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THE ROLE OF AGRICULTURAL PRACTICES IN FUGITIVE DUST EMISSIONS

FINAL REPORT
June 8, 1981

MRI Project No. 4809-L

For

California Air Resources Board
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ABSTRACT

For the San Joaquin Valley, the Sacramento Valley, and the Imperial Valley, Midwest Research Institute quantified the impact of agricultural operations on fugitive dust emissions. Thirteen tests were performed in the spring of 1980 to quantify emission factors from discing, land planing, and vehicles traveling on unpaved farm roads. Six tests were performed in the fall of 1980 to quantify emission factors from sugar beet harvesting.

Since fugitive emissions from a given operation can vary depending on physical properties of the soil or equipment, and depending on climate, predictive equations were developed to relate total, inhalable and fine particulate emission factors to important independent variables. Significant relationships were determined between the emission factor and the soil silt content.

An inhalable particulate emission inventory performed for the three valleys showed that in 1978, agricultural operations produced 148,000 Mg/year of fugitive dust less than 15 μm in aerodynamic diameter. Field crops yielded the most significant emissions while soil preparation was the most significant category of operations.

Two categories of control techniques were suggested: (a) those that included control equipment to be added to the farm implement and (b) those that included operational modifications. Control efficiencies and potential emission reductions were estimated for these control techniques.

ACKNOWLEDGMENTS

This study was performed by Midwest Research Institute (MRI) over a period extending from July 1979 to April 1981. The project leader and primary author of this report was Mr. Thomas A. Cuscino, Jr. He was assisted in the writing of this report by Mr. John S. Kinsey and Mr. Richard Hackney.

The emission factor quantification portion of this work was directed by Mr. Russel Bohn of MRI. Other members of the MRI field sampling team were Mr. David Griffin, Mr. Thomas Walker, and Mr. Frank Pendleton.

Some preliminary visibility impact measurements were collected by Mr. Ward Saunders and Ms. Susan Knauss of Meteorology Research, Inc. and Environmental Systems and Services, respectively.

Valuable assistance on the identification of agricultural operations and control techniques was provided by KVB, Inc. under the direction of Mr. R. Michael Roberts with assistance from Mr. Michael J. Berlant and Mr. Douglas Dale.

Finally, preparation of a glossary of agricultural terms was performed by Professor Monte McKibbon of the Orange Coast College in Santa Ana, California.

This report was submitted in fulfillment of Contract No. A8-125-31 by MRI under the sponsorship of the California Air Resources Board (CARB). Dr. Robert Grant of CARB monitored project performance. Work was completed as of March 31, 1981.

Approved for:

MIDWEST RESEARCH INSTITUTE

Andrew Trenkotin

for M. P. Schrag, Director
Environmental Systems Department

June 8, 1981

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SUMMARY AND CONCLUSIONS

Fugitive dust from agricultural operations is suspected of contributing significantly to the nonattainment status of many agricultural counties in California. Such agricultural operations include (a) plowing, (b) discing, (c) fertilizing, (d) applying herbicides and insecticides, (e) bedding, (f) flattening and firming beds, (g) planting, (h) cultivating, and (i) harvesting. These operations can be generically classified as soil preparation, soil maintenance, and crop harvesting operations.

Since nearly all 58 counties in California have cropland within their boundaries, and since the mix of crops and cultural practices varies highly, only the major agricultural areas were selected for this study. The following agricultural valleys and counties within each valley were selected:

- San Joaquin Valley (Fresno, Kern, Tulare, Kings, San Joaquin, Merced, Madera, and Stanislaus counties).

- Sacramento Valley (Solano, Sacramento, Yolo, Colusa, Glenn, Sutter, Butte, Yuba, and Tehama counties).

- Imperial Valley (Imperial County).

These 18 counties comprise 76% of the total cropland in California.

The objectives of this study were:

1. Identify those agricultural operations likely to produce large quantities of fugitive dust emissions.

2. Quantify the emissions from these operations in terms of total particulates and by inhalable particulate and fine particulate size ranges. Total particulate includes all particle sizes; inhalable particulate includes particles less than 15 μm in an aerodynamic diameter, and fine particulate includes particles less than 2.5 μm in aerodynamic diameter.

3. Evaluate the effects of changes in soil moisture and other factors on fugitive dust emissions and the influence of dust levels on visibility at varying distances downwind of the sources.

4. Define potential changes in agricultural practices or equipment which would reduce inhalable particulate levels and would improve visibility.

To determine what agricultural operations were likely to produce large quantities of emissions, it was necessary to determine the types and frequencies of the operations by crops and by valley. Data were gathered from farm advisors in each county, from county crop reports, and from Crop Cost to Produce reports. Finally, agricultural specialists at the University of California-Riverside and Davis campuses identified typical agricultural practices in each of the valleys by crop. These data were summarized in tables which display by crop and by valley the area of land devoted to the crop and the type and frequency of agricultural operations typically expected.

The quantification of air quality impact from agricultural operations required the measurement of emission factors and visibility impact from the most significant sources. Thirteen tests to measure emission factors and five to measure visibility impact from soil discing and planing were conducted in April of 1980. Six tests to measure emission factors from leaf beating and sugar beet digging were conducted in October 1980. The exposure profiling technique developed by Midwest Research Institute (MRI) was used to collect the data necessary to calculate emission factors. Three emission factors per test representing total particulate, inhalable particulate, and fine particulate were calculated.

Fugitive emission generation is highly dependent on climate, soil properties, and equipment characteristics. Consequently, any given set of emission factor measurements will probably not be applicable to a geographic or climatic setting different from the measured setting. The most reliable method to assure usefulness from fugitive emission measurements, therefore, is to quantify the independent variables along with the dependent variables and to develop a predictive equation. MRI developed predictive equations for soil preparation emission factors applicable to four different types of operations as measured over six sites in two states. The operations were discing, land planing, sweep plowing, and chisel plowing. The sites included two in California and four in Kansas. The data for Kansas were collected under a prior EPA study (EPA-450/3-74-037, "Development of Emission Factors for Fugitive Dust Sources, 1974).

Control techniques to minimize fugitive dust from agricultural operations were identified. These control techniques can take the form of separate, additional equipment or can consist simply of operational modifications. One piece of additional equipment which has promise is the Spinning Cup Fog Thrower (SCFT). This device generates an electrically charged fog that attracts the dust particles to larger water droplets, which then settle to the ground. This device has promise mainly because it requires a minimal amount of water.

The following are the main conclusions gleaned from this study:

1. California has more agricultural land than any state in the nation. California has a total land area of 406,000 km^2 (100.2 million acres) of which approximately 135,000 km^2 (33.3 million acres) was classified as agricultural as of December 1977. Of this agricultural land, 36,000 km^2 (9.1 million acres) was devoted to the following crops:

Crop category	km^2	(acres)
Vegetables and melons	3,630	(896,000)
Fruits and nuts	6,780	(1,670,000)
Field crops	26,500	(6,530,000)

Field crops constitute 71.8% of the cropland in the state.

2. The three agricultural valleys upon which this study focused accounted for 76% of the cropland in the state.

3. The dependence of the measured emission factors on soil moisture content produced negligible improvement in the predictive equations. This phenomenon has also been observed in wind erosion measurements when conditions are far from the moisture threshold.

4. Emissions were predicted quite satisfactorily by simply correlating the emission factor with a soil sizing parameter called the silt content. The following predictive equations for soil preparation operations were developed:

$$EF_{TP} = 538(s)^{0.6}$$

$$EF_{IP} = 0.25 \times 538 \times (s)^{0.6} = 135(s)^{0.6}$$

$$EF_{FP} = 0.1 \times 538 \times (s)^{0.6} = 53.8(s)^{0.6}$$

where EF = emission factor (kg/km^2)
TP = total particulate
IP = inhalable particulate
FP = fine particulate
s = soil silt content (%)

5. The TP emission factor equation for soil preparation has an overall correlation coefficient of $r = 0.941$, which means that 88% of the variation in EF_{TP} can be explained by the variation in silt content. This relationship is more than 99% significant; that is, only one time in 100 could this value occur by chance. The one-sigma precision factor is 1.29, which means that 68% of the predicted values lie within a factor of 1.29 of the measured value. The two-sigma precision factor is 1.67, which means that 95% of the predicted values lie within a factor of 1.67 of the measured values.

6. The one-sigma precision factor for the IP emission factor equation is 2.17; the two-sigma precision factor is 4.7. The one-sigma precision factor for the FP emission factor equation is 2.33; the two-sigma, 5.42.

