The 1989 Recommended Pesticide and Nitrogen Use Survey: Description and Policy Applications

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The public and the agricultural community are concerned with the impact of agrichemical use on the environment. Of particular concern is the impact of pesticides and nitrogen on the quality of surface and ground waters (Nielson and Lee 1987). Water quality is vulnerable to pesticide and nitrogen contamination due to a variety of managerial and biogeophysical factors, among them soil, climate, and cropping practices (Schaller and Bailey 1983). Although a national effort is under way to address agricultural contributions to water contamination, lack of data is hindering progress. Data are needed to characterize agrichemical use and its subsequent fate and transport throughout the ecosystem. Reliable data are vital for informed policy decisions weighing the potential risks and benefits (Delwiche 1970). In the absence of that data about total amounts of agrichemicals being used on crops and the rates and methods of application, it is difficult to describe the link between agricultural production practices and environmental quality, or to assess the impacts of programs and policies addressing water quality.

This report documents the 1989 Recommended Pesticide and Nitrogen Use Survey. The survey was conducted to alleviate part of the data deficiency by collecting detailed information on recommended pesticide and nitrogen uses and application practices in 48 states. Information on usage was obtained by crop, tillage practice, and soil texture. Crops covered in the survey included alfalfa, barley, corn grain, corn silage, cotton, oats, pasture, other hay, peanuts, sorghum grain, sorghum silage, soybeans, spring and winter wheat, and sunflowers. Tillage practices included spring and fall plow conventional tillage, conservation tillage, ridge tillage, and no tillage. By providing detailed information on the rate and total amount of agrichemicals applied to the soil surface, the survey provides data for investigating the behavioral and economic links between environmental quality and decision making within agricultural production. In addition, the data can be used in assessing the impacts of policies and programs addressing water quality.

The report proceeds as follows. The following section presents the conceptual framework behind the 1989 Recommended Pesticide and Nitrogen Use Survey. The actual survey design of the pesticide component is described in the third section. The fourth section presents the technical aspects of the pesticide use component in terms of editing, default data, data review, and data validation. Summary comments of how the data will be used are outlined in the fifth section. The final section describes the nitrogen use component of the survey and uses of the nitrogen data.

The Conceptual Framework: The Mass Balance Concept and the 1989 Survey

An assessment of agriculture's contribution to environmental degradation requires (1) knowing where and how much agrichemicals are used in crop production, and (2) understanding how site characteristics and transport mechanisms result in contamination. Following Kneese et al. (1970), we employ the mass balance approach to account for agricultural chemicals entering and existing in the environment. The mass balance approach establishes an identity between chemicals applied to the earth's surface and amounts distributed in soil, water, and atmospheric sites. The mass balance equation requires that the sum of amounts applied equals the total sum of the amount transported in sediment, wind, and water, the amount transformed by biological and chemical processes, and the amount stored in soil and water systems.

$$\Sigma \text{ Applied} = \Sigma \text{ Transported} + \Sigma \text{ Transformed} + \Sigma \text{ Stored}. \qquad (1)$$

To incorporate the mass balance approach into resource management, the Center for Agricultural and Rural Development (CARD) at Iowa State University, in cooperation with the USDA Soil Conservation Service (SCS), utilizes a large-scale natural resources modeling system called the Agricultural Resources Interregional Modeling System (ARIMS) (English et al. 1989). ARIMS simulates production and resource use patterns and projects the use of soil resources and other factors employed in agricultural production. ARIMS has been used extensively to project soil erosion rates and the impacts associated with alternative conservation policy, and to support both the 1980 and 1985 Resource Conservation Act (RCA) appraisals. The system is rich in detail about the productivity characteristics of soils used in agriculture and the technologies employed in crop and livestock production activities.

A current cooperative project between CARD and the SCS is to improve ARIMS projections by incorporating into the system more detailed information about the application of production inputs such as nitrogen and pesticides applied to cropland. Phase one of this project collects information about recommended use rates and application practices of nitrogen and pesticides employed in crop production, the objective being to merge this data with the existing crop enterprise data already supporting ARIMS. Phase two, a longer term project, assesses the fate and transport of agrichemicals applied to crops and in the process of crop production.

The 1989 Recommended Pesticide and Nitrogen Use Survey was administered in phase one. The survey determined typical production use practices and recommended application rates. With this information, support data for modeling can be augmented and used to report levels of pesticide and nitrogen use associated with levels and patterns of crop production in an ARIMS solution. Estimating total amounts of pesticide and nitrogen applied essentially estimates the left-hand side of the mass balance equation (1): the sum of total amounts applied. ARIMS is used to examine alternative conservation and environmental policy issues and to project specific information about aggregate use levels of pesticides (i.e., herbicides and insecticides) and nitrogen for regional source areas. The results can be used to assess environmental quality concerns. In addition, one can evaluate the risks and benefits associated with agricultural and environmental policy initiatives that influence the use of these inputs.

The Recommended Pesticide Use Component

A pesticide use survey was administered to SCS state-level soil conservationists and agronomists. The survey collected information on typical sets of pesticide chemicals recommended for use on cropland in production. The sets of chemicals are referred to as "baskets" of chemicals specific to each crop and tillage practice used by farmers in the state. Figure A.1 depicts the survey form. Explicit schedules detailing each crop-chemical basket and the relative percentages for each chemical in the identified set of basket chemicals were included on the survey form sent to each state conservationist. The relative percentage for each chemical in a basket identified the chemical's contribution to total pounds of active ingredients (AI) applied to the crop acres. The data used to compile the schedules were extracted from a 1985 pesticide use database compiled by Resources for the Future (RFF) (Gianessi 1988).

