,722	DEF	60,104	Propargite	203,148
Sulfur	80,417	Prometryn	58,235	Trifluralin	159,707
Disulfoton	75,292	Malathion	52,726	Profenofos	151,673
Permethrin	75,243	Pendimethalin	46,627	Folpet	139,132

TABLE 2 (Continued). HIGHEST USE PESTICIDES BY COUNTY
(1987 sampling includes only forms received by Sept 1)

MARICOPA

1985		1986		1987	
All Pesticides					
3,972,702		2,809,841		2,033,994	
Five Highest Use Pesticides					
Sodium chlorate	1,655,051	Sodium chlorate	885,427	Methyl parathion	526,765
Methyl parathion	539,269	Methyl parathion	618,551	Monocrotophos	484,877
DEF	389,427	Monocrotophos	230,284	Trifluralin	136,981
Methamidophos	300,765	Chlordimeform	128,471	Malathion	133,365
Chlordimeform	237,427	Dicofol	97,485	Acephate	111,749

PIMA

1985		1986		1987	
All Pesticides					
132,060		29,019		242,583	
Five Highest Use Pesticides					
Sodium chlorate	87,907	Methyl parathion	12,296	Mancozeb	94,061
Methyl parathion	29,999	Methomyl	5,312	Dicrotophos	37,526
Chlordimeform	3,215	Dimethoate	4,328	Methyl parathion	24,445
Carbofuran	2,464	Permethrin	1,672	Endosulfan	21,712
Prometryn	1,897	Diazinon+endosulfan	1,476	Methomyl	20,273

PINAL

1985		1986		1987	
All Pesticides					
2,824,926		2,832,663		2,364,278	
Five Highest Use Pesticides					
Sodium chlorate	1,455,654	Sodium chlorate	1,761,680	Methyl parathion	840,997
Methyl parathion	473,146	Methyl parathion	313,646	Monocrotophos	315,567
Chlordimeform	192,095	Parathion	106,830	Chlordimeform	261,066
DEF	77,890	Chlordimeform	99,354	Dicofol	129,761
Endosulfan	50,915	Ethephon	55,874	Acephate	110,377

TABLE 2 (Continued). HIGHEST USE PESTICIDES BY COUNTY
(1987 sampling includes only forms received by Sept 1)

YUMA

1985		1986		1987	
All Pesticides					
2,602,581		1,595,168		2,844,987	
Five Highest Use Pesticides					
Sulfur	1,193,441	Dimethoate	205,987	Sulfur	2,146,938
Malathion	212,823	Methomyl	171,852	Azinphos-methyl	98,737
Methomyl	129,469	Formetanate	103,190	Dicofol	84,353
Dimethoate	107,189	Chlorpyrifos	96,304	Phosdrin	84,115
Phosdrin	85,734	Parathion	64,924	Dimethoate	77,662

When applications to selected crops were compared (Table 3), cotton was seen as consistently receiving the highest total pesticide load, followed in order by citrus, alfalfa and lettuce.

TABLE 3. SELECTED CROPS AND TOTAL PESTICIDE LOAD
(LBS. ACTIVE INGREDIENT/NUMBER OF ACRES TREATED)
IN ARIZONA AS REPORTED BY CUSTOM APPLICATORS 1985,1986,1987
(1987 sampling includes only forms received by September 1)

Crop	1985	1986	1987
Alfalfa	394,514	525,984	766,366
Barley	7,805	60,694	16,794
Bermuda Grass Seed	15,177	43,873	27,030
Broccoli	103,075	118,438	16,611
Cauliflower	123,238	46,923	27,991
Citrus	1,397,516	248,778	2,318,822
Corn	147,048	22,133	51,226
Cotton	7,520,747	6,250,627	5,290,419
Grapes	23,228	90,009	19,400
Lettuce	600,440	596,221	251,635
Melons	119,214	117,552	212,945
Onions	4,641	22,822	6,859
Sorghum	54,159	14,854	119,438
Wheat	87,116	46,234	110,005

As previously noted, however, the 1080 Forms have certain severe limitations which must be taken into consideration.

1. Some of the information entered on specific records is illegible and/or inaccurate.

2. Only custom applicators are required to submit these forms. Although these records would cover virtually all the pesticides flown on by aerial application, many materials are applied with ground equipment by private or commercial applicators, who do not turn in records of applications. The 1987 total for certified agricultural applicators is 1,573; category breakdown is 1,009 private, 247 government, 317 commercial and 91 custom applicators.

3. Certain crops, such as fruits and vegetables, represent even more of a slanted picture because custom applicators apply only a small portion of the chemicals used on these crops.

Stan Heathman, the Cooperative Extension Weed Specialist for Arizona, estimates that as little as 20% to 30% of herbicide applications are accounted for on the 1080 forms. Herbicides usually applied by ground equipment (and therefore not subject to 1080 reporting) include glyphosate, bromacil, cyanazine, alachlor, cacodylic acid, DCPA, dalapon, diuron, DMSA, linuron, picloram, metolachlor, and EPTC. Several of these show high volume sales in Arizona.

Nematicides are also generally applied by private applicators. Both aldicarb and Telone II are sold in Arizona, yet they rarely are recorded on the 1080 forms. Fungicides are often applied as a seed treatment prior to planting; no records of these treatments appear on the 1080 forms.

<u>Comparing the Two Data Sources</u>

A comparison between the Form 1080 calculations and the sales survey data reveals both similarities and differences (Table 4). For example, sulfur and methyl parathion are shown as both being sold and used in 1980, whereas sulfur is indicated as being sold in 1986 but no use is reported. This type of difference most probably occurs because growers (private applicators) apply their own sulfur rather than hiring a custom applicator.

TABLE 4. MOST COMMONLY SOLD/USED INSECTICIDES/ACARICIDES IN ARIZONA

SALES Determined from Annual Sales Data, University of Arizona		**USE** Determined from 1080 Forms	
1980	1986	1980	1986
Sulfur	Sulfur	Sulfur	Methyl Parathion
Methyl Parathion	Methyl Parathion	Methyl Parathion	Monocrotophos
Permethrin	Diazinon	Methomyl	Dimethoate
Feeding Stimulants	Dimethoate	Monocrotophos	Chlordimeform
Chlordimeform	Chlordimeform	Permethrin	Methomyl

Even with all their shortcomings, the 1080 form reports still represent the only source of raw pesticide use data available on a county and state basis. Taken in conjunction with the sales survey results, they can provide valuable parameters for some of the major pesticides applied in Arizona agricultural production, as long as the recognized limitations are considered.

OTHER PESTICIDE USE INDICATORS

Cotton as a Heavy Pesticide User

Cotton production is traditionally one of the major factors in Arizona agriculture. This crop is also one of the most intensive users of insecticides and other agrochemicals. Examining the history of this commodity can provide an additional important insight into the entire pesticide use picture.

In the late forties, fifties and early sixties, two of the most widely used compounds in Arizona (as well as nationally) were DDT and Toxaphene. Estimated Arizona DDT figures based only on cotton and lettuce acreage in central and western Arizona (Ware, 1974) are provided in Table 5.

TABLE 5. ESTIMATED USE OF DDT ON COTTON AND LETTUCE IN ARIZONA 1945-1968 1/

Year	Technical DDT (1000's Lbs)
1945	8
1946	804
1947	1,162
1948	1,400
1949	1,849
1950	1,412
1951	2,730
1952	3,162
1953	3,072
1954	2,900
1955	2,640
1956	2,689
1957	2,689
1958	3,803
1959	3,714
1960	4,142
1961	3,861
1962	3,977
1963	3,895
1964	3,739
1965	545
1966	1,072
1967	2,520
1968	528

1/ Ecological History of DDT in Arizona, Ware, 1974

Arizona DDT use began in 1944, and application rates were 1% active ingredient. By 1946, when the first 10% DDT dust in sulfur was applied to cotton, the average application rates had reached 1 to 3 pounds active ingredient per acre (Ware, 1974). As the table shows, DDT was steadily applied in sizable amounts from 1951 through 1964.

Immense quantities of DDT were applied to Arizona cotton acreage in a major effort to eradicate the pink bollworm; certain locations received especially heavy applications. In a single area comprising 75,068 acres, for example, 743,406 pounds of DDT technical material were applied from May-July, 1959. By 1960 about 685 tons of active ingredient had been deposited in the area. These figures (taken from a Department of Health Services report prepared in collaboration with US Fish and Wildlife Service, Boers Dairy Preliminary Assessment) represent only the DDT used in connection with this program and do not include other private or federal applications to cotton (Parsons, 1987).

In 1965, because of hay and milk contamination, Arizona became the first state in the country to establish a ban on DDT. This pesticide, however, had already been used with great effectiveness and at low cost for 20 years on most crops in Arizona. DDT has been detected in 10 verified California groundwater incidents (Cohen, 1986). Since this pesticide is very tightly bound, however, these detections do not necessarily represent groundwater contamination from normal land application.

Toxaphene, another compound historically used on cotton in great amounts, was first applied in Arizona in 1948. The first available sales data (1966) show that 1.028 million pounds of technical material were sold in the state. The record sales high occurred in 1969, when 2.5 million pounds were sold. Approximately a million pounds per year were sold between 1966-1978, although sales totaling over 2 million pounds occurred in 1967, 1968, 1969, 1974, 1975 and 1977. Ninety percent of the toxaphene was estimatedly applied to cotton (Ware statement at Arizona Board of Pesticide Control March 21, 1979 Hearing); this pesticide, however, was also used on a variety of commodities in the state, including celery, cole crops, lettuce, peppers, alfalfa, and livestock.

In 1976 the combination of milk contamination and diminishing efficacy brought about the removal of toxaphene from Cooperative Extension insect control recommendations. Toxaphene has been detected in five verified incidents of contaminated groundwater in California (Cohen, 1986); since this chemical is highly adsorbed to soil particles, however, the entry into groundwater is not believed to have occurred from normal agricultural application.

Cotton Insect Pests and Controls

In the 1940's, the primary insect pests of cotton in the state were the lygus bug, cotton leaf perforater and bollworm; control was accomplished through the chlorinated hydrocarbons (toxaphene and DDT), nicotine and the arsenicals. During the 1950's, when cotton was grown as a perennial, boll weevils were able to overwinter in cotton stubs and increased in importance as pests. One nonchemical control measure introduced since then has been mandatory plow-down and growth of cotton as an annual to help reduce overwintering boll weevils.

An important new development in Arizona during the sixties was establishment of the pink bollworm, traditionally a major problem in other areas of the country. The chemicals used against this pest included organophosphates (mainly azinphos-methyl and methyl parathion), DDT and toxaphene. Field experiments conducted in Maricopa County in 1967 showed the most effective compounds for pink bollworm control were azinphos-methyl, azinphos-methyl plus toxaphene, toxaphene plus DDT, and azodrin (Progressive Agriculture in Arizona). Between 1972 and 1976, the tobacco budworm also developed into a major pest of cotton, although it had already been in the state for more than 20 years. Organophosphates were used against this insect until resistance became a problem. For control of mites, acaricides such as dicofol and propargite were also used.

Since the late seventies, cotton growers have been turning to the synthetic pyrethroids as preferred materials. These insecticides are generally desirable because of their quick knockdown action and low application rates; they also offer a wide spectrum of control and are particularly effective against lepidopterous (leaf-eating) pests. Pink bollworm resistance, however, is an ever-increasing problem.

The rising popularity of pyrethroids have contributed to the overall decline in total pesticide quantities applied in agriculture, especially to cotton. Application rates for chlorinated hydrocarbons (such as DDT and toxaphene) and organophosphates like methyl parathion called for .4 to 5 pounds active ingredient per acre. Average application rates for pyrethroids used in Arizona, like fenvalerate and permethrin, are only 0.1 pound active ingredient.

A 1979 nationwide survey conducted by the Economic Research Service (ERS) of the US Department of Agriculture confirmed that nearly 85% of Arizona cotton acreage was treated with insecticides (including pyrethroids); the resulting load was 1,859,000 pounds of active ingredient (Table 6). The ERS study was based on interviews with 200 cotton and vegetable growers statewide.

TABLE 6. INSECTICIDE USE ON COTTON IN ARIZONA 1979[1/]

Compound	Acres Treated	Lbs Active Ingredient	Average Applications	Total Applied	1979[2] Sales
	---Thousands---				
Acephate	88	86	1.8	154,000	194,500
Aldicarb	21	23	1.0	23,000	122,100
Azinphosmethyl	49	53	3.8	201,000	42,500
Carbophenothion	13	25	3.1	77,500	1,000
Chlordimeform	117	94	3.7	347,800	291,300
Fenvalerate	97	23	2.2	50,600	28,300
Methidathion	42	19	1.0	19,000	47,200
Methomyl	28	12	1.0	12,000	236,100
Methyl parathion	25	41	2.0	82,000	298,800
Monocrotophos	69	55	1.3	71,500	158,500
Permethrin	159	46	1.9	87,400	187,700
Sulfur	14	239	1.5	358,500	1,011,000
Other	-	69	-		-
Total	-	794	-		28,153,000
Total Tank Mixes	-	835	-		-
Total Insecticides	-	1,629	5.6		-

1/ Source: USDA Economic Research Service
2/ Source: University of Arizona Annual Sales Survey

Provided in the last column of the table are the total sales reported in the Council for Environmental Studies survey results for that year. When these data are compared with the ERS figures, the correlation difficulties mentioned earlier become evident. The discrepancies can most likely be attributed to such factors as out-of-state purchases, pesticides saved from previous seasons, sales for other uses, and omissions because of voluntary data collection procedures.

Further comparison with information generated from custom applicator (Form 1080) records for the following year reveals certain similarities and differences. The ERS survey, for example, identified the insecticides most heavily used on cotton in 1979 as sulfur, chlordimeform and acephate. During 1980, however, custom applicators reported using the insecticides chlordimeform, acephate and chlorpyrifos in the greatest quantities. Both sources thus indicate chlordimeform and acephate as forerunners; the absence of sulfur as a heavily used custom insecticide is logical if one considers that growers most often apply this material themselves and do not file 1080 records.