7. There were not enough tests to develop a predictive equation for harvesting. The average IP emission factor for the six tests on the harvesting of sugar beets was 740 kg/km^2 (6.6 lb/acre). This represents harvesting which requires leaf beating and digging operations. Actually, the

average emission factor for leaf beating was nearly the same as the average emission factor for sugar beet digging. The emission factor for harvesting by swathing or combining is still uncertain. Testing by another research organization has suggested that the harvesting of field crops like cotton, wheat, and grain sorghum, which require no digging, may be insignificant in comparison to harvesting operations which require digging.

8. The Spinning Cup Fog Thrower (SCFT) has potential for use in the control of agricultural fugitive emissions. A large farm implement would probably require a minimum of three SCFT's and would require 57 to 114 ℓ water/hr (15 to 30 gal. water/hr). Dust control in the range of 65 to 75% has been suggested as possible, but the value is highly speculative since it has not been tested in an agricultural setting.

9. Wind erosion control has been thoroughly studied, especially in the midwestern states, and many control techniques are available. The techniques which might be most useful in California are: (a) vegetable cover; (b) improved tillage practices; (c) windbreaks (trees, crops, and artificial devices can act as barriers to the wind); and (d) closer crop row spacing.

10. Many operational modifications have potential to reduce emissions. These modifications include (a) the punch planter; (b) the low energy crop production system with wide span equipment; (c) the plug planter; (d) herbicides as a replacement for cultivation or tillage; (e) sprinkler irrigation to minimize land planing; (f) the laser-directed land plane to minimize leveling operations; (g) listing of tomato fields in the fall to eliminate the spring harrowing and rolling; (h) development of high quality, long-lasting alfalfa to reduce soil preparation operations; (i) double-cropping of corn with wheat or other small grain to avoid having to stubble disc or plow twice per year; and (j) aerial seeding to avoid the soil disturbance of ground seeding.

11. Based on uncontrolled IP emission factors, soil preparation is the largest agricultural source of emissions in the three valleys, comprising 44.9% of the total emissions in the San Joaquin Valley, 53.3% of the total in the Sacramento Valley, and 55.7% of the total in the Imperial Valley.

12. The San Joaquin Valley yields the largest portion of agricultural emissions from the three valleys combined, with 62.2%; 29.1% originates in the Sacramento Valley; and 8.7% originates in the Imperial Valley.

13. Field crop operations yield the largest portion of emissions in the three valleys, comprising 77% of the total in the San Joaquin Valley, 86% in the Sacramento Valley, and 87.8% in the Imperial Valley.

RECOMMENDATIONS

MRI makes the following recommendations:

1. The emission factors from uncontrolled nondigging harvesting operations such as combining, swathing, and raking should be quantified. Since this current study was the first to focus strongly on the testing of emissions from agricultural operations, only those operations thought to be most important in terms of emissions were tested. But, given the vast amount of nondigging harvesting that is occurring in California, these operations also merit testing.

2. The efficiency of any control which is implemented must be substantiated by testing. This testing should consist of a combination of before and after control tests.

3. The precision of the predictive equations for the inhalable particulate and fine particulate emission factors for soil preparation operations should be improved. This can be accomplished by expanding the data base via more tests.

4. Controlled and uncontrolled tests should be performed, where possible, using the exposure profiling technique. This technique provides the most direct measurement of the desired variable, i.e., the emission factor.

5. Future emission inventories in California which use the emission factor data in this report should use inhalable particulate or fine particulate emission factors but not the total particulate emission factors. The total particulate emission factors are very accurate, but do not represent the air quality impact of agriculture even at the boundaries of the farms let alone beyond those boundaries, since many of the larger particles settle rapidly.

SECTION 1.0

INTRODUCTION

The effort in California to control air pollution has focused primarily on emissions discharged from stacks, ducts, or flues, and carried to the point of discharge in confined flow streams. Control strategies have been based on the assumption that the primary air quality impact of industrial operations resulted from the discharge of air pollution from conventional ducted sources.

However, failure to achieve the air quality improvements anticipated from the control of ducted emissions has spurred a detailed reexamination of the air pollution problem. Evidence is mounting which indicates that fugitive, nonducted, emissions contribute substantially to air pollution in both urban and rural areas of the country. Suspended particulates and volatile organics are two pollutant categories of widespread nonurban fugitive emissions.

Fugitive dust sources can be defined as sources from which emissions are generated by the forces of machinery or wind acting on exposed aggregate materials. Many agricultural operations are major sources of rural fugitive dust, including soil or crop operations, vehicular travel on unpaved farm roads, and wind erosion of farm soil. Agriculture-related operations such as stubble burning and pesticide application are not included in this study.

California has more agricultural land than any other state. Of California's total land area of 406,000 km^2 (100.2 million acres), approximately 135,000 km^2 (33.3 million acres) was classified as agricultural as of December 1977. In 1977, 36,900 km^2 (9.1 million acres) of the following crops were harvested:

	km^2	(Acres)
Vegetables and melons	3,630	(896,000)
Fruits and nuts	6,730	(1,670,000)
Field crops	26,500	(6,530,000)

California is comprised of 58 counties, shown in Figure 1 and identified in Table 1. Table 1 also shows harvested area on a county-by-county basis and ranks the counties based on harvested area. Graphical presentations of the state's agricultural areas are shown in Figures 2 and 3. Many of the total suspended particulate (TSP) nonattainment areas include major agricultural areas.

Figure 1. Identification of California counties.

TABLE 1. RANKING OF COUNTIES BY HARVESTED CROP AREA[a]

County ID no. (see Fig. 1)	County	Harvested cropland km^2 (acres)	Rank by harvested area
1	Del Norte	13.0 (3,220)	51
2	Siskiyou	761 (188,000)	18
3	Modoc	441 (109,000)	22
4	Humboldt	69.3 (17,100)	42
5	Trinity	4.00 (987)	56
6	Shasta	100 (24,700)	39
7	Lassen	161 (39,800)	32
8	Tehama	277 (68,300)	26
9	Plumas	37.3 (9,220)	44
10	Mendocino	97.2 (24,000)	40
11	Glenn	903 (223,000)	15
12	Butte	859 (212,000)	16
13	Sierra	26.0 (6,430)	45
14	Lake	103 (25,400)	38
15	Colusa	988 (244,000)	12
16	Sutter	1,000 (248,000)	11
17	Yuba	147 (36,400)	33
18	Nevada	4.94 (1,220)	54
19	Placer	133 (32,900)	35
20	El Dorado	18.9 (4,660)	46
21	Sonoma	344 (84,900)	24
22	Marin	17.0 (4,200)	47
23	Napa	117 (28,900)	36
24	Yolo	1,490 (369,000)	7
25	Solano	624 (154,000)	20
26	Sacramento	575 (142,000)	21
27	Amador	12.8 (3,160)	52
28	Alpine	0	57
29	Contra Costa	193 (47,600)	31
30	San Joaquin	1,960 (483,000)	4
31	Calaveras	15.1 (3,720)	48
32	Tuolumne	4.74 (1,170)	55
33	Mono	13.2 (3,270)	50
34	San Francisco	0	58
35	San Mateo	73.7 (18,200)	41

(continued)

TABLE 1. (continued)

County ID no. (see fig. 1)	County	Harvested cropland km^2 (acres)	Rank by harvested area
36	Alameda	113 (27,800)	37
37	Stanislaus	1,140 (281,000)	9
38	Mariposa	7.53 (1,860)	53
39	Santa Cruz	68.9 (17,000)	43
40	Santa Clara	195 (48,200)	30
41	Merced	1,320 (326,000)	8
42	Madera	919 (227,000)	14
43	Monterey	1,030 (255,000)	10
44	San Benito	212 (52,400)	29
45	Fresno	4,460 (1,100,000)	1
46	Inyo	13.6 (3,360)	49
47	Kings	1,840 (454,000)	5
48	Tulare	2,430 (600,000)	3
49	San Luis Obispo	765 (189,000)	17
50	Kern	3,160 (781,000)	2
51	San Bernadino	217 (53,700)	28
52	Santa Barbara	378 (93,400)	23
53	Ventura	745 (184,000)	19
54	Los Angeles	262 (64,800)	27
55	Orange	143 (35,200)	34
56	Riverside	944 (233,000)	13
57	San Diego	287 (70,800)	25
58	Imperial	1,810 (448,000)	6
	Total	34,100 (8,410,000)	

[a] Based on 1974 data.