Each state agronomist was asked to review and update the information with the latest recommended use information. State agronomists were asked, after revising the chemical basket, to re-estimate, for each crop/tillage combination, each chemical's proportion (percentage) of the total pounds of active ingredients of herbicides and insecticides applied. This aggregate proportion is called the "basket percentage rate" (BPR). The BPR estimates capture both multiple applications and applications of pesticide mixes.

The state conservationists were also asked to provide recommended application rates and number of applications per growing season for each chemical in the basket (Figure A.2). This information was obtained by specific soil texture and tillage practice.

To compare pesticide use across different tillage practices and crops, we constructed a common unit of measure: pesticide intensity on treated acres (PITA). PITA acts as a common denominator to account for different recommended application rates for each chemical. The pesticide intensity on treated acres is measured as the proportion of treated acres that receives a chemical from a given set of chemicals. PITA transforms the stock measure, indicating the proportion of total pesticides used into a flow measure of intensity to reveal spatial use patterns. PITA estimates thereby make treated acres comparable. Hence, a simple simultaneous equation routine is developed to convert BPR's into estimates of PITA. The PITA for each chemical is determined as follows:

$$BPR_i = \frac{(APPR_i * TO_i)\, PITA_i}{\sum_{i=1}^{n} [(APPR_i * TO_i)\, PITA_i]} \qquad i = 1, \ldots, n, \qquad (2)$$

where $APPR_i$ = application rate for chemical i;

TO_i = times over for chemical i;

BPR_i = basket percentage rate, which is the percentage for a specific chemical out pounds of total active ingredients applied to the state production of a crop;

$PITA_i$ = percentage of pesticide-treated acres receiving a chemical; and

n = number of chemicals.

To fully specify the system, we assume

$$\sum_{i=1}^{n} PITA_i = 1. \qquad (3)$$

The system of (2) and (3) is solved for the PITA variables using a Gaussian elimination method to solve simultaneous equations.

As an example of how PITA values are related to the percentage share of total pounds of active ingredients applied, consider the case for corn under conventional tillage, where the shares of total pounds applied for a set of chemicals--Alachlor, Atrazine, and Metolachlor--are 29 percent, 46 percent, and 25 percent. If application rates for these chemicals are equal, then the estimates for the percentage shares of treated acres receiving each chemical would be equal to that of total pounds applied. The recommended application rates for these chemicals differ, however; requiring 3.0 lb/ac. for Alachlor, 2.25 lb/ac. for Atrazine, and 1.75 lb/ac. for Metolachlor. Because of the difference, the percentage share of treated acres receiving each chemical is not equal to the percentage of total pounds applied for each. Given the respective application rates, the PITA estimates for the three chemicals are 22 percent for Alachlor, 46 percent for Atrazine, and 32 percent for Metolachlor. PITA estimates reflect that Alachlor is applied at a recommended application rate above the average for the three chemicals: the significance of this is that for Alachlor to account for 29 percent of the total pounds of active ingredients applied, it would be applied to 22 percent of the treated crop acres at the recommended rate of 3.0 lb/ac. Likewise, for Metolachlor to account for 24 percent of the total pounds of active ingredients applied, it would be applied to 32 percent of the treated acres, since its recommended rate is only 1.75 lb/ac.

The product of a chemical's PITA estimate multiplied by per acre application rate equals the representative use rate per pesticide-treated acre. Because herbicide chemical application rate recommendations differ by soil texture, a PITA is specific for soils of fine, medium, or coarse texture and tillage practice. The result is a representative use rate ($AI/ac_{i,k,m,t}$) for each chemical in each crop/tillage/ texture basket of chemicals, calculated as

$$AI/ac_{i,k,m,t} = (PITA_{i,k,m,t} * APPR_{i,k,m,t}), \qquad (4)$$

where i = 1, ..., n chemicals,
k = 1, ..., n crops,
m = 1, ..., n tillage practices,
t = 1, ..., n soil textures, and
$AI/ac_{i,k,m,t}$ = active ingredients per acre.

These estimates of active ingredients per acre for each basket chemical are used to compute the total pounds of pesticide AI associated with crop production given estimates of crop production acreage and the proportion of planted acreage treated with pesticides.

An aggregate measure of crop production is used to compute the relative magnitude of chemical application associated with regional crop production mixes and patterns. Specifically, to obtain estimates of pesticide chemical application levels, estimates of cropland used for crop production (rotations) by crop and tillage practice are combined with representative per acre use rates (AI/ac.) to compute total pounds of active ingredients for each chemical by crop and region.

Editing, Entering, and Processing Survey Data

Given the potential for error with this survey process, several parts were edited in detail to guarantee the accuracy of the information provided. In some instances pesticide use data reported in terms of formulation had to be converted to pounds of active ingredients, the common unit of measure. The data was entered into an SQL relational database format. Edits designed to check for values out of reasonable ranges and for incomplete basket percentages were built into the data entry process.

Default Data for Missing Values

In instances where respondents could not provide complete information about pesticide use and application rates, we consulted other sources of information, such as current Extension Service publications reporting pesticide application. Default data for application rates and percentage of planted acres treated were available from these publications. In addition, we consulted USDA publications reporting pesticide information for selected states and crops. Other sources included chemical manufacturers handbooks and interviews with SCS agronomists.