In another area, the ERS study determined that all 624,000 acres of cotton in the state were treated with a herbicide in 1979. Preferred materials were trifluralin and pendimethalin for herbicide use, and DEF and sodium chlorate as defoliants. Table 7 indicates the number of cotton acres treated and total pounds of active ingredient applied and sold for several herbicides.

Table 7. HERBICIDE USE ON COTTON IN ARIZONA; ACRES TREATED, LBS. ACTIVE INGREDIENT APPLIED[1/] AND SALES VOLUME[2/], 1979

Herbicides	Acres Treated	Active Ingred. Applied (Lbs.)	Active Ingred. Sold (Lbs.)
	thousands		
Dinitramine	25.8	14.5	28.1
Diuron	53.5	51.7	49.5
Fluchloralin	13.8	15.5	1.6
Glyphosate	34.6	28.5	143.0
Pendimethalin	180.2	151.9	155.0
Profluralin	27.7	20.8	13.2
Prometryne	86.8	97.1	159.8
Trifluralin	138.6	105.2	222.6
Other	-	37.4	-
Total	-	522.6	772.8
<u>Tank Mixes</u>			
Prometryne/Trifluralin		18.5/10.7	-
Other	-	36.3	-
Total Tank Mixes	-	65.5	-
<u>Total Herbicides</u>	-	588.1	

1/ Source: USDA Economic Research Service
2/ Source: University of Arizona Annual Sales Survey

For comparison, the last column of the table provides the sales data from the annual pesticide survey. While totals for some materials agree fairly closely, in most cases the results appear quite different (as previously seen with insecticides) and the same skewing factors apply.

Vegetable Use Data

Included in the ERS study results are Arizona-supplied data for lettuce and four other vegetable crops: cantaloupes, carrots, onions and watermelons. Data for lettuce are provided in Table 8; this commodity represents another major recipient of Arizona pesticide applications (cotton and lettuce account for the bulk of the pesticide load in this state). For this reason, the figures for the total number of pounds recorded as being used in custom applications on this crop were also calculated. If ERS survey data for 1979 are compared with information from the 1080 forms for the year 1980, the indications are that in 1979 almost eight times as many acres of lettuce were treated with pronamide (3,176) as in the following year (460), and also that more than three times as many acres were treated with propham (1,623 in 1979 vs 586 in 1980). This might be construed as representing a drastic reduction in treatment level, but a far more likely explanation is that a very large percentage of herbicide applications are made by growers (who do not file 1080 forms).

In addition, the 1080 forms indicate far more usage of the selected pesticides (9 insecticides and 1 fungicide) in terms of total quantity than the ERS data reveal. Enough similarities can be seen, however, to show that existing data can provide some definitions of actual pesticide usage on lettuce in the 1979-1980 time period. The differences, on the other hand, pinpoint how sketchy and varied the few existing estimates of specific use figures would be.

TABLE 8. PESTICIDE USE ON LETTUCE: ACRES TREATED, TIMES APPLIED, RATES[1/] AND TOTAL QUANTITY USED [2/] IN ARIZONA, 1979, 1980

Pesticides	Acres Treated	Times Applied Season	Rate/ Acre (Lbs.)	Custom Appl (Lbs.) in 1980
Herbicides				
Benefin	8843	1.0	1.2	-
Pronamide	3176	1.0	1.0	702
Propham	1623	1.0	2.7	3192
Other	-	-	4.9	-
Total	-	-	1.4	-
Insecticides				
Acephate	3836	1.6	0.8	6079
B.T.	2834	1.4	-	-
Diazinon	2244	1.8	0.6	779
Dimethoate	1266	1.0	0.3	3201
Endosulfan	2448	1.2	0.9	10783
Methomyl	8973	2.7	0.7	16870
Mevinphos	4724	3.2	0.9	29381
Permethrin	3698	1.4	0.2	-
Phorate	771	1.0	1.0	448
Other	-	-	3.4	-
Total	-	-	0.7	-
Fungicides				
Maneb	3147	2.2	1.4	25683
Other	-	-	2.0	-
Total	-	-	1.4	-
Tank Mixes				
Total	-	-	1.2	-
All Pesticides				
Total	-	-	1.0	-

1/ Source: Economic Research Service
2/ Calculated from Arizona Custom Applicator Reports (Form 1080)

The next four compilations (Tables 9 through 12) are supplied to indicate specific ERS data for the other crops classified as vegetables for data gathering purposes -- cantaloupes, carrots, onions and watermelons. These tables have been reprinted from the USDA Economic Research Service publication, <u>Pesticide Use on Vegetables in the Southwest, 1979</u>.

TABLE 9. PESTICIDE USE ON CANTALOUPES. ACRES TREATED, TIMES APPLIED, RATES AND TOTAL QUANTITIES USED IN ARIZONA, 1979

Pesticides	Acres Treated	Times Applied/ Season	Rate/ Acre (lbs.)	Total Quantity (Thous. Lbs.)
<u>Herbicides</u>				
Trifluralin	1652	1.0	0.5	826
Other	-	-	5.0	55
Total	-	-	0.5	881
<u>Insecticides</u>				
Dicofol	1773	1.0	0.9	1624
Dimethoate	705	1.0	0.3	211
Other	-	-	0.4	35
Total	-	-	0.7	1870
<u>Fungicides</u>				
Benomyl	2455	3.1	2.2	16790
Folpet	2475	2.6	1.8	11619
Other	-	-	1.6	18
Total	-	-	2.0	28427
<u>Tank Mixes</u>				
Total	-	-	-	1768
<u>All Pesticides</u>				
Total				32946

Source: Economic Research Service

TABLE 10. PESTICIDE USE ON CARROTS: ACRES TREATED, TIMES APPLIED, RATES AND TOTAL QUANTITIES USED IN ARIZONA, 1979

Pesticides	Acres Treated	Times Applied/ Season	Rate/ Acre (Lbs AI)	Total Quantity (Lbs)
<u>Herbicides</u>				
Linuron	688	1.0	0.8	516
Trifluralin	1277	1.0	0.5	639
Total	-	-	0.6	1155
<u>Insecticides</u>				
Diazinon	473	1.0	0.5	237
Methomyl	1255	2.0	0.4	1105
Total	-	-	0.5	1342
<u>Fungicides</u>				
Maneb	380	2.5	0.9	841
<u>Nematicides</u>				
D-D	859	1.0	58.0	49775
<u>All Pesticides</u>				
Total	-	-	7.9	53113

Source: Economic Research Service

TABLE 11. PESTICIDE USE ON ONIONS: ACRES TREATED, TIMES APPLIED, RATES AND TOTAL QUANTITIES USED, ARIZONA 1979

Pesticides	Acres Treated	Times Applied/ Season	Rate/ Acre (Lbs AI)	Total Quantity (Lbs)
Herbicides				
DCPA	1506	1616	1.1	7569
Insecticides				
Diazinon	286	2.0	0.5	286
Methomyl	1470	1.9	0.4	1231
Mevinphos	271	2.0	0.7	353
Other	-	-	0.4	129
Total	-	-	0.5	1999
Fungicides				
Maneb	1479	2.2	1.3	4299
Other	-	-	1.4	405
Total	-	-	1.3	4704
Tank Mixes				
Total	815	2.6	0.5	1068
All Pesticides				
Total	-	1.4	-	16408

Source: Economic Research Service

TABLE 12. PESTICIDE USE ON WATERMELONS: ACRES TREATED, TIMES APPLIED, RATES AND TOTAL QUANTITIES USED, ARIZONA, 1979

Pesticides	Acres Treated	Times Applied/ Season	Rate/ Acre (Lbs AI)	Total Quantity (Lbs)
<u>Herbicides</u>				
Bensulide	264	1.0	0.5	1321
<u>Insecticides</u>				
Demeton	440	1.0	0.6	248
Endosulfan	440	1.0	0.5	211
Other	-	-	-	35
Total	-	-	-	494
<u>Tank Mixes</u>				
Total	704	1.4	0.7	406
<u>All Pesticides</u>				
Total	-	-	1.0	2221

Source: Economic Research Service

Although these vegetable pesticide use tables provide very limited information, some general trends can be noted:

1. More herbicides and insecticides are applied to lettuce than to other vegetable crops.

2. The total of fungicides applied to cantaloupes is almost 2.8 times greater than the quantity applied to lettuce.

3. Pesticides are usually applied only once or twice to vegetable crops and at reduced rates (1. to 6.5 lbs ai) per application.

Pest Control Advisor Preferences

With the goal of supplementing available statistical data on pesticide use (which are subject to certain serious limitations), research procedures were expanded to include contacts with a number of individuals experienced in agricultural pest control. In a mail-out questionnaire and personal interviews, entomologists, extension agents, pest control advisors, applicators and growers were asked to indicate compounds recommended for pest control on various Arizona crops (refer to Appendix D for a copy of the questionnaire and accompanying letter).

The pest control recommendations for insecticides on cotton appear in Table 13. The same information for herbicides/defoliants on cotton is presented in Table 14. Both the surveys and interviews indicated that, while control strategies vary according to pest complex, worker safety, days to harvest and costs, certain compounds have consistently been used for over 40 years. Among these are the insecticides sulfur and parathion and the herbicides sodium chlorate and trifluralin.

TABLE 13. INSECTICIDE PEST CONTROL RECOMMENDATIONS FOR COTTON 1940-1985 INDICATED BY AGRICULTURAL PERSONNEL WORKING IN PEST CONTROL (IN ORDER OF PREFERENCE)

1940-1945	1955	1965	1970
Sulfur	Toxaphene	DDT	Azinphos-methyl
Cryolite	DDT	Toxaphene	Monocrotophos
Sodium arsenite	Sulfur	Endosulfan	Toxaphene
Calcium arsenate	Parathion	Malathion	Methyl parathion
Nicotine sulfate	BHC	Dicrotophos	Parathion
Pyrethrum	Demeton	Azinphos-methyl	Dimethoate
Sabadilla	Aramite	Methyl parathion	Malathion
Paris green	Dieldrin	Parathion	Sulfur
Rotenone	Endothall	Dimethoate	Dicofol
Calcium cyanide		Sulfur	
Carbon bisulfide		Dibrom	

1975	1980	1985-1987
Methyl parathion	Chlordimeform	Chlordimeform
Azinphos-methyl	Permethrin	Methyl parathion
Toxaphene	Azinphos-methyl	Cypermethrin
Chlordimeform	Fenvalerate	Fenvalerate
Methomyl	Methyl parathion	Methomyl
Monocrotophos	Methomyl	Monocrotophos
Aldicarb	Monocrotophos	Azinphos-methyl
Dicofol	Sulprofos	Gossyplure
Dimethoate	Gossyplure	Acephate
Carbaryl	EPN	Permethrin
Dicrotophos	Dimethoate	Malathion
	Aldicarb	Propargite
	Chlorpyrifos	Oxamyl
	Dicofol	Dicofol
	Propargite	Dimethoate
	Sulfur	Chlorpyrifos
	Dicrotophos	Aldicarb
	Methidathion	Sulfur
		Sulprofos
		Flucythrinate

TABLE 14. HERBICIDE/DEFOLIANT PEST CONTROL RECOMMENDATIONS FOR COTTON 1940-1985 INDICATED BY AGRICULTURAL PERSONNEL WORKING IN PEST CONTROL (IN ORDER OF PREFERENCE)

1940-1945	1955	1965	1970
Herbicides/Defoliants			
Sodium chlorate	Sodium Chlorate	Sodium Chlorate	Sodium Chlorate
	Diuron	Diuron	Trifluralin
	Dalapon	Trifluralin	Dalapon
	Minuron	Dalapon	Diuron
	TCA	TCA	Monuron
		Monuron	Chlorothal

1975	1980	1985-1987
Sodium chlorate	Sodium chlorate	DEF
Trifluralin	Trifluralin	Sodium chlorate
Prometryn	Prometryn	Trifluralin
MSMA	MSMA	Prometryn
Diuron	DSMA	Diuron
Profluralin	Pendimethalin	Glyphosate
Chlorothal	Glyphosate	Fluazifop-butyl
Bensulide	Diuron	Arsenic acid
	Profluralin	MSMA
		Pendimethalin
		Paraquat
		Sethoxydin
		Cyanazine

LAND USE PROFILE

Available indicators of pesticide use in Arizona, as discussed in the preceding chapter, offer at best a tenuous and incomplete picture of application patterns. Since existing statistical data alone cannot realistically provide sufficient information, a historical profile showing the use of land throughout the state was developed to afford an additional dimension. Included are a brief overview of statewide agricultural activities, a narrative time line from 1940 to the present, and profiles of specific counties. Major pesticide discoveries, commercial availabilities and legislative/regulatory developments are described, to supply a national framework for the Arizona scene.

The primary data on land use were taken from annual editions of the Arizona Agricultural Statistics publications, prepared by the Agricultural Statistics Service and the University of Arizona Department of Agricultural Economics. These publications show the number of acres of different commodities reported each year as being under cultivation in various counties.

Additional insight was gained by studying technical bulletins issued for various commodities; individuals possessing expertise in different aspects of agricultural cropping and pesticide use patterns were also interviewed through questionnaires and personal consultations. The resulting battery of information was synthesized to develop the following sections.

OVERVIEW

Ranching and farming have traditionally been a major source of income in Arizona, ever since early settlement of the territory. Many crops which still rank as important commodities have been grown since the early 1800's, although on a much smaller scale. Second and third harvestings of certain commodities can be obtained because of the favorable climate; specialty crops of high economic value also form an important part of agribusiness activities.

By 1975, livestock production was valued at $505 million and crop production at $542 million. In 1986, agribusiness increases resulted in livestock value of over $714 million and crop value of almost $838 million. Also, in this same year, cash receipts from agriculture totaled $1.55 billion; approximately 97 percent of these sales can be attributed to just 25% of the farm operations in the state. The majority of income is obtained from cattle, cotton, vegetables and feed grains.