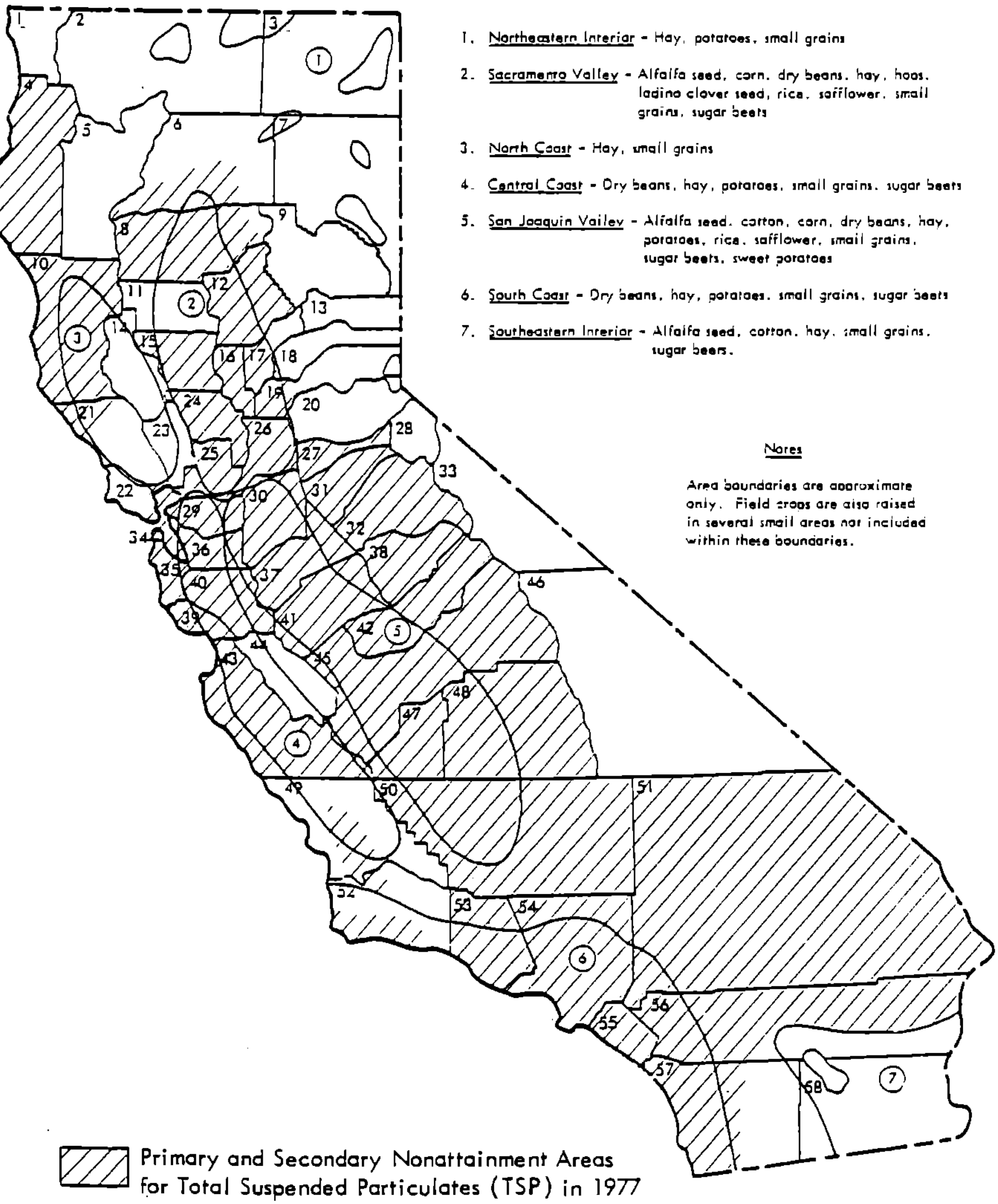


Figure 2. California's major field crop areas and important field crops of each area.

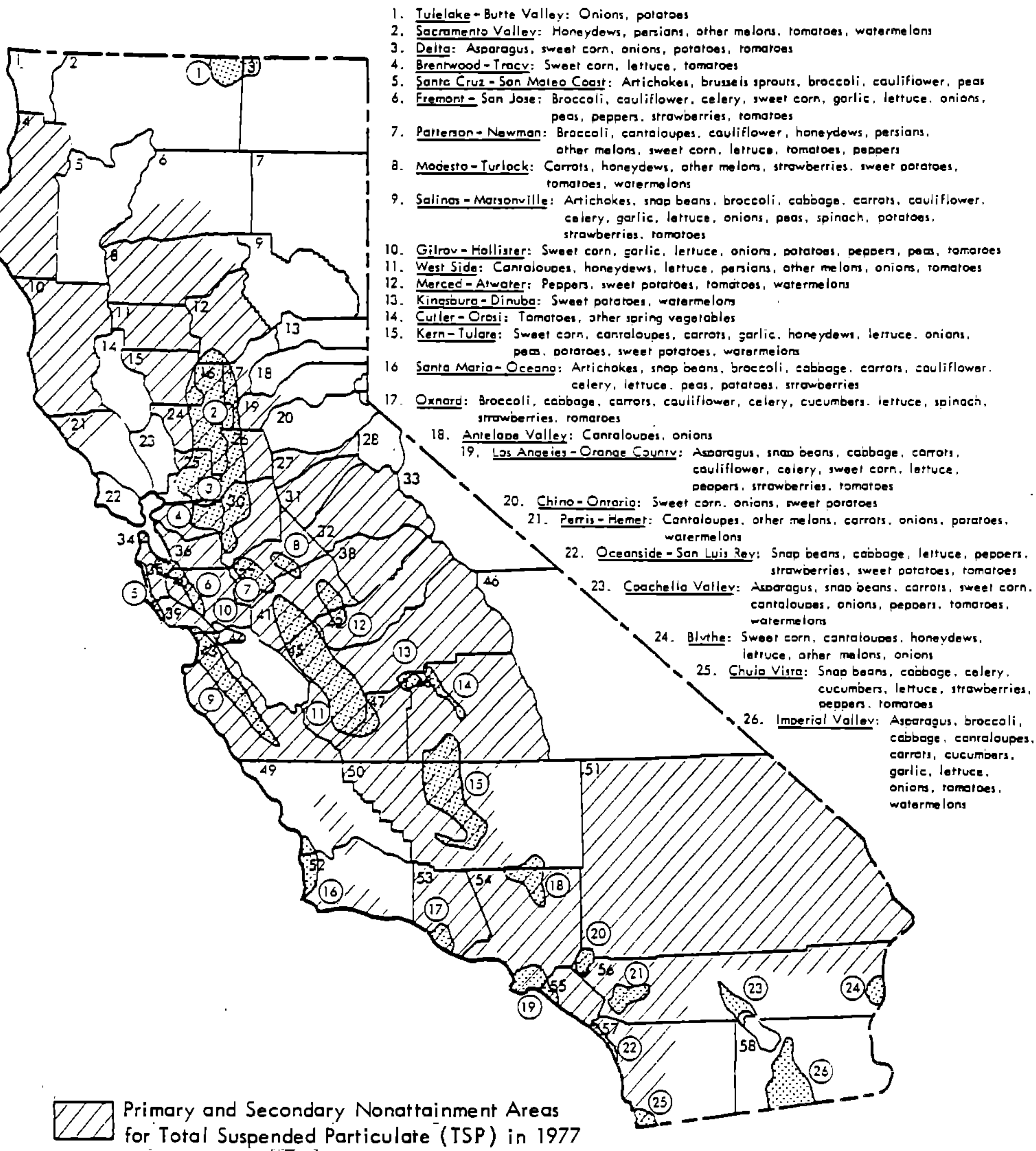


Figure 3. California's major fresh market vegetable, melon and potato producing districts.

Generic classification of agricultural operations is as follows: plow, disc, fertilizer, control weeds and insects, bed, flatten and firm bed, plant, cultivate, and harvest. Depending on the type of crop and whether it is a row or close-grown crop, the number of times one or more of the above operations is performed may vary from not at all to several repetitions.

1.1 PROJECT OBJECTIVES

The need for this study arose for several reasons: (a) the vastness of agricultural land in California, (b) the potential for generating large amounts of agricultural fugitive dust, and (c) the fact that many TSP nonattainment areas include major agricultural valleys. Against this backdrop, the following project objectives were developed:

1. Identify those agricultural operations likely to produce large quantities of fugitive dust emissions.

2. Quantify the emissions from these operations in terms of total particulates (TP) and by size range.

3. Evaluate the effects of changes in soil moisture and other factors on fugitive dust emissions and the influence of dust levels on visibility at varying distances downwind of the sources.

4. Define potential changes in agricultural practices or equipment which would reduce inhalable particulate (IP) levels and would improve visibility.

1.2 REPORT STRUCTURE

The body of this report contains: (a) a survey of agricultural operations and equipment, (b) methodology and results of emission factor quantification for agricultural operations, (c) presentation of predictive emission factor equations, and (d) evaluation of promising modifications to agricultural practice that should minimize fugitive dust.

A small amount of visibility impact data were collected by Meteorology Research, Inc. during this study. Since there were not enough data to draw definitive conclusions, the test methodology and results are not included in this report.