Information on how pesticide use differed for different tillage practices, is often not readily available from a published source. Although the survey specifically requested this information, in many cases the respondent did not report the necessary level of detail. A default data generation procedure was developed that used a generic computer program to assign pesticide use values to other tillage practices. Generally, respondents provided information for conventional tillage practices. In some instances, these data were assigned to those tillage practices not reported on the survey form. This default data generation procedure was used prior to the data review by state conservationists and agronomists, giving them the opportunity to react to the default data constructed for the alternative tillage practices. During the review, it was made clear that the data was not final; it was up to the reviewers to suggest revisions in chemical baskets and recommended application rates associated with crops and tillage practices. Final review of data was conducted by SCS National Technical Center pesticide specialists and agronomists.

Data Review Process

The preliminary pesticide data were tabulated for review using simple table formats allowing reviewers to examine data specific to their states. Table formats also allowed them to compare their state data with that of neighboring states. This provided them an opportunity to identify the missing crops/chemicals and to correct inaccuracies in the data. Necessary edits were made to the database based on the response received from these individual state specialists.

Data Validation

Verification of the pesticide data involved tabulation of the survey responses for review by state agronomists. Validation of the survey data is more difficult because comparable pesticide use data for recent years is unavailable. The validation procedure involved calculating total amounts of pesticide chemicals used at the state and crop levels and comparing it with USDA and Extension Service publications on pesticide uses. Estimates of total pounds of pesticides applied to crops in a state are computed by multiplying each chemical representative use rate by total acres treated of each crop/tillage and texture combination. Computing these estimates required data for (1) total planted acres, by crop (USDA 1989); (2) percentage of planted acres by tillage practice (CTIC 1987); (3) percentage of planted acres by soil surface texture (SCS 1987), and (4) percentage of planted acres treated with pesticides. Tables A.1 and A.2 give the percentage of planted acres treated with herbicides and insecticides by state and crop.

Two variables required to calculate total amounts of active ingredients applied ($TAI_{i,k,m,t}$) of a specific chemical at the state level are

1. ($TAT_{k,m,t}$), total acre-treatments, and
2. ($AI/ac_{i,k,m,t}$), active ingredients per acre,

where
- i = 1, ..., n chemicals,
- k = 1, ..., 15 crops,
- m = 1, ..., four tillage practices, and
- t = 1, ..., three soil textures.

The variable total acre-treatment(TAT) is calculated as follows:

$$TAT_{k,m,t} = \{[(TPA_k * \%TPAL_{k,m}) \%TPATk_{k,t}] \%PAT_k\}, * ACTM, \tag{5}$$

where TPA = total planted acres by crop,

%TPAL = the percentage of total planted acres by crop tillage,

%TPAT = the percentage of total planted acres by NRI soil surface texture,

%PAT = the percentage of planted acres treated for pests, and

ACTM = average treatments per acre (see Tables A.3 and A.4).

Representative use rates--active ingredients per acre--are determined by equation (4). Estimates of total pounds of active ingredients of a chemical applied to cropland acres in a state are obtained as follows:

$$\sum_{k=1}^{15} \sum_{m=1}^{4} \sum_{t=1}^{3} (TAT_{k,m,t} * AI/ac_{i,k,m,t}) = TA_i. \qquad (6)$$

Not all states have current extension service data on pesticides applied in crop production. Likewise, published data from USDA reports give pesticide used for selected major crops and production regions. Results of the above calculations were compared to available reports of pesticide use showing total pounds of active ingredients.

Conclusions: Uses of the 1989 Survey Data in ARIMS

The pesticide survey data will be used with the CARD Agricultural Resources Interregional Modeling System (ARIMS) in three ways: (1) to update per acre pesticide costs for each ARIMS crop production activity, (2) to report detailed chemical use in units of pounds of active ingredients for an ARIMS solution, and (3) to analyze agricultural and conservation policies that impose restrictions on cropland and agrichemical input use.

Estimating Rotation Activity Pesticide Costs

Estimates of pesticide costs for the ARIMS activity sets can be updated by calculating each chemical cost (lb. of A.I. times price/unit) and summing across the set of chemicals in the rotation basket.

For example:

For rotation k = 1 and tillage practice m = 1,

$$\text{cost per acre} = \sum_{i=1}^{n} (AI/ac_i * \$/lb.\ AI_i).$$

Policy Analysis

For policy evaluations, the data can be used in several ways: (1) analyzing specific regional chemical use restrictions; (2) constructing a restriction on total chemical use, given a meaningful composite index; and (3) screening the ARIMS activity sets for environmental hazard rankings, given an index for each chemical's potential to become a environmental pollutant, and then discriminating against activities having an unacceptable potential for environmental hazard.

The Recommended Nitrogen Use Component

Current published data for nitrogen application rates by region, crop, and management practice were not available prior to this study. Previous evaluations of the U.S. agricultural sector requiring disaggregate data relied on Ibach and Adams (1967) (English et al. 1982; Stoecker 1974). U.S. Department of Agriculture (1990), Vroomen (1989), and Berry and Hargett (1989) provide aggregate levels of fertilizer use, but allocation among crops and management practices is not provided. None of these previous data provide rates differentiated by soil type.

The joint cooperative effort between the SCS Strategic Planning and Policy Analysis Division (SPA) and CARD resulted in administration of a survey form on nitrogen usage (Figure A.3). This form was mailed with pesticide rate forms from the national SCS office to state conservationists in all states. Each state agronomist or other designated person utilized available published recommendations and other knowledge and sources to fill in the surveys. The surveys reflect the 1989 growing season and are recommended rather than actual.

The nitrogen application rate survey collected information by major land resource area (MLRA) (USDA 1981) portions of states and for three soil quality groups within each area. An example of the nitrogen survey form is shown in Figure A.3. Crops covered by the survey include barley, corn grain, corn silage, cotton, oats, sorghum, sunflowers, spring wheat, and winter wheat. Alternative tillage practices surveyed are fall and spring conventional tillage, conservation tillage, and no tillage.