Over the long term, the most valuable cash commodities have been cotton, cattle, milk, lettuce and citrus. While approximately one-third of the cattle are on feed in 17 commercial feedlots, the largest component of the industry is range cattle. Dairy herds are being reduced, but milk production set a state record in 1986. Vegetable acreage has been steadily increasing; Arizona ranks third nationally in harvested area and total production/value of vegetables. Cash receipts from fruit and nut production now represent more than $120 million; these crops will be increasingly important in the near future. Citrus is the major fruit crop, with Arizona ranking third in national production; land speculation and urbanization, however, are causing declines in acreage.

The major agricultural areas are Maricopa, Yuma, Pinal, La Paz, Cochise and

Graham Counties, although all counties have some cropland in production. During the mid 1930's, the number of Arizona farms and ranches reached a record high of 14,300. By 1972, this figure had declined to a low of 6,200; in 1986, however, the total had climbed back to 8,600. The average size of an irrigated Arizona farm is 650 acres. Arizona land used for farming and ranching equals 37,500,000 acres, of which about 1,000,000 acres are cropland. Since 1960 the total harvested acreage in the state has remained fairly constant, ranging from 1 million to 1.3 million acres. Acreage in 1983 was considerably reduced in response to federal payment in kind programs, which subsidized farmers to decrease cropland.

Agricultural production in Arizona is characterized by relatively high crop yields per acre compared to national production figures. This is especially true for field crops such as cotton, wheat, hay, barley and corn silage. Under arid Arizona conditions, many crops require irrigation for production; irrigated acreage is generally located where water is easily accessible. Throughout the state, the number of irrigated acres being cultivated may expand or contract but the location changes only slightly. This explains why growers often find it necessary to rotate crops for better pest control.

At this time, the number of acres cultivated with grains is decreasing (see Appendix D for specific crop information). Some vegetable, fruit and nut acreage, however, is increasing. Certain crops, such as rapini, have been newly introduced but other crops like sugarbeets have virtually gone out of production.

The overall picture of acreage devoted to different commodities in the state must be considered in terms of pesticide load. Certain crops, such as vegetables, require intensive chemical treatment for high quality production; others, like cotton and alfalfa, are of concern because of the high acreage involved. Some commodities, including cattle, wheat and barley, either need minimal treatment or have application patterns which result in little environmental residue. Specialty crops, such as safflower, sesame or jojoba, often have few or no pesticides registered for use.

ARIZONA PATTERNS OF LAND AND PESTICIDE USAGE, 1940-1987

Information obtained from various sources has been synthesized to develop a time line reflecting chronological events throughout the state, against the background of the national scene.

1940 - 1949

Arizona agriculture in the 1940's was dominated by the production of field crops, with cotton the leading commodity. The major agricultural producing areas were Maricopa, Pinal and Yuma Counties.

The primary crops in Maricopa were hay, cotton, barley and sorghum, although significant acreage was also devoted to lettuce, citrus and cantaloupes. Irrigated acreage occupied such areas as the Salt River Valley, Queen Creek, Buckeye and other locations near principal waterways. Pinal's important crops were cotton and alfalfa, although sorghum and barley were also grown. This county's irrigated cropland was along waterways like the Santa Rosa and Santa Cruz washes.

In Yuma the major crops were alfalfa, lettuce, cantaloupes and safflower; a wide variety of other commodities, including cotton, citrus, barley, honeydew melons, bermuda grass seed, watermelons and sorghum, were also grown. The cost of irrigation in this county is relatively less expensive because of greater availability of surface water. Irrigated acreage is located primarily along the Colorado-Gila River water system.

During the 1940's, pesticides applied included arsenate of lead, nicotine sulfate, sulfur, sodium chlorate, copper sulfate, borax and cryolite. Although many synthetic organic pesticides were developed after World War II, these were not in extensive use until the next decade. In 1947, the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) was passed to protect farmers from dangerous and ineffective chemicals. Pest control management relied on available integrated techniques such as crop rotation and pest monitoring.

1950 - 1959

In this decade, cotton was the most important crop, occupying 34% of acreage in the state. The year 1953 saw a record high of 690,000 acres devoted to this commodity, until government allotments brought the figure down in 1954. Barley, sorghum, alfalfa and wheat were also major crops in the 1950's, and citrus, lettuce, melons and corn were produced in significant volumes. Maricopa, Pinal and Yuma were the major producing areas.

Many pest control changes took place in the 1950's; growers eagerly adopted the synthetic organic pesticides that had been developed in the forties. Different types of pesticides, such as insecticides, herbicides and fungicides, became commercially available on a much broader scale. Chlorinated hydrocarbons like DDT, toxaphene and dieldrin were the most extensively used insecticides, applied in large volumes (.5 - 3.0 pounds of active ingredient per acre); this class of compounds has long residual activity. Many organophosphates also became available in the 1950's; these substances, while generally more toxic to mammals than the chlorinated hydrocarbons, have shorter residual activity and half-lives. Malathion, azinphos-methyl and parathion were among the most popular in Arizona. Another chemical used extensively on crops was sulfur.

Initially, this broad crop protection arsenal dramatically increased yields of crops; cotton, for instance, went from 500 lbs to 1,200 lbs per acre.

1960 - 1969

During the sixties, cotton, grains and alfalfa remained the most significant crops in Arizona. The 1960 figure for cotton acreage was up to 434,000 acres (compared to the 1950 level of 373,000) and accounted for about 35% of the cropland. Citrus orchards occupied 29,000 acres (an increase of 10,000); lettuce acreage rose 12,000 acres to reach a total of 56,000 acres.

Certain changes in commodity acreage were county-specific. Maricopa County experienced notable gains in acreage for lettuce (an increase to 36,000 acres) and cotton (to 162,000 acres). Barley and corn plantings also rose, but land used for citrus, wheat, alfalfa, and cantaloupes decreased. In Pinal, cotton cropland almost doubled from 1940 levels, reaching 166,000 acres. Sorghum, lettuce and barley acreage increased, but alfalfa plantings decreased. Yuma

County also had a 270% increase in cotton acreage from the level in the forties, reaching a total of 35,000 acres. Notable increases in alfalfa, citrus and barley cropland also occurred, but safflower and lettuce acreage significantly decreased.

Cochise County evidenced major increases in alfalfa, sorghum, corn and wheat plantings. Cotton acreage, which was 20 acres in 1950, went to 18,000 acres in 1960. In Graham County, more acreage was devoted to field crops. Pima County cotton occupied 29,000 acres, compared to the 1940's level of 8,800. Sorghum acreage increased to 15,000 acres.

During the 1960's, a variety of new pest control compounds came on the market. Primary insecticides used in Arizona were DDT, toxaphene, azinphos-methyl, methyl parathion, parathion, endrin and endosulfan. Application rates rose dramatically; some compounds went from .5 - 1.0 lbs per acre to 3 - 4 lbs per acre. For certain Arizona pest eradication programs, as much as 25 pounds of DDT were applied per acre.

This inordinant use of pesticides very rapidly led to the dreaded phenomenon of resistance. Key pests of crops grown in Arizona, especially cotton, became resistant to insecticides that previously had been highly efficacious. The problem of resistance forced many growers to use mixtures of insecticides, seek out new products, and in many cases absorb ever-increasing costs, accompanied by diminishing profits.

Secondary pest outbreaks and resurgence also became common occurrences, because the broad-spectrum insecticides caused nonselective destruction of beneficial predators. For example, over 190,000 pounds of DDT and 2% parathion were applied in a 1959 pink bollworm eradication program on 6,390 acres in Rainbow Valley (Maricopa County). An outbreak of beet armyworm followed, and methyl parathion plus endrin had to be used to control that pest. The same sequence occurred when cotton fields were heavily treated with carbaryl to kill the tobacco budworm, resulting in an outbreak of spider mites.

In Arizona the nonregulated use of DDT and toxaphene prompted action from the dairy industry, because products contaminated with residues were being seized by the Food and Drug administration. Arizona was the first state to place a moratorium on use of DDT for agricultural purposes. The public concern over heavy pesticide use in the 1960's was translated into legislative action in the seventies.

1970 - 1979

Arizona agriculture in the 1970's was characterized by a decrease in acreage of certain major field crops like barley and corn. Cotton acreage also declined steadily until 1979, when it recovered to reach its second highest point (628,000 acres). In addition, cantaloupe and lettuce plantings declined. Significant increases took place, however, in cole crops, citrus (at its highest level with 61,300 acres in 1975), grapes, safflower, pecans and wheat. During this period, sugarbeets were grown for sugar as well as for seed; the high point for this crop was the 1970 level of 20,000 acres.

Distribution in major producing counties was fairly stable, except that the overall trend was for water-intensive crops like alfalfa to move out of areas having expensive pump-lift costs and into counties like Yuma. Maricopa County citrus acreage almost doubled from 1960 to 1975; major increases also occurred in wheat, potatoes and grape plantings. Land devoted to lettuce and barley substantially decreased, while cotton acreage fluctuated. Pinal experienced a sharp loss in lettuce acreage with loss of the Bud Antle Company in the Picacho area, along with declines in alfalfa and barley; but wheat, safflower and pecan plantings rose. Yuma County cropland devoted to barley and safflower decreased while alfalfa, wheat, lettuce, sorghum, citrus and corn acreages climbed.

During this decade, Cochise agricultural acreage increased enough to establish this county as one of the state's significant agricultural production areas. Oat plantings also gained, since this commodity is now used not only for grazing but also as feed for race horses. Barley, alfalfa, wheat and sorghum acreage also increased. Corn and alfalfa cropland decreased, however, possibly because irrigation costs in the county are among the highest in the state (as much as $60/acre foot, compared to $12 - $15 in La Paz County).

Graham County sorghum acreage rose 730% from 1960 to 1975. Pima cotton acreage declined substantially, but acres planted to wheat increased.

In the seventies, substantial national legislative changes affected pesticide usage in Arizona. The most significant shift was the transfer in 1972 of responsibility for registration of pesticides from the US Department of Agriculture (USDA) to the newly created Environmental Protection Agency (EPA). EPA also assumed authority over setting tolerances for pesticide residues in foods and feeds. In this same year, legislation amended FIFRA to protect the public and the environment from unreasonable adverse effects of pesticide use.

Insecticide use was also extensively regulated. Almost all the chlorinated hydrocarbons such as DDT, aldrin and dieldrin were cancelled for agricultural uses. The cancellation of DBCP, a widely used nematicide, seriously affected citrus production in this state. Other developments included setting of worker reentry standards, mandatory applicator certification for restricted pesticide use, and issuing of Rebuttable Presumptions Against Registration (RPAR) for many compounds. Overall, increased regulations affected production costs, worker safety and pesticide registration standards.

The availability of certain herbicides (e.g., glyphosate) and synthetic pyrethroid insecticides (e.g., permethrin) resulted in substantially altered pesticide use patterns. Most notable changes were increased use of herbicides (approximately 70% of cotton acreage was treated with herbicides in the seventies, compared to 30% in the sixties) and a significant decrease in cropland pesticide load because of pyrethroids. Application rates for pyrethroids are usually measured in tenths or hundredths of a pound, compared to .5 - 3 pounds for other classes of insecticides.

Another significant factor was the development of biological pest control, including microbial and viral insecticides, insect growth regulators and pheromones (sex attractants). Even with the variety of new technologies for pest control, growers continued to experience the problem of insecticide resistance. Insecticide applications to cotton in some low valley areas went from 5 to 18 seasonal treatments. Pesticide costs became a serious consideration in making decisions as to whether or not to treat and which product to use.

1980-1987

Cotton and cattle still dominate the agricultural production picture in the eighties; cotton occupies 39 - 42% of Arizona cropland, the highest percentage ever. The future of cotton production in the state will depend on export demand and corresponding commodity prices, irrigation costs and government programs. Overall, the land use trend has been toward decreased production of grains but increased emphasis on vegetable, fruit and nut crops. Acreage for barley, alfalfa, wheat, sorghum, safflower and citrus has decreased; sugarbeets are no longer produced here.

Acres of cole crops, melons, pecans, apples and bermuda grass seed have increased. Corn and cotton acreage continue to fluctuate. A few new crops have been introduced or are being grown to a significant degree; examples are mixed greens, leaf and romaine lettuce, sesame and, to a certain extent, peanuts and jojoba.

On a county basis, a few notable changes in production emphasis will affect the pesticide use picture. Cochise's more than 2,000 acres of apples have the potential to generate substantial income, and speculation about future vineyard locations is widespread. Graham County also has new plantings of apples, more than 3000 acres. This county's cotton and corn acreage have also increased.

Urbanization in Maricopa County has caused citrus acreage to decline, along with eleven different grains (except for wheat), alfalfa, lettuce and potatoes. Cotton plantings have expanded, as have grapes and melons. Safflower and sugarbeets are no longer grown in this county. Vegetable acreage is unpredictable because commodity prices vary so much with outside market forces.

Pima County is no longer a major producing area. While introduction of Central Arizona Project (CAP) water may bring a few hundred acres back into production in this area, much will depend on the cost of water and allocation of water rights.

Pinal County acreage has declined for all grains, safflower and lettuce; sugarbeets are no longer produced there. Cotton has increased to the point that it occupies more that 81% of cropland and about 99% of growers are cotton producers.

Yuma has less citrus, melons, grains, alfalfa and safflower (this crop is difficult to grow in close proximity to cotton because it harbors lygus bugs, a major pest of cotton). No sugarbeets are grown. Acreage has somewhat increased in peanuts, lettuce, cotton and bermuda grass seed.

Several federal and state regulations have affected crop production and pesticide usage in Arizona. One of the most far-reaching state laws was the 1980 Groundwater Management Act, which establishes Active Management Areas in major agricultural producing areas and prohibits expansion of irrigated acreage within these. Provisions also require individual farmers to reduce water use.

In 1986 the Environmental Quality Act (EQA) established the Department of Environmental Quality (DEQ) to interpret and implement articles specifically designed to protect aquifers from point source pollution. DEQ also has the mandate to evaluate pesticide usage in Arizona and establish criteria for monitoring groundwater contamination from pesticides.