In this report, the short ton (2,000 lb) is abbreviated as T. Also, numbers are recorded to three significant figures; therefore, columns of numbers may not add to the exact total listed. Rounding to three significant figures produces a rounding error not greater than 0.5%.

Since there are many abbreviations used in this report, an alphabetized list of abbreviations is provided in the back of the report.

SECTION 2.0

SURVEY OF AGRICULTURAL OPERATIONS AND EQUIPMENT

2.1 IDENTIFICATION OF SIGNIFICANT AGRICULTURAL AREAS

In order to determine which agricultural operations produce the most fugitive emissions, the type and number of operations, by crop, and the area over which they occur, were defined. Since this was a large endeavor in itself, the scope of the project was reduced by MRI and California Air Resource Board (CARB) personnel from all 58 counties in the state to the 18 counties shown in Figure 4. These counties comprise the San Joaquin, Sacramento, and Imperial Valleys, and their rank in terms of 1974 harvested area was as follows:

1. San Joaquin Valley (Fresno (1), Kern (2), Tulare (3), Kings (5), San Joaquin (4), Merced (8), Madera (14), and Stanislaus (9) Counties).

2. Sacramento Valley (Solano (20), Sacramento (21), Yolo (7), Colusa (12), Glenn (15), Sutter (11), Butte (16), Yuba (33), and Tehama (26) Counties).

3. Imperial Valley (Imperial County (6)).

Of the 34,100 km^2 (8.41 million acres) harvested in all California counties 1974, the counties in this study account for 76% of the total. The distribution by valley as follows:

Valley	km^2	(Acres)
San Joaquin	17,200	(4,250,000)
Sacramento	6,890	(1,700,000)
Imperial	1,810	(448,000)
Total	25,900	(6,400,000)

2.2 IDENTIFICATION OF AGRICULTURAL OPERATIONS BY CROP

The agricultural operations by crop and by valley are shown in Appendix A. For the sake of clarity, a glossary of agricultural terms was prepared and is included in this report. The agricultural operations can be grouped into two general categories: (a) preparing and maintaining the soil and (b) harvesting the crops.

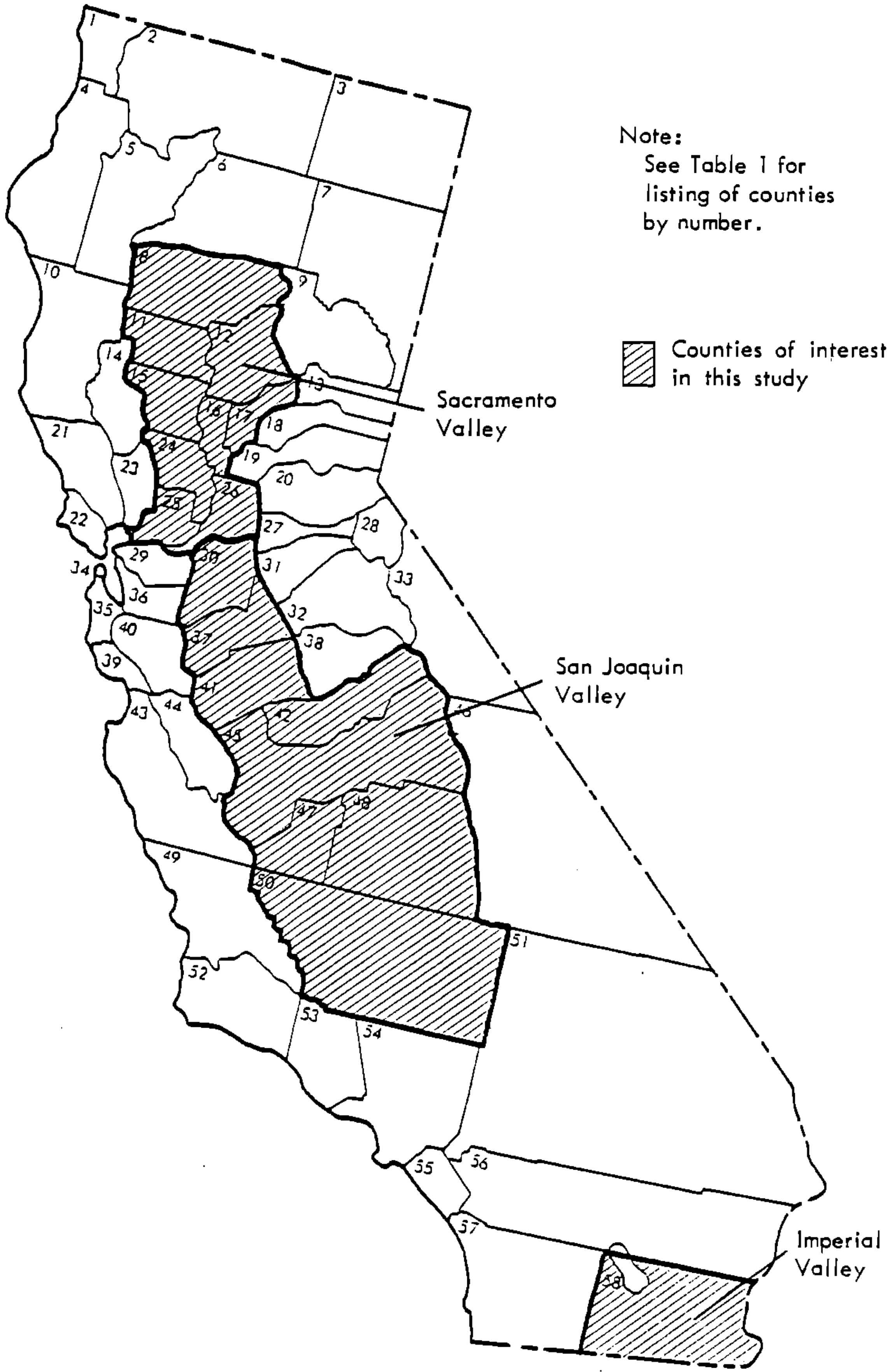


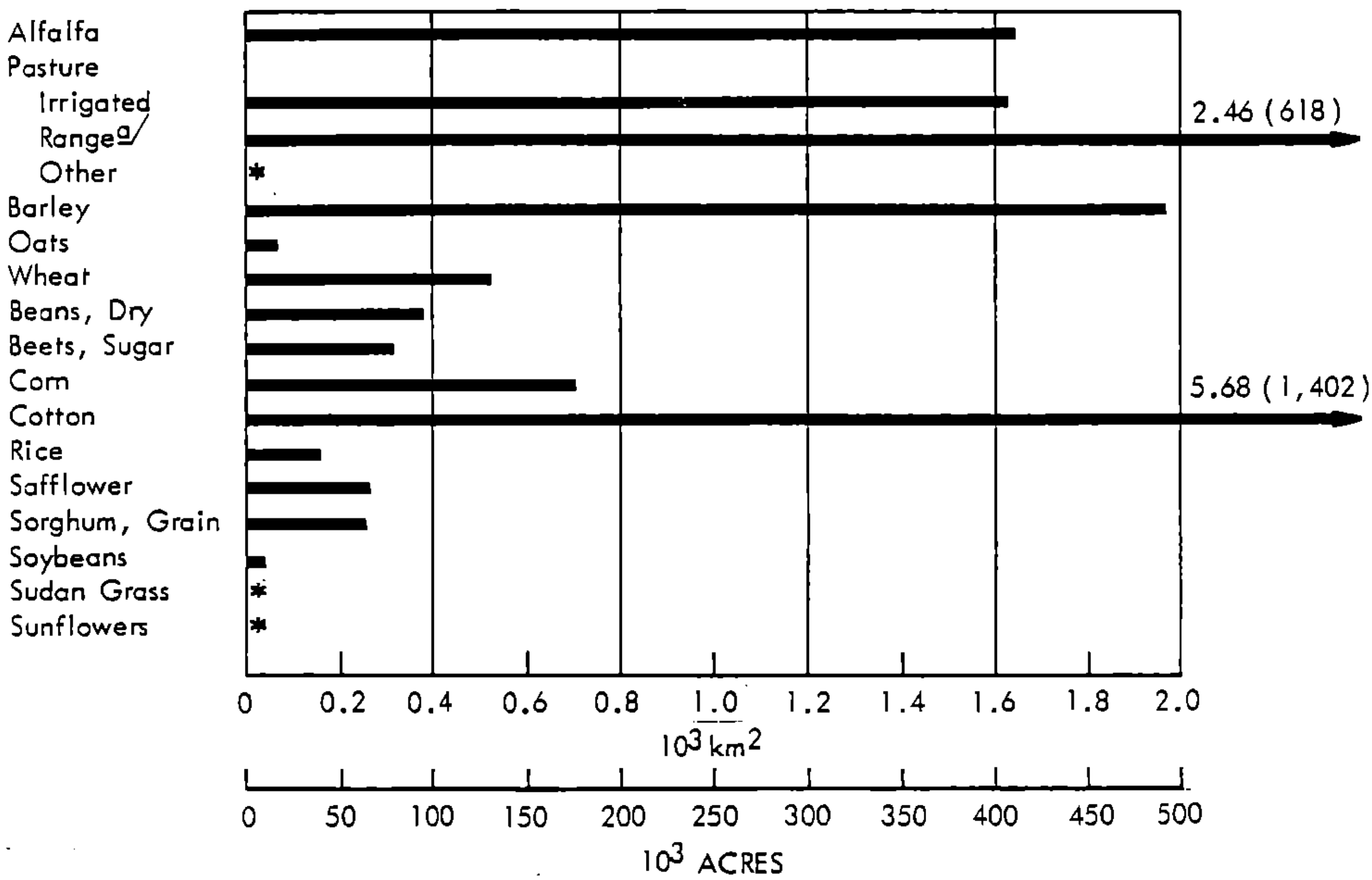
Figure 4. Major agricultural counties of California.