Credits for legume- produced nitrogen for crops in the first and second years after legume hay and in the first year after soybeans were also surveyed. The survey also collected information on the distribution of nitrogen application by season and on the source of nitrogen materials.

Rather than providing a full set of information, some states indicated that rates were constant across soils, substate areas, and rainfed versus irrigated lands. Other states provided only limited information and did not specify its applicability. Where information for an MLRA portion of a state was lacking, survey data from the same MLRA in an adjacent state was substituted. A statistical regression analysis over the collected data was used to determine the relationships among average nitrogen application rates across soil groups and to differentiate the data by soil group where needed (see Table 1). In this case information other than the average application rate was assumed constant across soils. When only the average rate was given, it was also assumed for the tillage practices and after legume application rates unless these practices were clearly marked as not applicable. States were given an opportunity to approve or correct the added data in a review process identical to the process used to verify the pesticide data. The nitrogen use data will be used to update nitrogen use coefficients in the ARIMS crop production sets and to produce estimates of total nitrogen use for a model solution (see Table 2).

Table 1. Recommended nitrogen application rate differences, by soil group

	Recommended Rate as % of Rate for Soil Group 1			
	Rainfed		Irrigated	
Crop	Soil 2	Soil 3	Soil 2	Soil 3
Barley	91	77	108	92
Corn grain	97	91	100	85
Corn silage	96	87	97	83
Cotton	119	120	95	98
Oats	90	75	105	94
Sorghum	93	78	95	98
Sunflower	100	91	124	128
Spring wheat	92	81	104	88
Winter wheat	93	81	101	80

Note: Soil groups are by Land Capability Classes as follows:
(1) I, II, and III; (2) IV; and (3) V, VI, VII, and VIII.

Table 2. ARIMS and nitrogen use survey soil group links

ARIMS[a] Soil Group	Land Use Capability Class/Subclass[b]	Survey Soil Group Class	Land Use Capability
1	I, IIwa, IIIwa	1	I, II, III
2	IIe	1	I, II, III
3	IIIe	2	IV
4	IVe	2	IV
5	IIc, IIIc, IVc	2	IV
6	IIs, IIIs, IVs	2	IV
7	IIw, IIIw, IVw	1	I, II, III
8	V, VI, VII, VIII	3	V, VI, VII, VIII

[a]In each region ARIMS represents the land resource for crop production by these eight soil groups. These are the soil groups used in the second Resource Conservation Act Appraisal.

[b]Subclass notations are standard except for wa, which indicates that a wetness problem has been adequately treated.

APPENDIX

Figure A.1.

STATE :____TENNESSEE________ Soil Conservation Service, USDA

Crop Pesticide Use Survey

PART II B: HERBICIDE 'Basket' by Crop and Predominant Soil

INSTRUCTIONS: Listed below are the baskets of insecticides by crop that cover 95 % of total chemical applied to the crop. The percent column indicates the relative share of that chemical in the basket. Please show the changes that you feel are needed to describe the typical basket more accurately. 'Typical' implies an average year with normal weather. Show baskets separately for continuous and rotation crop.

Crop	Predom. soil* on which crop is grown	Common name of the chemical	%	your chngs if continuous crop					your chngs if crop in rotation				
				Common Name	conv. till	% share if conv.	ridge	no-till	Common Name	conv. till	% share if conv.	ridge	no-till
Alfalf	Memphis	Paraquat			90	90		90		90	90		90
	MS0066	Glyphosate			5	5		5		5	5		5
Barley	Pembroke	2,4-D	100		95	95		45		95	95		45
	KY0107			Paraquat				50					50
Corn	Memphis	Atrazine	74		74	50		50		74	50		50
	MS 0066	Alachlor	16		16	5		5		16	5		5
		Metolachlor	7		7	5		5		7	5		5
		Cyanazine	2		2	5		5		2	5		5
				Paraquat		20		20			20		20
				Glyphosate		10		10			10		10

* Identify SOILS5 interpretation record number associated with the soil series.

Figure A.2.

STATE : TN

Pesticide class: HERBICIDE

Crop Pesticide Use Survey

PART I B : LABEL Rates for SINGLE Application (in lbs. active ingredient per acre)

INSTRUCTIONS: 1.Provided below are the LABEL rates for a SINGLE application. Adjust them to reflect your state's recommendations and also supply the rate and number of applications if not provided. 2. List additional chemicals as appropriate and supply the rate and average number of applications.