In addition, federal legislation can be expected to affect pesticide use in Arizona. The 1987 Endangered Species Act is viewed as one of the most important pieces of legislation that will influence application patterns in the 135 US counties that contain endangered species. Many of the commonly used pesticides may be restricted within zones where particular endangered species have their habitat. Implementation of this act is still under intensive state and federal evaluation.

Another potentially significant factor is the steadily increasing adoption of pheromones and sterilization of pink bollworm males. A USDA pink bollworm rearing facility in Phoenix sterilizes about 702 million moths per year, although the majority are used as part of a California Integrated Pest Management (IPM) program. Area specialists and IPM coordinators in Arizona are urging the use of sterile bollworm males and pheromones. A combination of such strategies could simultaneously fight the most serious cotton pest in the state and decrease pesticide treatments. While pheromones cost almost five times as much as conventional pesticides, the increased use of these substances (known by names like Disrupt-N-Lure and No Mate) was seen on Pesticide Application Reports (1080 Forms) submitted by custom applicators in 1987.

Growing pink bollworm resistance to pyrethroid pesticides and increasing control costs have encouraged many cotton growers to concentrate on optimum productivity rather than maximum yield. This simply means balancing the cost of late season control against the price of the extra cotton produced. For some farmers, earlier plow down dates are the result.

IPM programs, funded by USDA's Cooperative Extension and certain state governments, rely on a variety of techniques to manage pests, increase production yield and quality, and protect the environment from excessive pesticide use. Strategies include monitoring for pests, economic injury levels to determine when to treat with chemicals, use of selective pesticides, conservation of beneficial insects, planting of early maturing varieties, September first irrigation termination, earliest possible plow down of cotton stubs, and coordination of cotton planting and harvest with other growers in the region.

The overall pesticide trends in the 1980's are toward decreased total load because of lower application rates and combinations of new technologies with traditional pest control strategies (like crop rotation) to help combat insecticide resistance and reduce dependence on synthetic organic chemicals.

COUNTY AGRICULTURAL TRENDS

This section outlines general agricultural trends by county (more specific data can be found in Appendix F). Six counties in Arizona have at least 35,000 acres of cropland in production and generate agricultural cash receipts of $16.9 million dollars or more: Maricopa, Yuma, Pinal, La Paz, Cochise and Graham. While Maricopa, Pinal and Yuma generate 75% of these cash receipts from crop and livestock sales, Pima County, with less than 16,000 acres of producing cropland, had cash receipts in excess of $23 million.

Cochise County

Cochise has more than 48,000 acres of cropland in production, although irrigated areas have steadily declined since the 1960's. Acreage for sorghum, the primary crop, has dropped drastically; wheat, alfalfa and cotton acreage have decreased more gradually. Sugarbeets are no longer grown. The number of cattle has declined as well. This county has experienced, however, acreage increases in apples, pecans, pistachios, oats, lettuce and, to some extent, corn. Lettuce acreage is located primarily in the Kansas Settlement and Elfrieda regions.

Graham County

Graham has more than 37,000 acres of cropland in production; acreage has remained somewhat steady, with a few small increases. Cotton, always the primary crop in terms of acreage, is increasing. Acres of wheat are basically steady, but barley and sorghum acreage are decreasing. Alfalfa acreage was up in 1980 but has declined since then. The number of cattle has declined. Acreage has increased in apples, corn and cotton.

La Paz County

La Paz, created January 1983, is the northern portion of the previously much larger Yuma County. More than 85,000 acres of La Paz cropland are in production here; the most significant crops in terms of acreage are alfalfa, cotton and wheat. This county also has about 9,000 acres of various vegetables and 600 acres of pecan groves. Bruce Church Farms and Garin Company both have vegetable plantings in La Paz.

Maricopa County

Maricopa has approximately 350,000 acres of cropland in production, but acreage is decreasing becaused of land speculation and urbanization. A wide variety of crops has been grown in Maricopa since the late 1800's, mainly along the Salt River. The most significant crop has been and still is cotton (although total acreage fluctuates in response to government programs and commodity prices). In 1986 cotton was grown on approximately 120,000 acres, although the 1980 figure of 239,500 acres had set one of the highest records for cotton acreage in the county.

Maricopa has also traditionally devoted large areas of cropland to barley, sorghum, wheat, alfalfa, sugarbeets, lettuce and citrus. Present figures are approximately 120,000 acres of cotton, 53,000 acres of alfalfa, 15,000 acres of citrus, 62,000 acres of grains and 24,000 acres of vegetables. Current agricultural trends are toward diminishing acreages for grains, citrus and lettuce, with increases in certain vegetable (including broccoli, carrots and potatoes), melons (cantaloupe, honeydew and watermelon), and grapes. Safflower and sugarbeets are no longer grown.

Future developments can be expected to include continuing decreases in field crops, except for cotton which responds to commodity prices and government programs. More emphasis is being placed on Fall rather than Spring plantings. Because increasing urbanization is anticipated to cause losses of prime farmland and areas of relatively low irrigation cost, acreage decreases can be expected.

Pima County

Cropland acreage in this county has significantly declined because of land speculation and urbanization. While most acreage is still in cotton, alfalfa and grains are significant crops; other important Pima County crops include pecans and lettuce. Introduction of Central Arizona Project water from the Colorado River should bring some areas of the county into production, especially the land south and west of Tucson. The future of Pima County agriculture, however, will be determined by the cost of CAP water and trends in land speculation.

Pinal County

Pinal has approximately 192,000 acres of cropland in production. The primary crop has always been cotton; almost 99% of Pinal growers are cotton producers. Cotton acreage fluctuates but has decreased fron high 1980 levels to about 112,000 acres. Current totals for other crops are 12,000 acres of alfalfa, 46,000 acres of grains, 5,500 acres of pecans and 1,800 acres of vegetables.

Historically a large number of acres have been dedicated to production of sorghum, wheat, barley, alfalfa, lettuce and pecans. Decreases are occurring in alfalfa, grain and lettuce acreages, as well as number of cattle raised. Safflower and sugarbeets are no longer grown. While acreage increases have occurred in watermelons, honeydews, citrus, grapes and pecans, cotton is expected to remain this county's primary crop.

Yuma County

Although Yuma has only a little more than half the cropland acreage of Maricopa County, a wide variety of crops has been grown there since the 1930's. Historically, the major crops have been cotton, barley, alfalfa, wheat, sorghum, cantaloupes, lettuce and citrus. Currently, more than 166,000 acres of cropland are in production, primarily for cotton, alfalfa, wheat, bermuda grass seed, lettuce and citrus. Actual figures are 22,000 acres of cotton, 23,000 acres of citrus, 43,000 acres of alfalfa, 31,000 acres of lettuce, 45,000 acres of grains and about 39,000 acres of vegetables, including lettuce.

Acreage for alfalfa, wheat, sorghum, barley, cotton, potatoes, cantaloupes, honeydews and citrus has decreased, and sugarbeets are no longer grown. On the other hand, land planted to bermuda grass seed, peanuts, sesame, watermelons, lettuce, broccoli and cauliflower has increased. Yuma County used to produce about ninety percent of the world's bermuda grass seed; with the entry of California's Imperial Valley into the market, Arizona's share has fallen to 60%.

Improved economic conditions have brought some minor new plantings of citrus in Yuma. The citrus market (as well as the vegetable market) is very strongly influenced by the condition of particular crops in other states; thus complications with citrus production in Florida results in improved market conditions for Arizona citrus growers.

Yuma irrigation costs are relatively lower than other areas; because of urbanization and higher water prices in other counties, the future may bring expanded production or a shift in types of commodities grown in this county.

Other Counties

All counties in Arizona have some cropland in production:

Apache has around 10,000 acres of cropland, mostly alfalfa and grains. This county is also considered an important area for range cattle and sheep.

Coconino's approximately 1,400 acres of cropland are mainly alfalfa.

Gila has about 200 acres of cropland in alfalfa.

Greenlee has approximately 1000 acres of cropland, mostly in cotton.

Mohave has close to 15,000 acres of cropland, on which a fairly wide variety of crops is grown. Most acreage is devoted to alfalfa, and more than half as much to cotton. Mohave also produces grains, miscellaneous vegetables and nut trees.

Navajo has approximately 8,000 acres of cropland, mainly in alfalfa and grains. Sheep and hogs are also raised in this county.

Santa Cruz has about 1000 acres of cropland, primarily in grains.

Yavapai has around 9000 acres of cropland, mostly in alfalfa. Grains and pecans are also grown in Yavapai.

For more detailed county-specific information, refer to Appendices E and F.

FUTURE TRENDS AND CONSIDERATIONS

Arizona Agriculture

Both microeconomic and macroeconomic forces will influence the future directions that agriculture can be expected to follow. This section examines a few of the more important factors and the anticipated responses. For the most part, this information has been published by the University of Arizona Department of Agricultural Economics (Ayer, 1986).

Microeconomic Forces

Production decisions are based primarily on the potential to generate income. Since 1973, along with other farmers in the nation, Arizona agriculturists have experienced increasingly unstable incomes. Government subsidies now constitute a substantial portion of net farm income; in 1983, subsidies actually were greater than the net farm income. Since 1982, most federal subsidies have gone to cotton farmers -- specifically to large farms, although these are relatively few in number -- because these federal programs are based on production totals.

Overall income instability is increased by variable real prices for cotton, which partially reflect the downward trend caused by the "China factor." Since 1982, as a result of reduced regulation, production in China has sharply expanded. That nation, which formerly was a large importer of cotton, now produces approximately one third of the world's supply of that fiber. Since about ninety percent of Arizona cotton is exported, commodity prices are sharply affected by trade policy. Despite this, the 1987 crop year was very favorable for cotton farmers both in terms of yield and commodity price. In fact, 1987 cotton exports jumped to 6.7 million bales, more than three times the level for the 1985-1986 season.

The cost of water in Arizona is another force which will affect agricultural production. Pump lift costs for irrigation are a significant consideration in agriculture, especially since over half of available supplies need to be raised from groundwater that is located from 300 to 600 feet below the surface. Contracts for inexpensive hydroelectric power in the region near the Hoover-Boulder dam terminate in 1986 and 1987; how higher prices will affect farmers who formerly enjoyed these lower prices remains to be seen.

In Cochise, water accounts for almost 40% of the total variable costs for cotton production; this resource consumes approximately 20-30% of grower's variable costs in Pinal, Pima and Maricopa. Irrigation costs considerably less in Yuma because of surface water availability. CAP supplies are expected to be fairly expensive because of the lack of support canals and the cost of lifting the water 2,000 feet from Lake Havasu. In addition to high costs, laws such as the Arizona Groundwater Management Act will affect water usage. This legislation requires farmers to reduce water use and places limits on expanding irrigated acreage.

Land prices have dropped throughout the state, except in some irrigated areas of Pinal, Maricopa and Pima where land has been bought for urban development and water rights. Decreased land values erode the collateral against which growers can acquire loans for farming; this may have an important effect on whether a producer decides to continue farming or to sell out. The state's population growth rate, which is well above the national average, will result in increased pressure on land, water and other natural resources.

Macroeconomic Forces

Overall, the United States is losing export markets because of the fluctuating value of the dollar. The international worth of the American dollar has a direct negative effect on the volume of export, which heavily impacts on producers of such commodities as cotton, wheat, fruit (citrus and apples) and vegetables. Between 1981 and 1984, interest rates have been at an unusually high seven to nine percent. Faced with rising in-state operating costs and high real interest rates, growers find themselves reluctant to borrow money or purchase new equipment.

In addition, the 1985 tax code negated laws that previously favored long-term enterprises such as breeding herds, vineyards and tree crops. The US Department of Agriculture estimated that in certain cases the rate of return for investment in orchards, for example, may be reduced by as much as 33%.

Response Strategies

These forces of change can be expected to produce certain responses from Arizona agribusiness. Producers have already adopted new technologies to increase profits and maintain their livelihood in farming. As a water conservation measure, laser leveling has already taken place on half the irrigated fields in the state. This technology is estimated to save 800,000 acre feet of water a year -- roughly the amount of water used annually by a city the size of Tucson. The executive vice president for the Arizona Cotton Growers Association predicts that Arizona cotton producers will face "required efficiencies" for farming operations, enforced by such penalties as losses of water allocations for failure to adopt particular practices like laser leveling.

Drip irrigation is another technology with water-saving potential. Approximately fifty percent of the water used in conventional irrigation systems is delivered through drip irrigation. In 1985 about 40,000 acres in Arizona used this technology. The problems associated with drip irrigation in Arizona are difficulty in crop rotation, potential for increased salinization and the extra requirements for management.

Other responses include such techniques as rotating livestock, grazing on pastureland to increase carrying capacity, shifting to equipment that conserves energy and switching the types of crops produced, including increased emphasis on grapes, vegetables and tree crops. New strategies, however, will require accompanying changes in management. For example, conventional techniques may call for irrigating 12 times per season, while drip technology may increase that number to 100 times a season. Production of fruit and vegetable crops may produce increased instability in net farm income. Many new technologies will require not only high capital investment but also more intensive management.

One response almost certain to occur is increased participation in crop insurance plans and government subsidy programs. Microcomputers will become an even more important tool for facilitating management decisionmaking.

Future Trends in Pesticide Usage

Agriculture

From 1964 to 1985, national pesticide usage doubled from 540 million pounds to over one billion pounds. At the same time, agriculture's share of this total increased from 54% in 1964 to 77% in 1985. The major part of this growth can be attributed to increased herbicide use. Between 1986 and 1987, however, US pesticide use went down nine percent, which can be attributed partly to decreased acreage because of federal programs and partly to greater emphasis on reduced-input farming.

Overall pesticide use is expected to continue to rise; a recent study by the Fredonia Group, a marketing research firm, indicates that pesticide demand in dollar volume will grow 5% annually to 1990. Predicted growth is based on favorable economic factors, moderate agricultural advances and continued technological innovations. According to the study, also, biological control measures such as resistant crop varieties and natural predators are not expected to replace pesticides within the next decade.

The report also cited herbicides as experiencing the greatest increase over the next five years, with insecticides and fungicides having more limited markets and fewer technological breakthroughs. New generation pyrethroids will broaden the insecticide market to a degree, and a new type of fungicides known as sterile inhibitors is expected to impact significantly on this market.