Soil preparation includes such operations as plowing, discing, harrowing, shaping beds, and land leveling via planing or floating, while soil maintenance includes cultivation for weed removal and moisture control. From the tables in Appendix A, it is clear that soil preparation and maintenance operations are the most common, and since these are generally the dustier operations, any testing program must focus heavily on emissions from soil preparation and maintenance.

Also shown in Appendix A is the source extent in terms of harvested area by crop and by valley in 1978. Figures 5 through 13 portray, in summary form, the area harvested by crop and by valley. From these figures, it is clear that field crops occupy a major portion of the cropland land in the state (approximately two-thirds).

2.3 IDENTIFICATION OF TIME SCHEDULE FOR CULTURAL OPERATIONS BY CROP

The final item necessary for selecting the fugitive sources to be tested was to know when the agricultural operations occur. Appendix A shows a range of months during which each agricultural operation may occur. The range is necessary to account for such variables as weather which can accelerate or delay a cultural operation.



*= Negligible (Less than 500 acres)

a/ Acreage is 10% of total range pasture land since only 10% of such land requires land preparation in each year.

Figure 5. 1978 Acreage of harvested field and seed crops in the San Joaquin Valley.

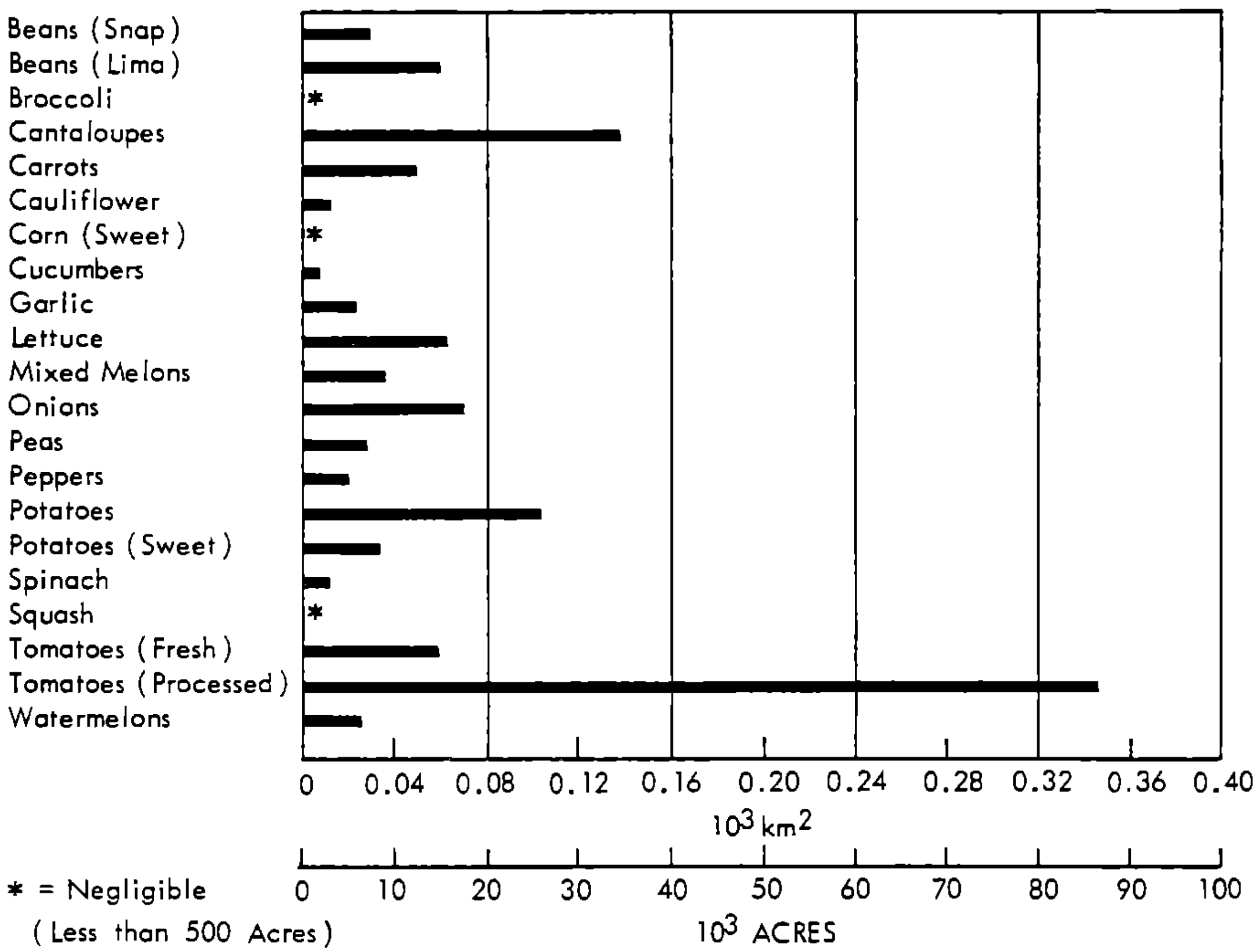


Figure 6. 1978 Acreage of harvested vegetables in the San Joaquin Valley.