Crop	List Chem. in all Baskets		price/ lb.AI	Coarse Soil				Medium Soil				Fine Soil			
				conv. till[a]		no till		conv till		no till		conv till		no till	
	Common name of the chemical	Trade Name		rate	#[b]	rate	#	rate	#	rate	#	rate	#	rate	#
Corn	2,4-D	Weedout	2.64	NR		NR		~~1.46~~ 0.5	1	~~1.66~~ 0.5	1	1.94	1	2.14	1
	Alachlor	Lasso 4-E	5.22	2.5	2	2.75	2	2.75	~~2~~ 1	~~3.0~~ 2.75	~~2~~ 1	3.25	2	3.5	2
	Atrazine	Atrazine 80W	2.40	2.0	2	2.25	2	2.0	~~2~~ 1	2.0	~~2~~ 1	3.0	2	3.25	2
	Cyanazine	Bladex 80W	4.60	1.6	1	3.2	1	2.4	1	~~4.0~~ 2.8	1	3.0	1	4.4	1
	Metolachlor	Dual 25G	6.36	1.75	2	2.0	2	2.25	~~2~~ 1	2.0	~~2~~ 1	2.5	2	3.0	2
	Trifluralin	Treflan 4-E		0.375	2	0.5	2	0.5	~~2~~ 1	0.625	~~2~~ 1	0.75	2	1.0	2
	Glyphosate	Roundup	15.30					1.0	1	1.0	1				
	Paraquat	Gramoxone	21.19					0.28	1	0.28	1				
	EPTC	Eradicane	4.81					1.2	1	1.2	1				
	Simazine	Princep	2.88					1.0	1	1.0	1				
	Linuron	Lorox	12.73					1.0	1	1.0	1				
	Pendimethalin	Prowl	6.65					0.75	1	0.75	1				
	Butylate	Genate Plus	2.94					4.2	1	4.2	1				
	Bentazon	Basagram	12.51					0.75	1	0.75	1				
Sorgum	2,4-D	Weedout		0.24	1			0.37	1	0.37	1	0.49	1		
	Alachlor	Lasso 4-E		2.75	2	3.0	2	2.75	2	3.0	2	3.75	2	4.0	2
	Atrazine	Atrazine 80W		NR		NR		2.0	1	2.4	1	3.0	1	3.0	1
	Cyanazine	Bladex 80W		NR		NR		1.2	1	1.36	1	1.6	1	1.6	1
	Trifluralin	Treflan 4-E		0.375	2	0.5	2	0.5	2	0.625	2	0.75	2	1.0	2
	Glyphosate	Roundup	15.30					1.0	1	1.0	1				
	Paraquat	Gramoxone	21.19					0.28	1	0.28	1				
	Metolachlor	Dual	6.36					2.0	1	2.0	1				
	Bentazon	Basagran	12.51					0.75	1	0.75	1				

[a] Includes conservation and ridge till

[b] average number of applications

Soil Conservation Service, USDA

Almost all crop production is on medium textured soils.

Part III. Nitrogen Application Rate, Timing and Source Survey

State ______________________

MLRA ______________________

Land Class/Subclass Group[a] ________

Crop		Average Nitrogen Application rate (lbs./acre)	Timing of Application (percent share)				Source of Nutrient (percent share)					Different Application Rates for Tillage Methods Etc. (lbs./acre)						
			Fall	Spring pre-plant	At planting	After emerg.	Anhydr. ammon.	Urea	Ammon. nitrate	Manure	Other	Fall plow conventional	Spring plow conventional	Conserv. till	Zero till	1st year after legume hay	2nd year after legume hay	After soybeans
Barley	Irrig.																	
	Nonirrig.																	
Corn grain	Irrig.																	
	Nonirrig.																	
Corn silage	Irrig.																	
	Nonirrig.																	
Cotton	Irrig.																	
	Nonirrig.																	
Oats	Irrig.																	
	Nonirrig.																	
Sorghum	Irrig.																	
	Nonirrig.																	
Sunflower	Irrig.																	
	Nonirrig.																	
Spring wheat	Irrig.																	
	Nonirrig.																	
Winter wheat	Irrig.																	
	Nonirrig.																	

[a] Land groups are
1. I, II, and III
2. IV
3. V, VI, VII, VIII

Table A.1. Percentage of planted acres treated with herbicides

State	Alfalfa	Barley	Oats	Corn Grain	Corn Silage	Sorghum Grain	Sorghum Silage	Spring Wheat	Winter Wheat	Pasture & Hay	Soybeans	Cotton	Sunflower	Peanuts
AL	--	63.0	21.0	96.0	96.0	91.0	91.0	--	19.0	6.3	94.0	97.0	--	96.0
AZ	11.6	--	--	95.0	95.0	50.0	50.0	--	79.0	1.4	--	99.0	--	--
AR	7.6	63.0	21.0	96.0	96.0	91.0	91.0	--	19.0	6.3	92.0	100.0	--	--
CA	11.6	63.0	21.0	95.0	95.0	50.0	50.0	--	79.0	1.4	--	86.0	--	--
CO	11.6	63.0	21.0	95.0	95.0	50.0	50.0	71.0	25.0	1.4	--	--	--	--
CT	4.4	--	--	95.0	95.0	--	--	--	--	0.2	--	--	--	--
DE	7.2	--	--	97.0	97.0	--	--	--	29.5	5.6	98.0	--	--	--
FL	--	--	--	97.0	97.0	--	--	--	29.5	5.6	91.0	99.0	--	96.0
GA	--	63.0	21.0	97.0	97.0	73.0	73.0	--	29.5	5.6	93.0	99.0	--	96.0
ID	11.6	63.0	21.0	95.0	95.0	--	--	87.0	88.0	1.4	--	--	--	--
IL	2.0	63.0	21.0	99.0	99.0	99.0	99.0	--	6.0	3.0	99.0	--	--	--
IN	2.0	63.0	21.0	97.0	97.0	--	--	--	9.0	3.0	98.0	--	--	--
IA	2.0	63.0	21.0	100.0	100.0	--	--	--	6.0	3.8	99.0	--	--	--
KS	2.0	63.0	21.0	95.0	95.0	82.0	82.0	--	35.0	3.8	95.0	90.0	--	--
KY	7.6	63.0	21.0	96.0	96.0	91.0	91.0	--	9.0	6.3	93.0	--	--	--
LA	7.6	--	--	96.0	96.0	91.0	91.0	--	19.0	6.3	92.0	98.0	--	--
ME	4.4	63.0	21.0	95.0	95.0	--	--	--	--	0.2	--	--	--	--
MD	3.2	60.0	40.0	98.0	98.0	--	--	--	60.0	5.6	98.0	--	--	--
MA	4.4	--	--	95.0	95.0	--	--	--	24.5	0.2	--	--	--	--
MI	20.0	14.0	14.0	98.0	100.0	--	--	--	20.0	6.3	100.0	--	--	--
MN	2.0	90.0	60.0	97.0	96.0	--	--	97.0	90.0	1.0	100.0	--	90.0	--
MS	--	--	--	96.0	96.0	91.0	91.0	--	19.0	6.3	95.0	99.0	--	--
MO	2.0	63.0	21.0	98.0	98.0	82.0	82.0	--	4.0	3.8	92.0	90.0	--	--
MT	2.3	65.0	41.0	38.0	38.0	--	--	75.0	75.0	1.3	--	--	--	--
NE	2.0	63.0	21.0	95.0	95.0	82.0	82.0	--	25.0	3.8	97.0	--	--	--
NV	11.6	--	--	--	--	--	--	71.0	79.0	1.4	--	--	--	--
NH	4.4	--	--	95.0	95.0	--	--	--	--	0.2	--	--	--	--
NJ	4.4	63.0	21.0	95.0	95.0	--	--	--	27.5	0.2	98.0	--	--	--
NM	11.6	--	--	95.0	95.0	50.0	50.0	--	79.0	1.4	--	99.0	--	96.0
NY	4.4	63.0	21.0	95.0	95.0	--	--	--	29.5	0.2	--	--	--	--
NC	7.2	63.0	21.0	97.0	97.0	73.0	73.0	--	29.5	5.6	88.0	98.0	--	96.0