In Arizona, overall agricultural pesticide usage has been decreasing because of use of materials with lower application rates, regulation of certain compounds like DBCP, and improved delivery systems including hydraulic sprayers, centrifugal energy nozzles, electrodynamic nozzles and sustained release formulations.

The future direction of agricultural research and extension will also have an influence on pesticide usage. One major factor will be the increased focus on techniques which facilitate the adoption of Integrated Pest Management (IPM), including greater interdisciplinary interaction in universities, development of predictive decisionmaking and mathematical modeling, and research into pesticide action and interaction.

Substantial emphasis is also being placed on biotechnology advances in crop protection. Plants are being bred for increased resistance to insects and other pests; as an example, ongoing experimentation is assessing the effects of injecting a microbial Bacillus Thuringiensis into the DNA of cotton germplasm for pest control purposes. Cotton is being bred to exhibit increased resistance to glyphosate, which would permit better use of this herbicide for weed control. As new technological tools to combat pest pressure become available, pesticide use patterns will change correspondingly.

Rangeland and Forests

In 1984 the Forest Service terminated its routine practice of aerially spraying forests for brush control, contributing to the decrease in total US pesticide load. Pesticide use on rangeland varies depending on pest conditions and state programs for bringing new land into production. During 1966 in Arizona 49,930 acres of rangeland were treated for brush control, compared with 66,984 acres the next year. Two years later, however, that figure was down to 29,931 acres. Rangeland has also occasionally been treated for grasshopper control.

While this report does not deal with current pesticide use on forests or rangeland, these applications should be taken into account in estimating the total statewide pesticide load.

Urban

Urban pesticide use may well become an area of increasing concern in the future and receive much more attention. In these areas, population density is more acute; as a result, urban applications are much heavier on a per acre basis than agricultural applications. Most urban pesticide use is for property protection and nuisance control, as well as aesthetic purposes like beautification of parks, schools or golf courses and weed control along right-of-ways and highways. Because of the aridity, pest control in Arizona requires far smaller amounts of pesticide than in other states like Florida.

While urban usage represents a smaller percentage of total pesticide use than agricultural purposes, these applications come under far less regulation. In addition, less data on amounts applied is available.

PRINCIPAL FINDINGS AND RECOMMENDATIONS

As the information from the various research projects is reviewed, certain significant indicators of Arizona pesticide patterns can be observed. These include reported sales and applications of various chemicals, along with geographic cropland areas, commodity distribution and resulting pesticide use patterns. When these specific indicators are synthesized and evaluated according to selected criteria, certain chemicals emerge as being of greater potential environmental concern. These can serve as a preliminary basis for further research and analysis to identify chemicals and areas on which to focus monitoring activities.

Certain trends, which may have already begun but can be expected to continue, will affect total deposits of chemicals on the land. In addition a section of recommendations, which evolved from researchers' experience with the evident shortcomings in available data, is provided. Suggestions are advanced as to areas in which pesticide usage information could be improved to provide more useful data for regulatory and other purposes.

Principal Findings

Even with the incomplete and unsatisfactory hard data available on Arizona chemical use, the evidence is clear that agricultural pesticides have been steadily sold and applied at a rate which reflects the importance of farming and ranching in this state's economy. Certain compounds, such as chlordimeform, methyl parathion and sulfur, consistently appear in different types of pesticide use records in the state. Persistent chemicals like DDT, toxaphene and DBCP are known to have been applied for long periods and often at increasing rates of active ingredient per acre before their cancellation.

Examination of land use in Arizona reveals that traditionally the same areas, located near principal waterways in various counties, constitute the major part of agricultural acreage. This distribution occurs because irrigation for most crops is essential in this state's arid environment. Cropping patterns indicate that certain commodities have been grown for many years, although overall acreage increased. Large farms, often devoted to a single crop, intensify the economic impact of pest infestations.

Major agricultural counties are Maricopa, Pinal and Yuma; other counties with significant plantings include La Paz and, to a lesser extent, Cochise and Graham. Pesticide use data reflect the mix of crops which occupy the principal farming areas in different counties. By major agricultural county, the following primary pesticides were reported in custom applications during 1985 and 1986:

Maricopa -- sodium chlorate, methyl parathion and chlordimeform
Pinal -- sodium chlorate, methyl parathion, and chlordimeform
Yuma -- dimethoate and methomyl

This differing mix of pesticides occurs because large percentages of cropland in Maricopa and Pinal are devoted to cotton (34% and 70% respectively); Yuma, on the other hand, not only grows a wider variety of crops but also has less significant acreage in cotton (11%).

The state agricultural production scene has been and still is dominated by cotton and cattle. Cotton accounts for approximately 40 percent of cropland and 70 to 75% of the insecticides used by custom applicators. Certain crops (like lettuce) require intensive pesticide use for high quality production; others, like alfalfa, are of concern because of the high acreage involved. Some commodities, including cattle, wheat and barley, either need minimal treatment or use application patterns which result in little environmental residue. Specialty crops (like safflower, sesame and jojoba) often have few or no pesticides registered for use.

Although chemicals are an indispensable part of modern agriculture, the risks and benefits of any pesticide must be evaluated to determine whether cancellation or continued use under amended conditions would be of greater value. Newer products which are less environmentally persistent and applied at lower rates have been and are being developed; their use in Arizona agriculture has already reduced the total pesticide load and averted some potential environmental impacts on air, land, water and wildlife. Trends toward biological products and Integrated Pest Management practices project less overall use of chemicals and shifting from those which are environmentally harmful.

Groundwater Considerations

As stated earlier, however, Arizona environmental concerns focus primarily on the quality of water supplies, especially groundwater. Until the 1970's, the general assumption was that pesticides would either dissipate or be so tightly bound to soil particles that they would not leach into and contaminate water. While this is for the most part true, some compounds leach very readily; and, in some cases, the breakdown products are more of a health threat than the parent compounds. Another factor is that once chemicals reach the vadose zone, they are less subject to normal degradation processes such as photolysis and microbial degradation.

Because of national concern over groundwater contamination, the Environmental Protection Agency has been conducting monitoring programs to detect pesticide residues in water supplies throughout the various states. As of May 1986, EPA had identified 17 different pesticides in the groundwater of 23 states, present as a result of normal land applications. Of these 17, nine are herbicides and eight are soil incorporated insecticides or fumigants. In some ways, therefore, Arizona appears to have a relatively lower potential for groundwater contamination by these pesticides than certain other states. Since the majority of US herbicide volume is applied to corn and soybeans (which are not extensively grown in Arizona), relatively small amounts of weed control materials are sold in this state compared to those which have heavy plantings of these commodities. Sales volumes of fumigants in Arizona are also reportedly low.

Three of these EPA-reported pesticides, however, have been found in studies of Arizona groundwater: the soil fumigants/nematicides aldicarb, DBCP and EDB. Registrations for DBCP and EDB products have been cancelled, and little aldicarb is sold in Arizona (10,707 pounds in 1986). Many parts of the state, however, experience a continuing need for soil fumigation and nematode control.

Chemicals of Potential Environmental Concern

Various indicators in the report have been synthesized to provide a summary chart (Table 15) which can offer guidelines for further groundwater research on chemicals of environmental concern. This table furnishes information on the following criteria:

1. Total sales volume over 100,000 pounds was reported between 1966 and 1980 in the University of Arizona Annual Sales Survey results.

2. An average sales volume greater than 25,000 pounds of active ingredient per year was reported between 1982 to 1986; the level of sales is indicated as high, medium or low.

3. The chemical was found in information filed by custom applicators on 1080 Forms during 1985 and 1986.

4. Pest Control Advisors and other people experienced in agricultural pest control included the pesticide in their recommendations.

5. Registrations exist for selected Arizona crops: alfalfa, broccol, citrus, cotton, lettuce and tomatoes.

6. The substance was found in the groundwater of more than one US state (as shown in published EPA bulletins or reports prepared by Jackie Rich and Stuart Cohen).

7. The pesticide has been found in Arizona groundwater.

The table also provides information on the counties in which these chemicals have been recently used in custom applications. Five of the chemicals (chlordane, DDT, DBCP, EDB and toxaphene) are permanently or temporarily banned; these have been included because of high sales and/or environmental persistence. The factors on the chart need to be combined with additional information on such characteristics as solubility, soil absorption, vapor pressure and dissipation, which may affect the potential for these chemicals to leach into soil below crop root zones and into groundwater.

TABLE 15. CHEMICALS OF ENVIRONMENTAL CONCERN AND INFORMATION ON SELECTED CRITERIA.

Compound	Total Sales (66-80)[1]	Avg. Sales (82-86)[2]	Counties[3] which appear on 1080 Form either 85 or 86	Recommended by Workers in AZ Pest Control	Registration on selected Arizona crops[4]	Number of other US States with groundwater findings	Found in Arizona Groundwater
Alachlor		L			C	4	
Aldicarb		L		*	C,Ci	15	*
Arsenic Acid		L	M,Y	*	C	1	
Atrazine		M	C,Pn,Y		C	6	
Carbaryl	*	L	C,M		C,Ci,A,L	1	
Carbofuran		H	G,L,Pi,Pn,Y		C,A	3	
Chlordane	*	M			Cancelled	1	
Chlordimeform	*	H	L,M,Pn,Y	*	C	0	
Chlorpyrifos		H	L,M,Pn,Y	*	C,A,Ci,B	1	
Cyanazine		L	L		C	2	
DBCP	*	L			Cancelled	5	*
DCPA	*	M	Y		C,A,L,B,T	1	
DDT	*	M			Cancelled	1	
DEF	*	H	L,M,Pn,Y	*	C	1	
Diazinon		H	C,L,M,Pi,Pn,Y		C,Ci,A,L,T,B	1	
Dicamba		L	M,Pn,Y			4	
Dichloropropene	*	H	Y		C,A,Ci,L,B,T	4	
Dimethoate		H	C,G,M,Pi,Pn,Y	*	C,Ci,A,L,T	1	
Dinoseb	*	H				1	
Disulfoton		H	C,G,M,L,Pn,Y		C,A,L,B,T	1	
EDB					Cancelled	8	*
Endosulfan	*	H	L,M,Pi,Pn,Y		C,Ci,A,L,B,T	1	
EPTC		H			C,Ci,A,T	0	
Ethyl Parathion	*	H	M,Pn		C,Ci,L	1	
Glyphosate		H	C,M	*	C,A,L	0	
Malathion	*	H	C,L,M,Pn,Y	*	C,A,L,B	1	
Maneb		H	L,M,Y		C,L,B,T	0	
Methomyl	*	H	C,L,M,Pi,Pn,Y	*	C,A,Ci,L,B,T	0	
Methyl Parathion	*	H	C,G,L,M,Pi,Pn,Y	*	C,Ci,L,B,T	1	
Metolachlor		L			C	2	
Mevinphos	*	M	C,L,M,Pn,Y		Ci,A,L,B,T	0	
Monocrotophos	*	M	L,M,Pn	*	C	0	
MSMA	*	M	L,Pn	*	C	0	
Oxamyl		L	L,M,Pn	*	C,Ci,T	2	
Paraquat		L	L,M,Pn	*	C,Ci,L,B,T	4	
PCNB		H				1	
Phorate		H	M,Y		C	1	
Prometryn	*	H	L,M,Pi,Pn,Y	*	C	0	
Simazine		M			Ci	3	
Sodium Chlorate	*	H	C,G,L,M,Pi,Pn,Y	*	C	0	
Sulfur	*	H	C,L,Y	*	C,Ci	0	
Toxaphene	*	H			Cancelled	1	
Trifluralin		H	C,G,L,M,Pn,Y	*	C,Ci,A,L,B,T	1	

1/ Annual Pesticide Sales Survey Vol. over 100k

2/ Annual Sales: H - >75,000; M - >25,000; L - >10,000

3/ C - Cochise; G - Graham; L - La Paz; M - Maricopa; Pi - Pima; Pn - Pinal; Y - Yuma

4/ Crops: A - Alfalfa; B - Broccoli; C - Cotton; Ci - Citrus; L - Lettuce; T - Tomatoes

Pesticide/Land Use Trends

The finding of three soil fumigants/nematicides in Arizona groundwater and the fact that nematode control continues to be a problem in certain areas of the state indicate a need for further attention to the use patterns for these chemicals. For example, the soil fumigant 1,2-Dichloropropene (Telone II) is applied to approximately 8 to 12 of the cotton acreage in Arizona; to early planted lettuce and carrots to control nematodes; in the spring to some melons, carrots and potatoes; and to citrus and grapes (although Nemacur, a systemic nematicide, is more frequently used on these two). The fumigants are generally used in the same areas that DBCP and EDB were used in the past -- primarily sandy soils in parts of Maricopa, Pinal, and Yuma counties.

Nematicides are highly water soluble and should be the object of additional monitoring. Available information does not enable estimation of nematicide usage. While sales in Arizona of both aldicarb and 1,2-Dichloropropene are reported on the annual survey, very few application reports (1080 forms) record their use because nematicides are generally applied with ground equipment by private or commercial applicators who do not submit reports.

Certain trends in custom applications have begun to develop, as indicated by the information on Pesticide Application Reports filed with the Commission of Agriculture and Horticulture; these are expected to continue in the future:

1. Fewer chlorinated hydrocarbons (heavily applied in the fifties and sixties) are being used.

2. The most popular materials are a combination of organophosphates, carbamates and synthetic pyrethroids (which are applied at much lower rates).

3. Despite higher costs, sex attractants (pheromones) are frequently added to customary application materials.

Both nationally and in the state, the overall agricultural pesticide load is decreasing. Contributing factors include use of materials with lower application rates, shifts to Integrated Pest Management techniques, regulation of certain compounds, and improved delivery systems. According to Arizona sales survey figures, in the last 21 years (1966-1987) the overall pesticide load for agricultural commodities declined (especially during the last eight years). Insecticides declined significantly; herbicide/defoliant use declined at a lesser rate; but fumigants and fungicides/bactericides showed a slight increase over the 21-year period.