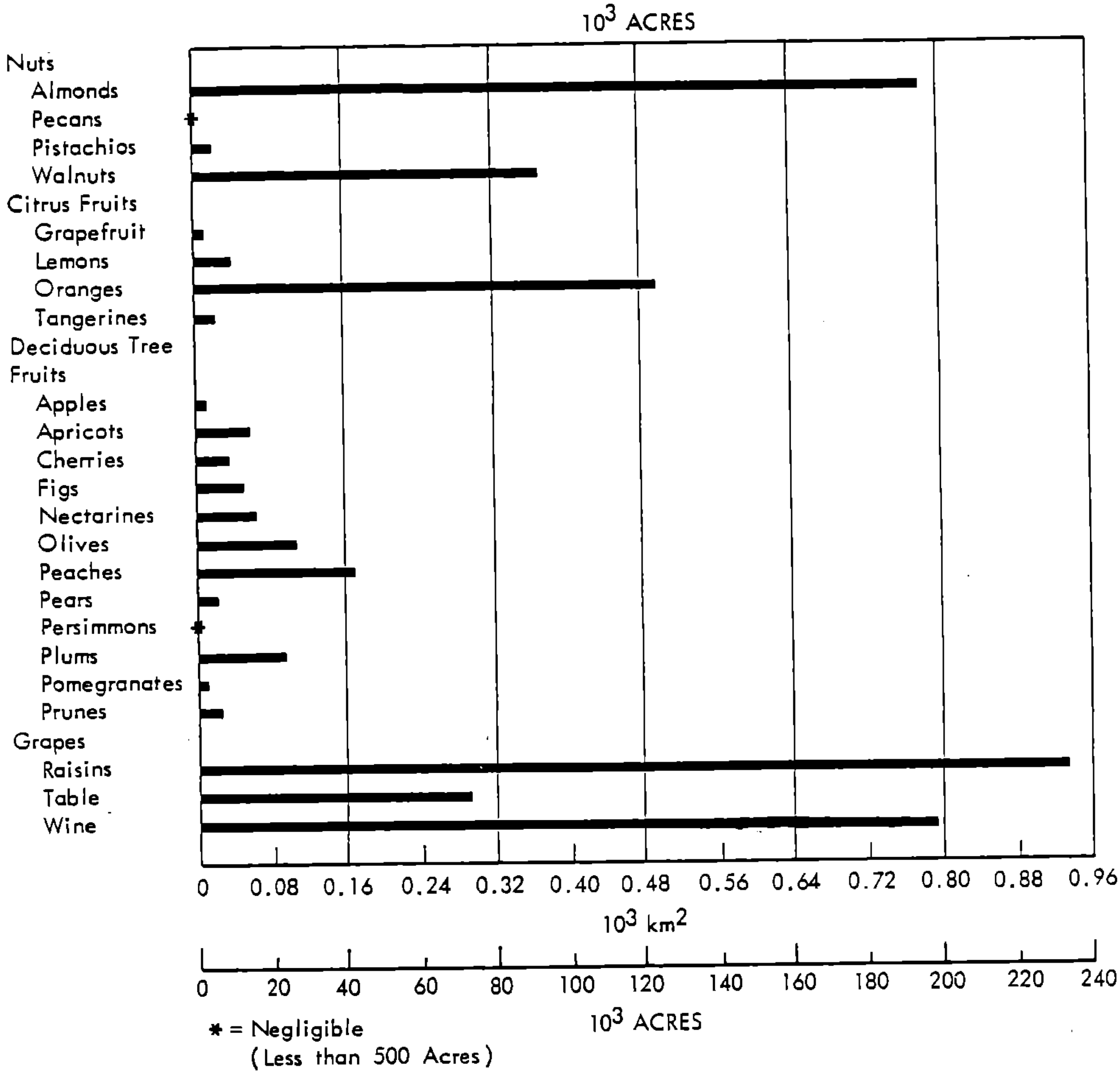
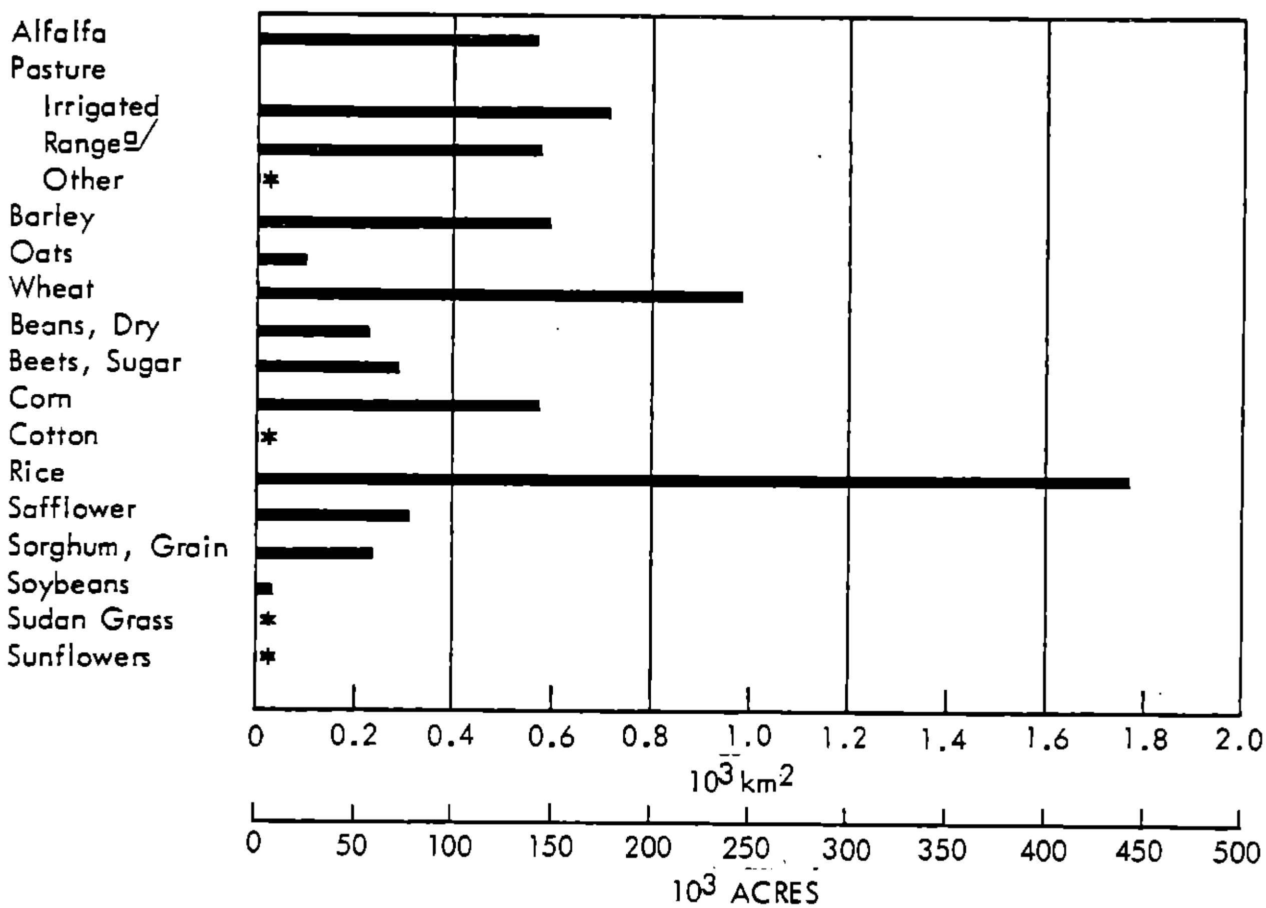


Figure 7. 1978 Acreage of harvested fruit and nut crops in the San Joaquin Valley.



* = Negligible (Less than 500 Acres)

a/ Acreage is 10% of total range pasture land since only 10% of such land requires land preparation in each year.

Figure 8. 1978 Acreage of harvested field and seed crops in the Sacramento Valley.

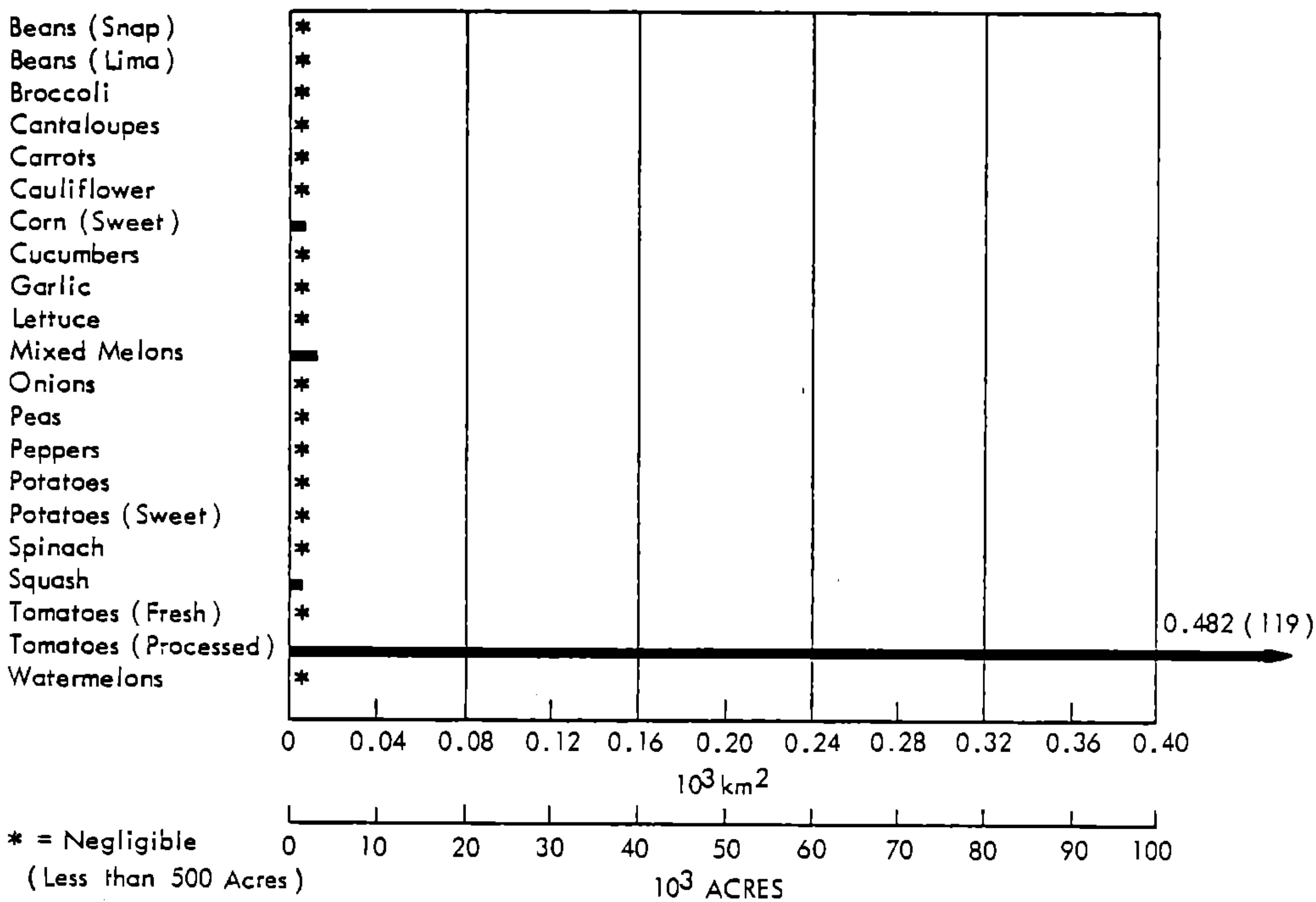


Figure 9. 1978 Acreage of harvested vegetables in the Sacramento Valley.