Table A.1. continued

State	Alfalfa	Barley	Oats	Corn Grain	Corn Silage	Sorghum Grain	Sorghum Silage	Spring Wheat	Winter Wheat	Pasture & Hay	Soybeans	Cotton	Sunflower	Peanuts
ND	2.0	63.0	21.0	95.0	95.0	--	--	80.0	83.0	3.8	95.0	--	78.0	--
OH	2.0	63.0	21.0	98.0	98.0	--	--	--	7.0	3.0	94.0	--	--	--
OK	22.8	63.0	21.0	80.0	80.0	56.0	56.0	--	48.0	6.5	67.0	90.0	--	96.0
OR	11.6	63.0	21.0	95.0	95.0	--	--	71.0	100.0	1.4	--	--	--	--
PA	4.4	63.0	--	95.0	95.0	--	--	--	29.5	--	98.0	--	--	--
RI	4.4	--	--	97.0	97.0	--	--	--	--	0.2	--	--	--	--
SC	7.2	63.0	21.0	97.0	97.0	73.0	73.0	--	29.5	5.6	91.0	100.0	--	96.0
SD	2.0	85.0	85.0	82.0	82.0	82.0	82.0	84.0	83.0	3.8	95.0	--	78.0	--
TN	7.6	--	--	96.0	96.0	91.0	91.0	--	19.0	6.3	93.0	100.0	--	--
TX	22.8	63.0	21.0	90.0	90.0	56.0	56.0	--	23.0	6.5	67.0	95.0	78.0	96.0
UT	11.6	40.0	20.0	95.0	50.0	--	--	20.0	45.0	1.4	--	--	--	--
VT	4.4	--	--	95.0	95.0	--	--	--	--	0.2	--	--	--	--
VA	7.2	63.0	21.0	97.0	97.0	--	--	--	29.5	5.6	91.0	98.0	--	96.0
WA	11.6	63.0	21.0	95.0	95.0	--	--	71.0	91.0	1.4	--	--	--	--
WV	7.2	63.0	21.0	97.0	97.0	--	--	--	29.5	5.6	--	--	--	--
WI	2.0	63.0	21.0	92.0	92.0	--	--	71.0	6.0	3.0	97.0	--	--	--
WY	11.6	63.0	21.0	95.0	95.0	--	--	71.0	4.0	1.4	--	--	--	--

Note: -- indicates crop was not grown.