Consideration of future land and pesticide trends in the United States and in Arizona identify several factors expected to have an important influence. Pesticide use, for example, will be affected by increased government regulation, shifting land use patterns, availability of improved technologies (new chemicals and agricultural practices) and increasing insect resistance to pyrethroids. Other anticipated changes include decreased pesticide application loads and selective choices of material, dosage and timing based on Integrated Pest Management principles. Some agricultural experts are predicting that government regulatory agencies may begin to use restrictions of privileges, such as water allocations, to enforce desired practices.

Land use patterns will be affected by such factors as commodity prices; urbanization; adoption of new technologies; regulation, such as the Arizona Groundwater Management Act, which controls expansion of irrigated land; and the costs of water for irrigation. Production of water-intensive crops like alfalfa has already shifted out of counties where water is costly (like Cochise), into those that can offer more affordable supplies (Yuma and La Paz). Another shift has involved moves from urbanized counties (Maricopa and Pima) into less populated areas (Pinal and Yuma counties).

Recommendations

This section primarily discusses various options for improving prediction capabilities through obtaining more reliable, inclusive and site-specific data. The two major regularly compiled data sources that were available to provide material for this study were the Pesticide Application Reports (1080 Forms) and the Annual Arizona Pesticide Sales Survey.

The 1080 Forms, filed for regulatory purposes to provide information about specific pesticide, amount applied, application method and acres treated, are subject to the following limitations:

1. Only custom agricultural applicators are required to file these reports concerning specific applications; many private agricultural and structural operators also apply quantities of pesticides without being required to submit application records.

2. The written forms at times contain illegible or inaccurate information.

3. While the Commission of Agriculture and Horticulture keeps the 1080 Forms for five years, the information which they contain has never been computerized and no usage calculations have been performed.

The Annual Arizona Pesticide Sales Survey is compiled by the Council for Environmental Studies from voluntary submissions by distributors. Since this reporting is not mandatory, the same firms do not necessarily respond each year. Omissions or additions can seriously skew these results and present a lopsided picture. Nevertheless, since these are the only specific compiled data with bearing on pesticide use in the state, they are frequently used for reporting to federal and state regulatory agencies.

As the study progressed, certain discrepancies became obvious in attempting to correlate these two data resources. For example, the annual survey reports indicated significant sales of nematicides (at least 112,000 pounds of Telone II were shown as being sold in the state in 1986); the use of nematicides, however, is greatly under-reported on the 1080 Forms since they are usually applied by private applicators.

The Department of Environmental Quality will be conducting pesticide monitoring activities to ensure the quality of groundwater on a continuing basis; in light of the expense and difficulty involved in detecting specific substances, the limitations on available accurate data pinpoint the following recommended areas for future activities:

1. At present, compiling data from the 1080 Forms is both difficult and time-consuming. An initiative to computerize the information on these forms

would make available a base of specific data on pesticide applications conducted by custom agricultural applicators in different counties.

2. DEQ will determine certain types of mandatory reporting required to carry out the provisions of the Environmental Quality Act. Since the Annual Arizona Pesticide Sales Survey already provides a voluntary accounting of activities dating from 1966, requiring distributors to report all sales of pesticides within the state would permit compilation of a reliable data source and eliminate the drawbacks of the current system.

3. Additional data gaps exist in the lack of records for pesticides applied by private applicators and ground equipment, as well as for nonagricultural purposes (i.e., structural, homeowner and other urban uses). Legislation which would enable collection of this data would significantly complement available knowledge of pesticide use patterns in the state.

4. Collection and synthesization of pesticide use data is a relatively new task for any state. Sufficient time must be allotted if Arizona is to develop an accurate database, although this effort can be pursued concurrently with initial monitoring activities. States that have compile similar statistics, such as Florida and California, have broken the project into discrete tasks and allowed from one to four years for accomplishing this objective. Many productive avenues of research presented themselves during this project, but the five-month time limit for conducting this particular research precluded their pursuit.

LITERATURE CITED

Authors

Ayer, H. 1986. Arizona Agriculture and Forces of Change. Extension Report #8624. Dept. of Agricultural Economics, University of Arizona, Tucson, AZ.

Cody, S. 1984. Comparison of Pesticide Use Data Collection Systems. University of Arizona, Tucson, AZ.

Cohen, D. 1986. "Groundwater Contamination by Toxic Substances" Evaluation of Pesticides in Groundwater. University of California Press, Davis, CA.

DeVoss, D. 1987. How The Bugs Finally Won. Los Angeles Times Magazine. Sept. 20, 1987. pp. 18-34.

Eichers, T.A., P.A. Andrilenas and T.W. Anderson, 1978. Farmers Use of Pesticides in 1976. AER-418. USDA, ESCS, December, 1978.

Ferguson, W. and I. McCalla, 1981. 1979 Pesticide Use on Vegetables In the Southwest, A Preliminary Report. Economic Research Service Staff Report No. AGES811221, Natural Resource Economics Division, ERS, USDA, Washington, D.C.

McDowell, R., C. Marsh and C. Osteen, 1982. Insecticide Use on Cotton in the United States, 1979. ERS Staff Report No. AGES820519. National Resource Economics Division, ERS, USDA, Washington, D.C.

Parsons, L. 1987. Boers Dairy Preliminary Assessment. Arizona Department of Health Services; U.S. Fish and Wildlife Service, Phoenix, AZ.

Rich, J. & Associates, 1982. Pesticides with Groundwater Pollution Potential in Arizona. Arizona Department of Health Services, Phoenix, AZ.

Rich, P. 1982. 1979 Herbicide, Defoliant and Desiccant Use on Cotton in the United States. ERS Staff Report AGES820504, Natural Resource Division, ERS, USDA, Washington, D.C.

Ware, G. 1953. Statement Read at the Hearing of the Arizona Board of Pesticide Control Regarding the Banning of Toxaphene in Agriculture. March 21, 1979, Phoenix, AZ.

Ware, G. 1974. "Ecological History of DDT in Arizona." Arizona Academy of Science. Vol. 9, No.2, June 1974. University of Arizona, Tucson.

Ware, G. 1978. Pesticides, Theory and Application. University of Arizona Press, University of Arizona, Tucson.

Watson, T. and D. Fullerton. 1969. "Pink Bollworm Control." Progressive Agriculture in Arizona. Vol. XXI, No. 2, pp. 4-6. College of Agriculture, University of Arizona, Tucson.

Watson, T. and D.G. Fullerton. 1969. "Evaluation of Insecticides for Pink Bollworm Control." Progressive Agriculture. Vol. XXI, No. 2, pp. 4-6. College of Agriculture, University of Arizona, Tucson, AZ. March 1969.

Others

Arizona Agricultural Statistics Service. 1964-1986. Arizona Agricultural Statistics, USDA, University of Arizona; Phoenix, Arizona.

Council for Environmental Studies. 1965-1986. Arizona Pesticide Sales Surveys. University of Arizona, Tucson, AZ.

Environmental Protection Agency. 1986. Pesticides in Groundwater - Background Document. Office of Groundwater Protection, Washington, D.C.

U.S.D.A. 1953. The Pesticide Situation for 1952-1953. Production and Marketing Administration, USDA, Washington, D.C.

Personal Communication

Byrne, D. 1987. Entomologist, University of Arizona, Tucson, AZ

Davis, L. 1987. Commission of Agriculture and Horticulture, Phoenix, AZ.

Evans, S. 1987. Former District Manager, Arizona Agrochemical.

Hamilton, K.C. 1987. Weeds Specialist, University of Arizona, Tucson, AZ.

Heathman, S. 1987. Weed Specialist, University of Arizona, Tucson, AZ.

Hine, R. 1987. Plant Pathologist, University of Arizona, Tucson, AZ.

Moore, L. 1987. IPM Statewide Coordinator, Entomology Dept., University of Arizona, Tucson, AZ.

Nigh, E. 1987. Plant Pathologist, University of Arizona, Tucson, AZ.

Roney, J. 1987. Retired State Entomologist, Phoenix, AZ.

Steadman, S. 1987. Cotton Specialist, Pinal County Cooperative Extension Service, Casa Grande, AZ.

Thacker, G. 1987. Agricultural Extension Agent, Pima County Cooperative Extension Service, Tucson, AZ.

True, L. 1987. Maricopa County Director, University of Arizona, Tucson, AZ.

Ware, G. 1987. Entomologist-Associate Director Ag. Exp. St. University of Arizona, Tucson, AZ.

APPENDIX A

Historical Time Line Development, Use and Regulation of Pesticides, 1200 BC - 1987 AD [1]

BC

1200 Biblical armies salt and ash the fields of the conquered; first reported use of nonselective herbicides.

1000 Homer refers to sulfur used in fumigation.

100 The Romans apply hellebore for the control of rats, mice, and insects.

AD

900 The Chinese use arsenic to control garden insects.

1649 Rotenone used to paralyze fish in South America.

1669 Earliest mention of arsenic as insecticide in Western world.

1690 Tobacco extracts used as contact insecticide.

1773 Nicotine fumigation by heating tobacco and blowing smoke on infested plants.

1787 Soap mentioned as insecticide. Turpentine emulsion recommended to kill and repel insects.

1800 Persian louse powder (pyrethrum) known to the Caucasus. Sprays of lime and sulfur recommended in insect control. Whale oil prescribed as scalecide.

1810 Dip containing arsenic suggested for sheep scab control.

1821 Sulfur reported as fungicide for mildew.

1845 Phosphorus paste is declared as official rodenticide for rats by Prussia; by 1859 it was used in cockroach control.

1848 Derris (rotenone) reported being used in insect control in Asia.

1854 Carbon disulfide tested experimentally as grain fumigant.

1858 Pyrethrum first used in the United States.

1860 Mercuric chloride solutions applied to destroy soil-inhabiting forms such as earthworms.

1867 Paris green used as an insecticide.

1868 Kerosene emulsions employed as dormant sprays for deciduous fruit trees.

1878 London purple reported as a substitute for Paris green (both are arsenicals).

1880 Lime-sulfur used in California against San Jose scale.

1883 Millardet discovers the value of Bordeaux mixture in France.

1886 Hydrogen cyanide used for citrus tree fumigation in California. Resin fish-oil soap used as scalecide in California.

1890 Carbolineum, a coal-tar fraction, used in Germany on dormant fruit trees.

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1 Source: Amended from George Ware's Pesticides: Theory and Application (1978) University of Arizona

1892 Lead arsenate first prepared and used to control gypsy moth in Massachusetts. First use of dinitrophenol compound, the potassium salt of 4-6 dinitro-o-cresol, as insecticide.

1896 Copper sulfate used selectively to kill weeds in grain fields. British patent refers to inorganic fluorine compounds as insecticides.

1902 The value of lime-sulfur as apple scab control discovered in New York.

1906 Passage of Federal Food, Drug, and Cosmetic Act (Pure Food Law).

1907 Calcium arsenate in experimental use as an insecticide.

1909 First tests with 40 percent nicotine sulfate made in Colorado.

1910 Passage of Federal Insecticide Act.

1912 Zinc arsenite first recommended as insecticide.

1917 Nicotine sulfate first used in a dry carrier for dusting.

1921 Airplane first used for spreading insecticide dust for catalpa sphinx at Troy, Ohio.

1922 Calcium cyanide begins commercial use. First aerial application of an insecticide to cotton, Tallulah, La.

1925 Selenium compounds tested as insecticides.

1927 Tolerance established for arsenic on apples by U.S. FDA. Ethylene dichloride discovered to have fumigant value.

1929 Cryolite introduced as an insecticide.

1930 First fixed nicotine compound, nicotine tannate, used as a stomach poison.

1931 Thiram, first organic sulfur fungicide, discovered.

1932 Methyl bromide first used in France as fumigant. Ethylene and acetylene discovered to promote flowering in pineapples; first plant growth regulators.

1934 Nicotine-bentonite combination, first dependable nicotine dust, developed.

1936 Pentachlorophenol introduced as wood preservative against fungi and termites.

1938 TEPP, first organophosphate insecticide, discovered by Gerhardt Schrader. Passage of pesticide amendment to Pure Food Law (1906), preventing contamination of food. Bacillus thuringiensis first used as microbial insecticide. DNOC, first dinitrophenol herbicide, introduced to United States from France.

1939 DDT discovered to be insecticidal by Paul Muller in Switzerland.

1941 Hexachlorocyclohexane (BHC) discovered in France to be insecticidal.

1942 First batch of DDT shipped to United States for experimental use. Introduction of 2,4-D, the first of the hormone (or phenoxy) herbicides.

1943 First dithiocarbamate fungicide, zineb, introduced commercially.

1944 Introduction of 2,4,5-T for brush and tree control and warfarin for rodent control.

1945 Early synthetic herbicide, ammonium sulfamate, introduced for brush control. Chlordane, the first of the persistent, chlorinated cyclodiene insecticides introduced. The first carbamate herbicide, propham, becomes available.

1946 Organophosphate insecticides, TEPP and parathion, developed by the Germans, made available to U.S. producers. First resistance in houseflies to DDT observed in Sweden.

1947 Toxaphene insecticide introduced; to become the most heavily used insecticide in U.S. agricultural history. The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) becomes law to protect farmers from dangerous and ineffective chemicals.

1948 Appearance of aldrin and dieldrin, the best of the persistent soil insecticides.

1949 Captan, first of the dicarboximide fungicides, appears. First synthesis of a synthetic pyrethroid, allethrin.

1950 Malathion introduced, probably the safest organophosphate insecticide. Maneb fungicide introduced.

1951 Introduction of first carbamate insecticides; isolan, dimetan, pyramat, pyrolan.

1952 Fungicidal properties of captan first described.

1953 Insecticidal properties of diazinon described in Germany. Guthion insecticide introduced. Board of Pest Control Applicators established by state legislature in Arizona.

1954 Passage of Miller Amendment to Food, Drug, and Cosmetic Act (1906); set tolerances for all pesticides on raw food and feed products. Ronnel, first animal systemic organophosphate insecticide, introduced.