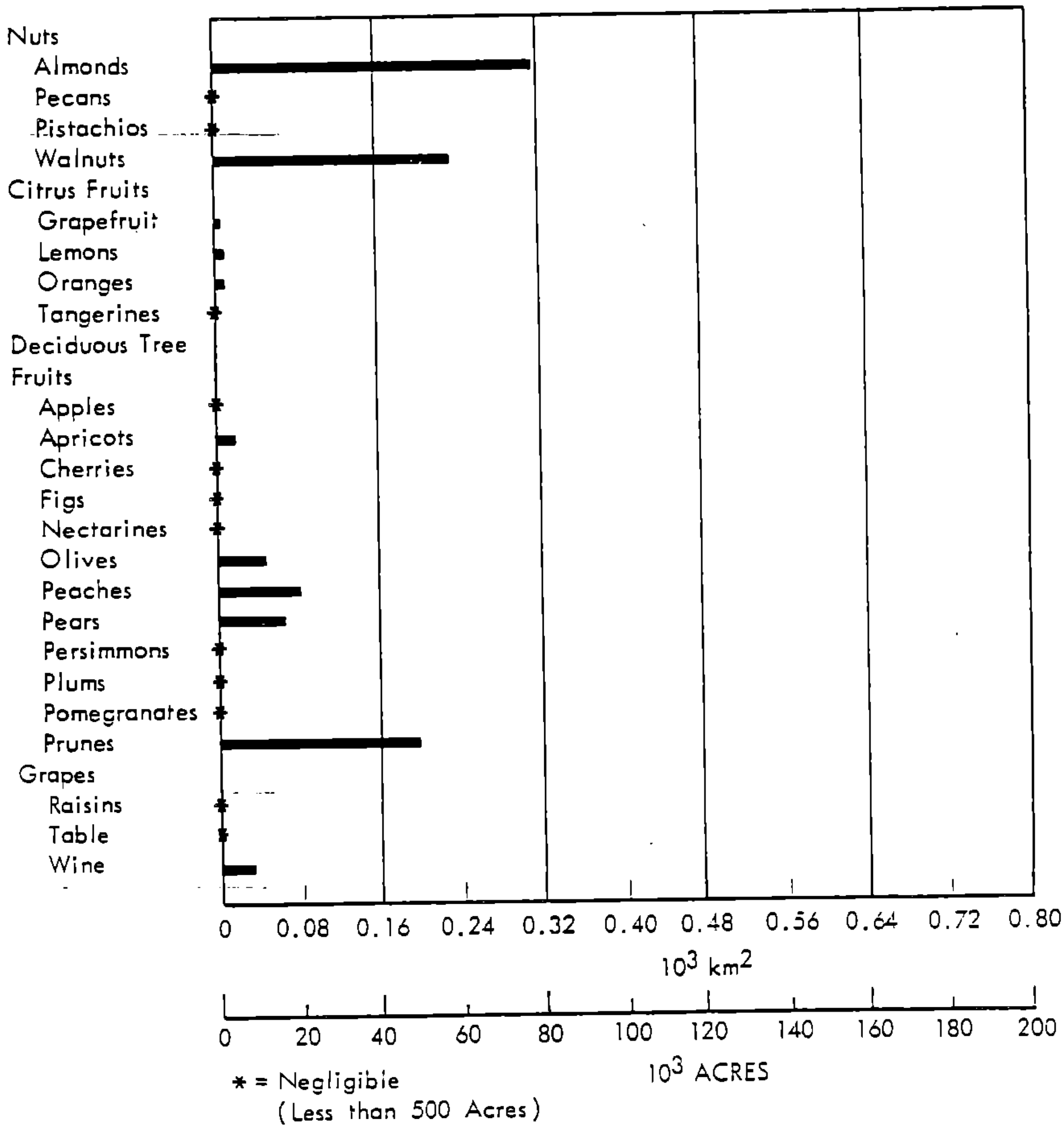


Figure 10. 1978 Acreage of harvested fruit and nut crops in the Sacramento Valley.

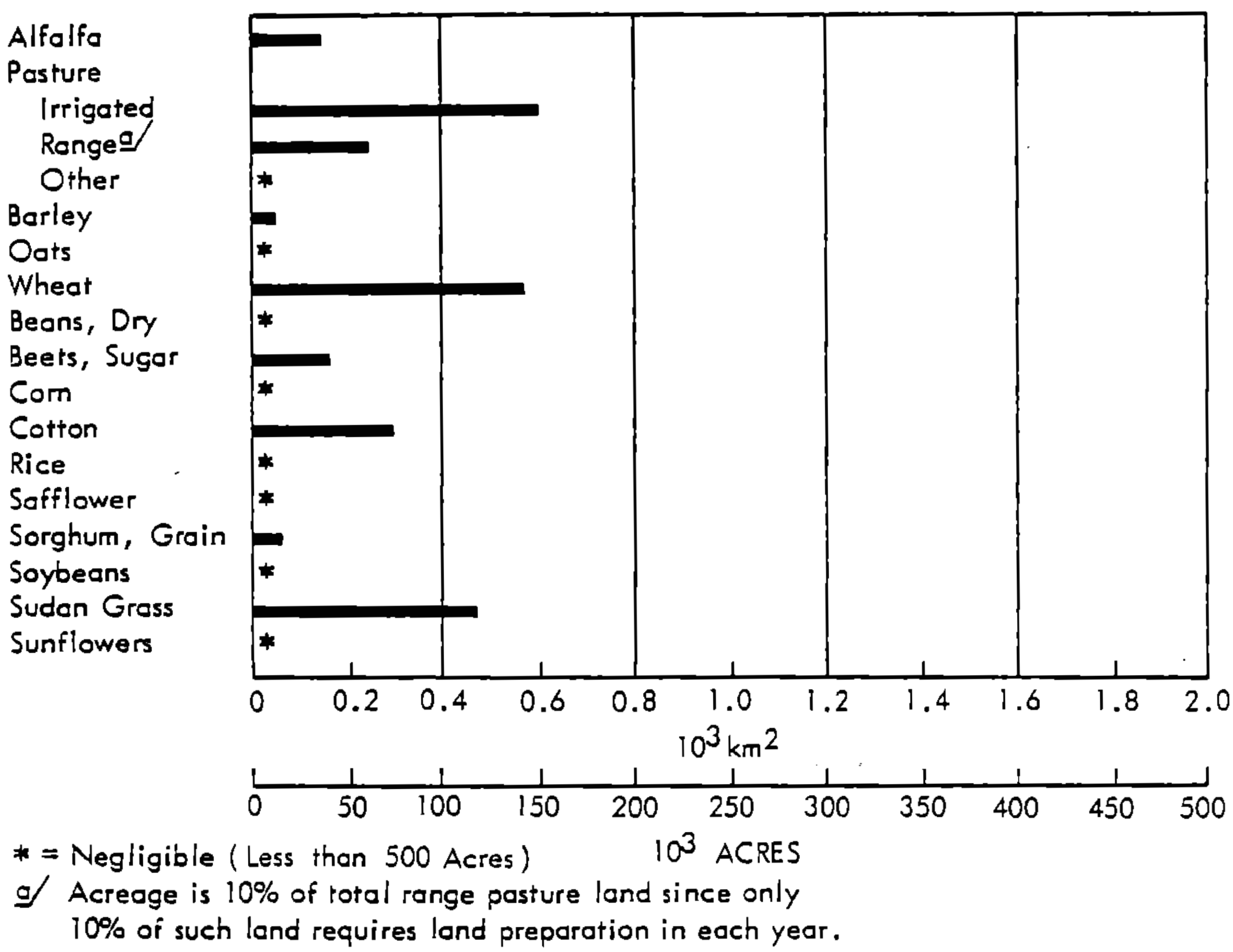


Figure 11. 1978 Acreage of harvested field and seed crops in the Imperial Valley.