Table A.2. Percentage of planted acres treated with insecticides

State	Alfalfa	Barley	Oats	Corn Grain	Corn Silage	Sorghum Grain	Sorghum Silage	Spring Wheat	Winter Wheat	Pasture & Hay	Soybeans	Cotton	Sunflower	Peanuts
AL	--	3.0	0.5	34.0	34.0	12.0	12.0	--	3.5	0.4	14.0	70.0	--	59.0
AZ	12.5	--	--	34.0	34.0	12.0	12.0	--	3.5	0.4	--	65.0	--	--
AR	12.5	3.0	0.5	34.0	34.0	12.0	12.0	--	3.5	0.4	14.0	75.0	--	--
CA	12.5	3.0	0.5	34.0	34.0	12.0	12.0	--	6.0	0.4	--	83.0	--	--
CO	12.5	3.0	0.5	59.0	59.0	12.0	12.0	2.9	14.0	0.4	--	--	--	--
CT	12.5	--	--	34.0	34.0	--	--	--	--	0.4	--	--	--	--
DE	12.5	--	--	34.0	34.0	--	--	--	3.5	0.4	14.0	--	--	--
FL	--	--	--	34.0	34.0	--	--	--	3.5	0.4	14.0	70.0	--	59.0
GA	--	3.0	0.5	34.0	34.0	12.0	12.0	--	3.5	0.4	4.0	70.0	--	59.0
ID	12.5	3.0	0.5	34.0	34.0	--	--	3.4	1.0	0.4	--	--	--	--
IL	12.5	3.0	0.5	39.0	39.0	12.0	12.0	--	2.0	0.4	30.0	--	--	--
IN	12.5	3.0	0.5	34.0	34.0	--	--	--	3.5	0.4	12.0	--	--	--
IA	12.5	3.0	0.5	29.0	29.0	--	--	--	3.5	0.4	4.0	--	--	--
KS	12.5	3.0	0.5	59.0	59.0	12.0	12.0	--	3.6	0.4	14.0	70.0	--	--
KY	12.5	3.0	0.5	32.0	32.0	12.0	12.0	--	3.5	0.4	1.0	--	--	--
LA	12.5	--	--	34.0	34.0	12.0	12.0	--	3.5	0.4	2.0	85.0	--	--
ME	12.5	3.0	0.5	34.0	34.0	--	--	--	--	0.4	--	--	--	--
MD	60.0	13.0	0.5	33.0	5.0	--	--	--	20.0	3.0	25.0	--	--	--
MA	60.0	--	--	34.0	34.0	--	--	--	3.5	0.4	--	--	--	--
MI	66.0	14.0	0.5	40.0	53.0	--	--	--	14.0	4.0	27.0	--	--	--
MN	20.0	14.0	0.5	20.0	20.0	--	--	2.0	2.0	0.4	2.0	--	25.0	--
MS	--	--	--	34.0	34.0	12.0	12.0	--	3.5	0.4	14.0	95.0	--	--
MO	12.5	3.0	0.5	28.0	28.0	12.0	12.0	--	3.5	0.4	35.0	70.0	--	--
MT	8.8	13.9	13.4	28.0	28.0	--	--	11.2	11.2	6.4	--	--	--	--
NE	12.5	3.0	0.5	55.0	55.0	12.0	12.0	--	0.6	0.4	1.0	--	--	--
NV	12.5	--	--	--	--	--	--	3.4	3.5	0.4	--	--	--	--
NH	12.5	--	--	34.0	34.0	--	--	--	--	0.4	--	--	--	--
NJ	12.5	3.0	0.5	34.0	34.0	--	--	--	3.5	0.4	14.0	--	--	--
NM	12.5	--	--	34.0	34.0	12.0	12.0	--	3.5	0.4	--	70.0	--	59.0
NY	12.5	3.0	--	27.0	27.0	--	--	--	--	--	--	--	--	--

Table A.2. continued

State	Alfalfa	Barley	Oats	Corn Grain	Corn Silage	Sorghum Grain	Sorghum Silage	Spring Wheat	Winter Wheat	Pasture & Hay	Soybeans	Cotton	Sunflower	Peanuts
NC	78.0	25.0	26.0	40.0	40.0	12.0	12.0	--	3.5	10.0	45.0	94.0	--	59.0
ND	12.5	3.0	0.5	34.0	34.0	--	--	1.9	1.9	0.4	14.0	--	9.0	--
OH	12.5	3.0	0.5	40.0	40.0	--	--	--	3.5	0.4	4.0	--	--	--
OK	12.5	3.0	0.5	34.0	12.0	12.0	--	6.0	0.4	14.0	70.0	--	--	59.0
OR	12.5	3.0	0.5	34.0	34.0	--	--	3.4	5.0	0.4	--	--	--	--
PA	12.5	3.0	--	40.0	40.0	--	--	--	3.5	--	14.0	--	--	--
RI	12.5	--	--	34.0	34.0	--	--	--	--	0.4	--	--	--	--
SC	12.5	3.0	0.5	34.0	34.0	12.0	12.0	--	3.5	0.4	14.0	70.0	--	59.0
SD	70.0	8.0	8.0	19.0	19.0	10.0	10.0	3.0	5.0	0.5	25.0	--	90.0	--
TN	70.0	--	--	34.0	34.0	12.0	12.0	--	3.5	0.4	14.0	70.0	--	--
TX	70.0	3.0	0.5	51.0	51.0	12.0	12.0	--	16.0	0.4	14.0	60.0	9.0	59.0
UT	10.0	10.0	0.5	90.0	90.0	--	--	10.0	10.0	0.4	--	--	--	--
VT	10.0	--	--	34.0	34.0	--	--	--	--	0.4	--	--	--	--
VA	10.0	3.0	0.5	34.0	34.0	--	--	--	3.5	0.4	14.0	70.0	--	59.0
WA	10.0	3.0	0.5	34.0	34.0	--	--	7.7	7.7	0.4	--	--	--	--
WV	10.0	3.0	0.5	34.0	34.0	--	--	--	3.5	0.4	--	--	--	--
WI	10.0	3.0	0.5	43.0	43.0	--	--	3.4	3.5	0.4	14.0	--	--	--
WY	10.0	3.0	0.5	34.0	34.0	--	--	3.4	3.5	0.4	--	--	--	--