1956 Introduction of first successful carbamate insecticide, carbaryl.

1957 Gibberellic acid, plant growth stimulant, made available to horticulturists.

1958 Atrazine, first of the triazine herbicides, and paraquat, first of the bipyridylium herbicides, introduced.

1959 FIFRA (1947) amended to include all economic poisons, (e.g., desicants, nematicides).

1960 Treflan herbicide becomes available. Bacillus thuringiensis first registered on lettuce and cole crops.

1961 Introduction of mancozeb fungicide. Arizona Applicators Act of 1953 amended to include Rule 17, section B, Safety Rules No. 14 to protect people, livestock and forage from pesticide drift.

1962 Publication of Silent Spring by Dr. Rachel Carson.

1965 Appearance of Temik, first soil-applied insecticide-nematicide. Rule 21 enacted in Arizona requiring commercial growers to obtain a grower's permit annually from the Board, and requiring seller's permits for sellers of insecticides. Rule 26 restricted the application of DDT in Arizona to liquid spray only. Exemptions were made for cotton fields located further than five miles from forage or feed grains.

1966 Appearance of methomyl insecticide, and chlordimeform acaricide-ovicide.

1968 Discovery of synthetic pyrethroids with greater activity than natural pyrethrins. Restructuring of Board of Pest Control Applicators in Arizona, renamed Board of Pesticide Control, membership increased from five to nine members. Rule 20 prohibited the use of DDT in Arizona for uses not specified on label. Rigid calibration, distance limitations and time periods were established. U.S. Food and Drug Administration placed embargo on 50,000 lbs. of Arizona butter shipped to California because of excessive DDT residues. U.S. Cooperative Extension Service in Arizona removed DDT from all pest control recommendations.

1969 In Arizona Rule 20 totally restricted the use of DDT for agricultural purposes in Arizona for the period of one year; the historic DDT moratorium. USDA adopts policy on pesticides to avoid use of persistent materials when effective, nonresidual methods of control are available. Publications of the Mark Report which laid groundwork for concerted environmental protection, resulting in Environmental Protection Agency in 1970.

1970 Formation of Environmental Protection Agency (EPA), which becomes responsible for registration of pesticides (instead of USDA). Arizona continues DDT moratorium under Rule 20. All registrations suspended for alkylmercury compounds as seed treatments. Authority to establish tolerances for pesticides in foods and feeds transferred from FDA to EPA.

1971 Glyphosate herbicide first introduced.

1972 Passage of Federal Environmental Pesticide Control Act (FEPCA or FIFRA amended), requiring all pesticides used in U.S. to be registered for specific uses on basis of testing. To protect public and environment from unreasonable adverse effects. Arizona extends DDT moratorim through its fourth year. Introduction of first microencapsulated insecticide, Penncap M, (methyl parathion).

1973 Development of first photo-stable synthetic pyrethroid, permethrin. Cancellation of virtually all uses of DDT by the EPA.

1974 First standards set for worker re-entry into pesticide treated fields by EPA, (e.g., re-entry intervals of 24 or 48 hours dependent on dermal toxicity of pesticide).

1975 Cancellation of all uses of aldrin and dieldrin, except as termiticides. Registration of first virus for budworm-bollworm control on cotton. First insect growth regulator (methoprene) registered with EPA.

1976 Rebuttable Presumption Against Registration (RPAR) issued for strychnine, endrin, Kepone, 1080, and BHC. Passage of Toxic Substances Control Act (TSCA) on October 11. Most pesticidal uses of mercury compounds canceled by EPA. Use of strobane voluntarily canceled.

1977 Use of dibromochloropropane (DBCP) suspended, and all registered uses for Mirex canceled by EPA. Copper Arsenate uses voluntarily canceled.

1978 EPA concludes the first full-scale RPAR of a pesticide, chlorobenzilate. Certification training completed for applicators, private and commercial, to use restricted-use pesticides. Additional amendments to FIFRA designed to improve pesticide registration process, whereby health, safety and environmental data submitted by manufacturer would be released to public. First list of restricted-use pesticides issued by EPA. All uses of DBCP voluntarily canceled except for pineapples. Cancellation of heptaclor and chlordane for almost all agricultural uses. Uses of sodium Arsenite voluntarily canceled. First registration of a pheromone (gossyplure for pink bollworm) for use on cotton.

1979 Suspension by EPA of most uses of 2,4,5-T and silvex used primarily in control of unwanted plant species on forests and rangeland.

1980 Through new legislation Congress assumes responsibility for EPA oversight. Arizona Groundwater Management Act - no expansion of irrigated acreage in active management areas and water use will be reduced (by individual farmers).

1981 Passage of the Comprehensive Environmental Response Compensation and Liability Act (known as "Superfund") for cleanup of toxic substance spills. Delaney Clause - Federal Food, Drug and Cosmetic Act amended, no cancer-causing food additives may be used, pesticides are not included in this classification. Regulatory action on pesticides must be preceeded by risk/benefit analysis.

1982 Board of Pesticide Control in Arizona places moratorium on Toxaphene, restricting use and application.

1983 EPA cancels almost all uses of EDB.

1984 EPA cancels most registrations for Endrin.

1985 Groundwater Quality Act passed in Arizona to protect aquifers from point source pollution.

1986 EPA cancels all remaining registrations of DBCP. Agricultural uses of Toxaphene cancelled. EPA suspends all distribution, sales and uses of Dinoseb. The Environmental Quality Act established a new Department of Environmental Quality in Arizona which proposes to adopt new administrative rules for the interpretation and implementation of the articles of the Environmental Quality Act which abolishes the Board of Pesticide Control.

1987 EPA brings FIFRA into compliance with the Endangered Species Act regulating 126 pesticides in 135 U.S. counties.

APPENDIX B

TABLE B1. CUMULATIVE PESTICIDE SALES OF COMPOUNDS SOLD IN EXCESS OF 100,000 LBS. ACTIVE INGREDIENT FOR YEARS 1966-1980. SOURCE: SALES SURVEY, UNIVERSITY OF ARIZONA

Carbaryl	2063k	Malathion	1646k
Chlordane	1569k	Methomyl	2142k
Chlordimeform (1972-1980)	1819k	Mevinphos	1577k
Cryolite	3108k	Monocrotophos	3007k
DCPA	1187k	MSMA	2533k
DBCP	3066k	Parathion	10081k
DDT (1966-1970)	4120k	Phorate	1821k
DEF	1778k	Prometryn	1548k
Dichloropropene	8855k	Sodium Chlorate	20608k
Dinoseb	1962k	Sulfur	14291k
Endosulfan	1586k	Toxaphene	21272k
Methyl Parathion	17736k		

TABLE B2. MEAN PESTICIDE SALES SOLD IN EXCESS OF 25,000 LBS. ACTIVE INGREDIENT FOR YEARS 1982-1986. SOURCE: SALES SURVEY, UNIVERSITY OF ARIZONA

Acephate	72740	Fenvalerate	41000
Aldicarb	33770	Glyphosate	122340
Azinphosmethyl	38160	Malathion	98300
Arsenic Acid	39380	Methomyl	75300
Benefin	30420	Maneb	89040
Carbaryl	32780	Mancozeb	46500
Carbofuran	32280	Methyl Parathion	322620
Chlordane	89840	Mevinphos	53180
Chlordimeform	103000	Monocrotophos	65500
Chlorpyrifos	32140	MSMA	55660
Copper Sulfate	25800	Parathion	69680
DCPA	39840	PCNB	139620
DEF	105580	Pendimethalin	50340
Diazinon	76960	Permethrin	67080
Dichloropropene	161900	Profenofos	34700
Dimethoate	139440	Prometryn	113780
Dinoseb	88820	Simazine	32160
Disulfoton	84260	Sodium Chlorate	102650
Endosulfan	67960	Sulfur	1129300
Diuron	25280	Trifluralin	135640
EPTC	80760	Zinc Sulfate	26680

APPENDIX C

The coefficient of variation for average application rate was +.06 pounds of the mean number of pounds of active ingredient applied. These parameters were used in consultation with a statistician from the Agricultural Econonomics Department at the University.

$$\text{Sample size } n = \frac{4z2\,\sigma\,2}{w2}$$

Where

4z2 = confidence interval. (The z value can be obtained from a statistical table which indicates that for a confidence interval of 95%, the coefficient is 2).

σ = A rough estimate of standard deviation, which can be obtained by using the range in an interval variable (application rate) and dividing by 4. From 500 samples of 1080 Forms, it was determined that the lowest application rate for any particular compound would be .015 pounds active ingredient and the highest rate 3 pounds active ingredient. This measure of range does not account for sulfur or sodium chlorate; therefore, average application rates for those compounds can be figured separately.

w = width of confidence interval or 2 times the tolerance. The error factor is $\pm$ .06 pounds below or above the mean. As a result, w = .125.

The final equation would then be as follows -

$$n = \frac{(4.4)\ (2.985/4)2}{.1252} = \frac{8.91}{.015} = n = 594 \text{ forms}$$

To select the first 1080 Form we chose from a table of random numbers arranged so each form had an equal probability of selection. Data were collected for 1985, 1986, and up until September 1, 1987. All the data were inputted into a database package, Infostar.

APPENDIX D

HISTORICAL PESTICIDE USE IN ARIZONA

Conducted by:
Pesticide Coordinator's Office
1109 E. Helen St.
Tucson, AZ 85719
(602) 621-4012

The purpose of these forms is to collect information on the types of pesticides which have traditionally been applied and are now being applied in each of the 15 counties in Arizona. We are asking your assistance in providing whatever relevant information you can give us. The only way of obtaining this kind of data is through reliance on expert opinion from those people that have actually worked in pesticide application or recommendation. I feel quite certain that there is valuable information out there that has never been recorded or summarized. The specific information that you are asked to provide includes the following:

1) Please rank (1-10) the compound you preferred in each given time frame. If more than one compound was widely used, rank both or all of them with a number one. Run a line through those chemicals that were not used.

2) Verify application rates given.

3) Indicate average number of applications per growing season.

4) Add any comments that may be relevant to that compound, commodity or time frame.

I have included insecticides, herbicides, and other pesticides. Please indicate any of these compounds that were or are in wide usage. A sample form is included in this packet so as to exemplify the format. If there are commodity forms included for which you are not familiar, please disregard those forms.

I realize that provision of this information may be time consuming and that your comments are based on recall, however, any information that you provide will be of great assistance.

Please fill out as much as time allows and return the forms by the end of September or as soon as possible. Feel free to contact me if you have any questions or comments. Thank you for your time.

Sincerely,

Tasha Brew
Research Technician
State Pesticide Coordinator's Office

TB:tc
cc: Dr. Paul Baker, State Pesticide Coordinator

Provided By: Tasha Brew
Research Technician
State Pesticide Coordinator's Office

ID#________/__________
(County/ID)

HISTORICAL PESTICIDE USE SUMMARY
ON PEST CONTROL WRITTEN RECOMMENDATIONS
FOR CITRUS (RANGE OF RATES - LBS/ACRE) PAGE 1 OF 5

1940	COMMENT	1945	COMMENT
odium Arsenite & aris Green &		15% Paris Green	
alcium Carbonate		DDT (.6-2)	
oap Emulsion		Cryolite	
aris Green		London Purple	
ead Chromate		Nicotine Sulphate	
ondon Purple		Rotenone	
icotine Sulphate		Sabadilla (.05 gall.)	
hloropicrin		Pyrethrum	
arbon Bisulfide		Sulfur (75-100)	
hite Arsenic			
odium Cyanide			
alcium Cyanide			
odium Chlorate 2/SQ. rod)			
otassium Chlorate 4/SQ. rod)			
orax (8/SQ. rod)			
ordeaux Mixture Copper Sulfate & Lime)			
ulfur (75-100)			

1955	COMMENT	1965	COMMENT
Aramite (.6)		Lead Arsenate (3)	
Lead Arsenate (3)		Guthion (.18-.5)	
DDT (4)		Toxaphene (1.2)	
Dieldrin (.5)		DDT (.4-3)	
Nicotine Sulphate		Dieldrin (.5)	
Malathion (1)		Nicotine Sulphate (.6 pints)	
1% Thanite (1956)		Malathion (.4)	
Bordeaux Mixture (Copper Sulphate & Lime)		Dicofol (.2-.37)	
Sabadilla (.05 gall.)		Tedion (.25)	
Sulfur (75-100)		Trithion (.25)	
		Diazinon (.5)	
		Lindane (1)	
		Naled (1)	
		Parathion (.5)	
		Dimethoate (.5)	
		Chlorobenzilate (.25)	
		Sabadilla (.05 gall.)	
		Sulfur (75-100)	
		Dioxathion (2)	
		Trifluralin (2)	

Provided By: Tasha Brew

COMM/CITRUS

ID#________/________
(County/ID)

1970	COMMENT	1975	COMMENT
B.T. (.5-1)		Bromacil (6.4)	
Bordeaux Mixture		Azinphosmethyl (1)	
Carbaryl (1)		B.T. (.5-1)	
Carbophenothion (.25-1.25)		Bordeaux Mixture	
Chlorobenzilate (.25-3.75)		Carbaryl (1.5-2)	
DBCP (2-6 gall.)		Carbophenothion (.25-1.25)	
Dimethoate (.5-1)		Chlorobenzilate (2.0)	
Dicofol (.25-4)		Dimethoate (.5-1)	
Diazinon (.5-2)		Dicofol (2.0)	
Dioxathion (2)		Diazinon (.5-2)	
Guthion (2-6)		Dioxathion (2)	
Lime		Ethion (2-3)	
Lindane (1)		Dinoseb	
Malathion (1-1.5)		Lime	
Naled (1)		Malathion (1-1.5)	
Petroleum Oils (50-150 gall.)		Naled (1)	
Paradichlorobenzene		Petroleum Oils (50-150 gall.)	
Parathion (.5)		Phosphamidon (2)	
Phosphamidon (2)		Phosalone (5-8)	
Sabadilla (1)		Sulfur (75-100)	
Sulfur (75-100)		Trifluralin (2)	
Tetradifon (Tedian) (.25-2.5)		Divron (1.6)	
Toxaphene (.4-1.2)		MSMA (3-6)	

Provided By: Tasha Brew

COMM/CITRUS

ID#________/________
(County/ID)

1975	COMMENT	1980	COMMENT
Paraquat (.5-1)		Bromacil (6.5)	
Simazine (1.6)		Azinphosmethyl (.25-.38)	
		B.T. (.5-1)	
		Bordeaux Mixture	
		Carbaryl (1.5-2)	
		Carbophenothion (2.5-3.75)	
		Chlorobenzilate (2.5)	
		Dimethoate (.25-.5)	
		Dicofol (1.6-4)	
		Diazinon (2)	
		Diovathion (3)	
		Ethion (2-3)	
		Fometanate (1.5-4)	
		Lime (cover)	
		Malathion (.25-.5)	
		Methomyl (.45)	
		Naled (1)	
		Phosphamidon (1-2)	
		Phosalone (5-8)	
		Sulfur (75-100)	
		Trifluralin (2)	
		Methidathion (.25-.5)	

Provided By: Tasha Brew

ID#________/__________
(County/ID)

1980	COMMENT	1985	COMMENT
Glyphosate (2-4 Qts.)		Bromacil (6.5)	
Divron (1.6)		Azinphosmethyl (.25-.38)	
MSMA (3-6)		B.T. (.5-1)	
Paraquat (.5-1)		Bordeaux Mixture	
Simazine (1.6)		Carbaryl (1)	
		Chlorobenzilate (2.5)	
		Dimethoate (.25-2)	
		Dicofol (1.6-4)	
		Diazinon (.5-1)	
		Ethion (4-6)	
		Dinoseb	
		Diuron (1.6)	
		Lime (cover)	
		Malathion (.25-.5)	
		Methomyl (.9)	
		Naled (1)	
		Sulfur (75-100)	
		Simazine (1.6)	
		Trifluralin (.5-2)	
		Acephate (1)	
		Oxamyl (.5-1)	
		Paraquat (.5-1)	
		Propargite (2-3)	
		Cyhexatin	

APPENDIX E

MAJOR CROPS BY COUNTY 1980-1986 AVERAGE ACRES
(only acreage >1000 recorded)

Abbreviations:

Crops: L = 1000 - 4999 Acres
M = 5000 - 9999 Acres
H = > 10,000 Acres

Livestock: L = 125,000 - 199,999 Head
M = 200,000 - 299,999 Head
H = > 300,000 Head

	ALL HAY	APPLES	BARLEY	BERMUDA GRASS SEED	BROCCOLI CAULIFLOWER	CANTALOUPES	CARROTS	CITRUS	CORN	COTTON	GRAPES	HONEYDEWS	LETTUCE	ONIONS	PEANUTS	PECANS	PISTACHIOS	POTATOES	SAFFLOWER	SESAME	SORGHUM	SUGARBEETS	WATERMELONS	WHEAT	CATTLE SHEEP
APACHE	M								M																L
COCHISE	M	L	L						H	H			L			L	L				L	'75 L		L	
COCONINO	L																								
GRAHAM	M	L	L						L	H											H			L	
GREENLEE	L																								
LA PAZ	H		L			L				L		L	L											H	
MARICOPA	H		H		L	L	L	H	M	H	L		L	L				M			L	'70 H	L	H	H
MOHAVE	M									L														L	
NAVAJO	M								L																
PIMA	L		L							H						M					L			L	
PINAL	H		H					L		H			L			M					L	'80 M		H	M
SANTA CRUZ	L																								
YAVAPAI	M																								
YUMA	H		L	M	L	L		H		H			H		L				L	L	L	'75 M		H	M

APPENDIX F

Arizona Commodity-Specific Information

Wheat: Wheat was one of the first crops grown commercially in Arizona. Peak acreage was 325,000 acres in 1975, but crop acreage has been declining ever since. Current level is 114,000 acres. Many wheat varieties are first tested for growing conditions in Yuma and then introduced into other parts of the country. La Paz, Maricopa, Pinal and Yuma Counties all have wheat plantings of over 10,000 acres. Few pesticides are applied to the wheat crop.

Barley: Barley, another of the earliest crops commercially produced in Arizona, was at its highest level in 1950 with 191,000 acres but has been steadily decreasing. The 32,000 acres grown in 1986 were planted primarily for crop rotation and grazing. Barley plantings greater than 10,000 acres can be found in La Paz and Pinal Counties. Barley also uses few pesticides.

Sorghum: This crop has traditionally met an important statewide need for livestock feed. The 254,000 acres planted in 1967 were the record high. Since 1975, acreage has declined rapidly; with only 15,000 acres planted in 1986. The only Arizona county with more than 10,000 sorghum acres is Graham. Pesticide use is minimal on sorghum.

Corn: Corn is also used to satisfy the demand for livestock feed in Arizona. The record high of 70,000 planted acres occurred in 1978. Most corn acreage is found in Apache, Cochise and Maricopa Counties, although at present all have under 10,000 acres planted (by contrast, Cochise alone had 41,000 acres of corn in 1978). Irrigation costs had caused acreage to decline rapidly.

Production of sweet corn usually requires pesticide use. Preferred compounds, according to Arizona pest control advisors, are fenvalerate, methomyl, carbofuran and atrazine. Pesticide use on field corn, however, is minimal.

Alfalfa: Alfalfa, another early Arizona crop, achieved record high acreage in the 1960's — about 275,000 acres. Second and third cuttings of alfalfa are common here and help meet the state livestock feed demand. Acreage, which is fairly constant, in 1986 was 177,000 acres. All counties grow some alfalfa but only La Paz, Maricopa, Pinal and Yuma counties have more than 10,000 acres. Alfalfa is a relatively high water user and as a result, production areas have shifted to counties where water is less expensive.

Pesticide use on alfalfa is significant because of the number of acres; substances used in production include chlorpyrifos, carbofuran, disulfoton, dimethoate, methomyl, diazinon, benefin, 2,4-D and trifluralin.

Safflower/Sesame: The record high for safflower, grown in Arizona since the 1960's, was 44,500 acres in 1975. Most of this crop is grown in Pinal, Maricopa and Yuma Counties, primarily for oil production and livestock meal. Drastic declines in acreage resulted in only approximately 100 acres being planted in Yuma for 1986, compared to 3,000 acres in 1985. Sesame, grown in Arizona since the 1950's, is used primarily for oil and confectionary purposes. In 1986, 10,000 acres were grown in Yuma County.

Neither of these crops requires extensive use of pesticides; in addition, few pesticides are registered for sesame.

Sugarbeets: This crop, grown here since the late 1930's, was primarily used for seed until the late 1960's. In 1970 sugarbeets were grown on 20,000 acres, mostly in Yuma, Maricopa and Cochise Counties. Spreckles Sugar Company had a processing plant in Chandler, with several loading docks throughout the state. Since this plant closed in 1982, sugarbeets have not been grown commercially in Arizona. Preferred pesticides were disulfoton, carbaryl, chlorpyrifos, methomyl, phorate, sulfur and endofumisate.

Bermuda Grass Seed: Several years ago Yuma County produced approximately 90% of the world's bermuda grass seed. Since California's Imperial Valley now grows this crop, Arizona's share of the worldwide market has fallen to about 60%. Bermuda grass is used along river levies and other earthen structures requiring erosion control, as well as for sod and turf. Acreage for this crop, grown in Arizona since the late 1930's, is steadily decreasing. In 1985 eleven thousand acres were planted in Yuma county, with only 7,400 acres in 1986. Pesticides used on bermuda grass seed include carbofuran, disulfoton, phosdrin, parathion, phorate, acephate, cypermethrin and trifluralin.

Vegetables

Many different vegetables have been grown in Arizona since the mid 1900's, including broccoli, cabbage, cauliflower, cantaloupes, honeydews, watermelons, lettuce, carrots, onions and potatoes (melons are included with vegetables because they appear under this heading in the Arizona Agricultural Statistics publications). Many minor crops, such as asparagus, beets, sweet corn, spinach and tomatoes, have historically been grown on smaller plots. The majority of vegetable acreage is in Yuma (39,000 acres) and Maricopa (24,000 acres). Significant acreage is also planted to vegetables in La Paz (11,000 acres), Cochise (3,200 acres) and Pinal (1,800 acres).

Arizona ranks third nationally in harvested area and total production/value of vegetables. Vegetable acreage in the state has been steadily increasing. In 1985, the production area for the 8 principal vegetables and potatoes totaled 75,900 acres — up 10% from 1984. Vegetable production value increased 17% in 1986 over the previous year's figures. Iceberg lettuce remains the most significant Arizona vegetable crop, accounting for 49% of the total value of production. Other vegetables with significant acreage are cauliflower, cantaloupe and potatoes. Miscellaneous vegetables — predominantly leaf and romaine lettuce, greens, cabbage, green onions, squash and rapini — make up 19% of total value of production.

Vegetables are a significant concern because high-quality production requires substantial amounts of chemical treatment. Arizona's choice for vegetable pest control is shifting to more pyrethoids, resulting in lower application rates and a decrease in total pesticide load. Preferred pesticides used in production also include phosdrin, malathion, parathion, dichloropropene, diazinon, methomyl, acephate, methyl parathion, trifluralin, benfluralin, bensulide, pronamide, and zineb.

Fruits and Nuts

Fruit and nut trees, cultivated in Arizona since the late 1800's, were not grown commercially until the 1930's. The acreage planted to certain fruit and nut trees has been steadily, and sometimes dramatically, increasing. Cash receipts from fruit and nut production now represent more than $120 million; these crops will become increasingly important in the near future.

Citrus: The major fruit crop is citrus, with Arizona ranking third in national production. Citrus has been produced commercially since the 1930's, at which time approximately 22,000 acres of trees existed. In 1975 the record high of 61,000 acres of citrus trees were in production. Acreage has since declined significantly, primarily because of land speculation and urbanization. The largest declines have been in grapefruit and lemons. Even though acreage is decreasing, the total value of sales continues to increase. Citrus is grown primarily in Maricopa, Yuma, and Pinal Counties. Pesticides recommended extensively on citrus include dimethoate, sulfur, dicofol, bordeaux mixture, and simazine.

Grapes: Grapes have been grown in Arizona since the 1940's; acreage in 1970 reached 5,300 acres. Production steadily declined in the 1970's but began to rebound in 1980. In 1984 grapes produced more income to the grower than the sorghum and corn crops combined. Arizona grape-bearing acreage in 1986 totaled 6,238 acres -- up 115% from 1981 — and production was the highest on record in the state. Acreage can be expected to remain fairly stable, because of California's overproduction of grapes. Major producing areas include Maricopa, Yuma and Cochise Counties. Pesticides used in grape production include carbaryl, sulfur, triadimefon and paraquat.

Apples: Although Arizona has grown apples since the 1930's, they did not become a significant agricultural commodity until the eighties. The surge in apple production took place in Graham and Cochise Counties where the primary crops had been cotton and corn. Production of apples in 1980 was almost four times the 1985 level. Although apples can generate an income of up to $10,000 per acre, plantings are not expected to increase dramatically from the present level of over 5,000 acres. Pesticides used on apples include formetanate, azinphos-methyl, dimethoate, demeton, oryzalin, metalaxyl and triadimefon.

Miscellaneous Deciduous Fruit Trees: (Apricots, peaches, figs and plums).

Apricots have been grown in Maricopa county since the 1940's, but production has always been stifled by root rot, thrips and warm weather. Apricots grown in southern Arizona produce an excess of blooms (as many as three times per year), which prohibits the required dormancy period. Currently about 200 acres of apricots are grown in Arizona.

Peaches have also been grown for many years in Arizona but are not a significant agricultural commodity in terms of acreage. Figs at present are grown on 90 acres; production and profits for this minor crop have historically been low because of problems with the corn sap beetle and bacterial spread. Plums have been grown in Arizona since the 1960's, but production has been restricted by disease problems and marketing complications; Arizona now has 92 acres planted to plums.

Nut Trees

Producing acres of nut trees in Arizona total over 18,000 acres, with 14,000 of these planted to pecans. Pecans have been grown commercially in Arizona since the 1930's, and the oldest groves are in Sahuarita and Picacho. In the past Yuma pecan production had problems because of a high water table. Instate pecan acreage reached a high in 1970 but then declined; productive acres have been increasing since 1981 to the current 114,000 acres. Aphids are a statewide problem. Pesticides used on pecans include aldicarb, disulfoton, dimethoate, and divron.

Pistachios and almonds are relatively new commercial crops in Arizona. The 1306 acres of pistachios are located primarily in Cochise and Maricopa counties; about 2,800 acres of almonds are grown in Maricopa.

LIVESTOCK

Cattle: Ranching has long been a significant industry in Arizona. In 1867 the state contained 200,000 head of cattle. By 1907 this figure had risen to 1.05 million, with the highest head count of 1.75 million recorded in 1918. In 1986 the industry generated a gross income of $425.9 million, from 1 million head of cattle and calves. Approximately one-third of these are on feed in 17 commercial feedlots, but the largest component of the industry is still range cattle. Counties with the largest number of cattle are Maricopa, Pinal, Yuma, and Apache.

Cattle are regularly treated with insecticides but the amount of chemical that reaches the soil is minimal, because pest control recommendations suggest ear tags, pour-on applications and/or high compression sprays. Dipping vats are rarely used (personal conversations, Carlton Camp, and Ed LeViness, 1987).

Dairy: The dairy industry has been encouraged to reduce herds by over ten thousand cows under a 1986 national Dairy Buyout Program. Milk production set a state record in 1986. Arizona now has about 86,000 head of milk cows.

Sheep: The number of sheep has steadily declined since the mid 1970's. Currently the state has 283,000 head of sheep, mostly in Apache, Navajo, and Maricopa Counties.

Hogs: Hogs and pigs have been husbanded in Arizona since before the 1870's but inventories did not exceed 100,000 head until 1977. The state high of 175,000 head was 1985; present count is 155,000 head. Gross income for this industry in Arizona in 1986 was $33.4 million. Navajo County has the highest hog and pig counts.