Note: -- indicates crop was not grown

Table A.3. Average herbicide treatments per acre by crop and state

State	Alf/Hay	Corn	Cotton	Peanuts	Small Grains	Sorghum	Soybean	Sunflower	Spring Wheat	Winter Wheat
AL	1.34	1.52	3.16	3.5	1.16	1.10	1.63	--	--	1.11
AZ	1.34	1.18	1.40	--	1.21	1.00	--	--	--	1.11
AR	1.34	1.52	2.99	--	1.16	1.10	1.46	--	--	1.00
CA	1.34	1.18	1.27	--	1.21	1.00	--	--	--	1.07
CO	1.34	1.18	--	--	1.21	1.00	--	--	1.09	1.00
CT	1.34	1.58	--	--	--	--	--	--	--	--
DE	1.34	1.58	--	--	--	--	1.32	--	--	1.01
FL	1.34	1.52	3.16	3.5	--	--	1.63	--	--	1.11
GA	1.34	1.52	3.16	3.5	1.16	1.10	1.63	--	--	1.11
ID	1.34	1.18	--	--	1.21	--	--	--	1.26	1.18
IL	1.34	1.28	--	--	1.11	1.31	1.45	--	--	1.20
IN	1.34	1.13	--	--	1.11	--	1.24	--	--	1.20
IA	1.34	1.51	--	--	1.11	--	1.42	--	--	1.20
KS	1.34	1.23	1.28	--	1.16	1.00	1.42	--	--	1.04
KY	1.34	1.52	--	--	1.16	1.10	1.45	--	--	1.20
LA	1.34	1.52	3.16	--	1.16	1.10	1.56	--	--	1.11
ME	1.34	1.58	--	--	1.16	--	--	--	--	--
MD	1.34	1.58	--	--	1.16	--	1.32	1.5	--	1.00
MA	1.34	1.58	--	--	--	--	--	--	--	1.00
MI	1.34	1.22	--	--	1.11	--	1.24	--	--	1.20
MN	1.34	1.57	--	--	1.11	--	1.59	1.5	1.23	1.20
MS	1.34	1.52	3.33	--	1.16	1.31	1.81	--	--	1.20
MD	1.34	1.09	3.33	--	1.11	1.10	1.42	--	--	1.20
MT	1.34	1.18	--	--	1.21	--	--	--	1.09	1.04
NE	1.34	1.13	--	--	--	1.20	1.24	--	--	1.00
NV	1.34	--	--	--	1.21	--	--	--	1.90	1.04
NH	1.34	1.58	--	--	--	--	--	--	--	--
NJ	1.34	1.58	--	--	1.16	--	1.32	1.5	--	1.00
NM	1.34	1.18	1.40	3.5	1.21	1.00	--	--	--	1.04
NY	1.34	1.58	--	--	1.16	--	--	--	--	1.00
NC	1.34	1.58	1.28	3.5	1.16	1.10	1.32	1.5	--	1.04
ND	1.34	1.23	--	--	1.16	--	1.24	--	1.22	1.04
OH	1.34	1.25	--	--	1.11	--	1.19	1.5	--	1.20
OK	1.34	1.52	1.28	3.5	1.16	1.10	1.46	--	--	1.03
OR	1.34	1.18	--	--	1.21	--	--	--	1.90	1.45
PA	1.34	1.58	--	--	1.16	--	1.19	--	--	1.04
RI	1.34	1.58	--	--	--	--	--	--	--	--

Table A.3. continued

State	Alf/Hay	Corn	Cotton	Peanuts	Small Grains	Sorghum	Soybean	Sunflower	Spring Wheat	Winter Wheat
SC	1.34	1.52	1.28	3.5	1.16	1.10	1.76	--	--	1.11
SD	1.34	1.39	--	--	1.16	1.31	1.24	1.5	1.06	1.20
TN	1.34	1.52	3.33	3.5	1.16	1.10	1.89	--	--	1.11
TX	1.34	1.52	1.28	--	1.16	1.10	1.76	1.5	--	1.11
UT	1.34	1.18	--	--	1.21	--	--	--	1.09	1.04
VT	1.34	1.58	--	--	--	--	--	--	--	--
VA	1.34	1.58	1.29	3.5	1.16	--	1.32	--	--	1.04
WA	1.34	1.18	--	--	1.21	--	--	--	1.90	1.12
WV	1.34	1.58	--	--	1.16	--	--	--	--	1.04
WI	1.34	1.19	--	--	1.11	--	1.59	--	1.23	1.20
WY	1.34	1.18	--	--	1.21	--	--	--	1.09	1.04

SOURCE: 1. Agricultural Resources: Situation and Outlook Report AR-13. Feb 1989. ERS, USDA.
2. Agricultural Resources: Situation and Outlook Report AR-9. Jan 1988. ERS, USDA.
3. *Pesticide Use on Selected Crops, Aggregate Data, 1977-80.* Ag. Information Bulletin No. 494. June 1985. ERS, USDA
4. *Field Crop Pests: Farmers Report--the Severity and Potential.* Ag. Information Bulletin No. 487 Feb. 1985. ERS, USDA.

Note: -- indicates crop was not grown.

Table A.4. Average insecticide treatments per acre by crop and USDA region

Region	Alf/Hay	Corn	Cotton	Peanuts	Small Grains	Sorghum	Soybeans	Sunflower	Wheat
Appln	2.01	1.12	4.60	4.6	1.65	1.19	1.50	1.3	1.21
C. Belt	2.01	1.08	4.60	--	1.76	1.22	1.30	1.3	1.29
Delta	2.01	1.12	5.60	--	1.76	1.22	1.50	--	1.29
Lake	2.01	1.01	--	--	1.76	--	1.30	--	1.29
Mountain	2.01	1.89	4.60	--	1.65	1.19	1.00	--	1.06
N. East	2.01	1.03	--	--	1.65	1.19	1.30	1.3	1.21
N. Plns	2.01	1.77	--	--	1.65	1.19	1.00	1.3	1.21
Pacific	2.01	1.89	3.15	--	1.16	1.00	1.30	--	1.06
S. East	2.01	1.23	9.20	4.4	1.65	1.19	1.76	--	1.21
S. Plns	2.01	1.89	4.00	4.0	1.65	1.19	1.30	1.3	1.21

SOURCES: Agricultural Resources: Situation and Outlook Report A-R13. 1988. ERS, USDA.
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Note: -- indicates crop was not grown.

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