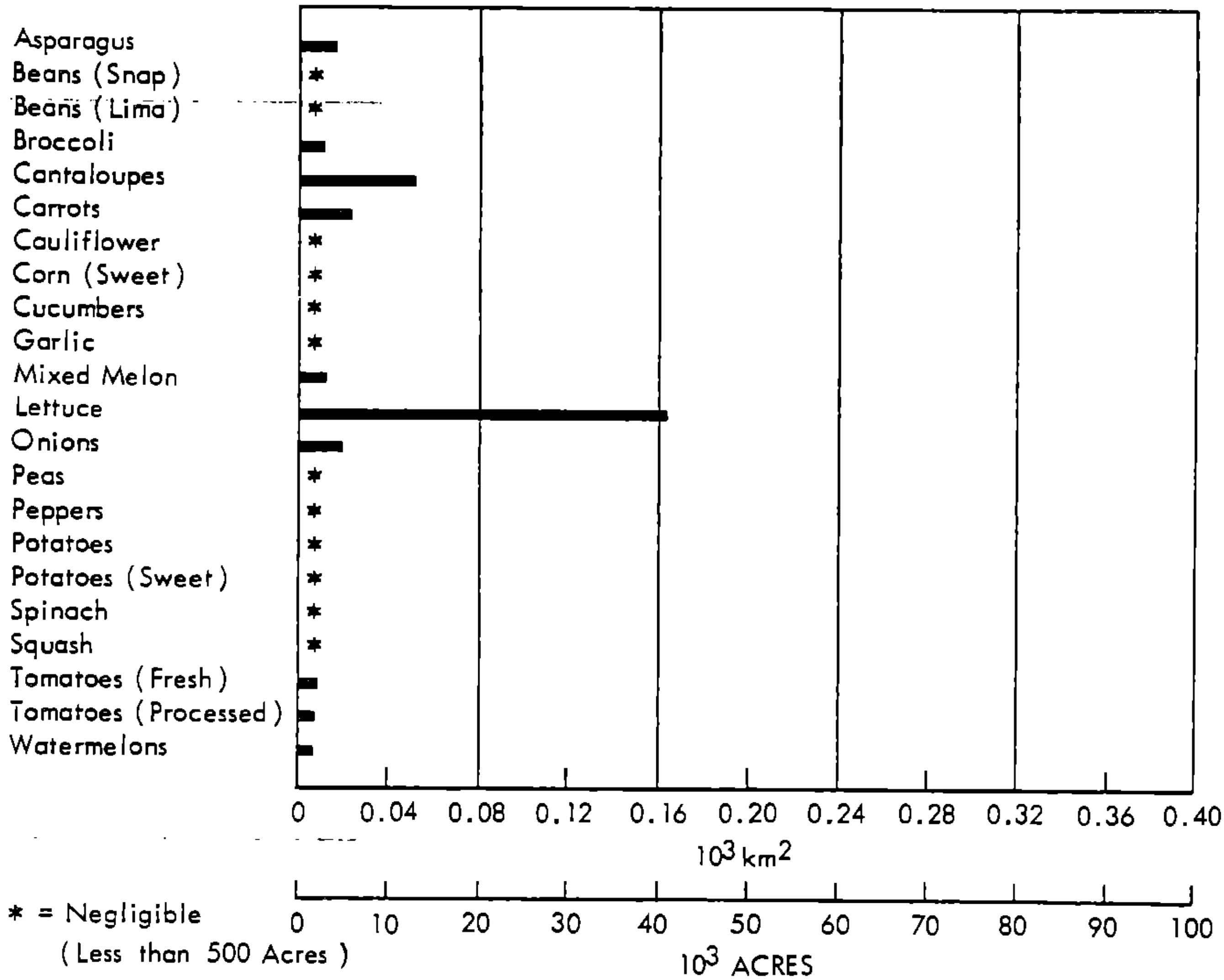


Figure 12. 1978 Acreage of harvested vegetables in the Imperial Valley.

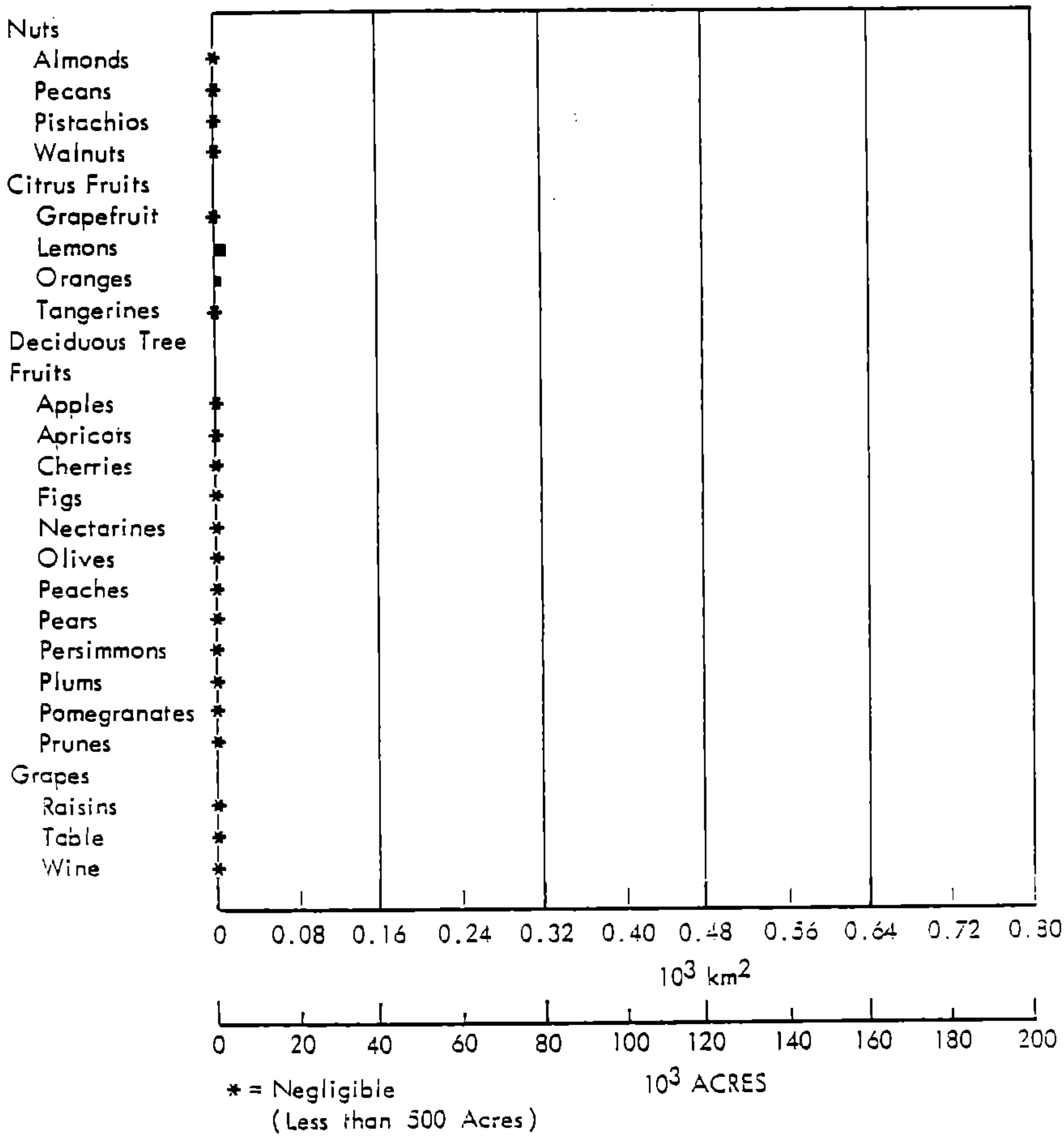


Figure 13. 1978 Acreage of harvested fruit and nut crops in the Imperial Valley.

SECTION 3.0

MEASUREMENT OF SIZE-SPECIFIC EMISSION FACTORS

The most important objective of this project was to quantify the air quality impact of the most significant agricultural operations. The following sections present the criteria for test site selection, the emission factor testing methodology, and the testing results and subsequent calculation procedures.

3.1 SELECTION OF AGRICULTURAL OPERATIONS AND TEST SITES

There were several criteria of both a theoretical and practical nature which were of concern in test site selection:

1. The magnitude of the area over which a given agricultural operation was utilized,

2. The number of times per year a given operation was employed on the same area,

3. The juxtaposition of the time schedule of agricultural operations and the time schedule of MRI and Meteorology Research, Inc., field testing personnel,

4. The availability of extant emission factor and visibility impact data based on previous testing of agricultural operations,

5. The money available in the project, and

6. Feasibility of testing the operation.

Based on the large areas of harvested land in the San Joaquin and Sacramento Valleys in comparison to the Imperial Valley, it was decided to locate the testing sites in the Central Valley (San Joaquin and Sacramento Valley combined). This decision also saved travel costs.

Testing was planned to measure emissions from soil preparation and maintenance and harvesting. Since soil preparation and maintenance operations were 18 times more prevalent than crop harvesting, it was decided that more tests would be performed on soil preparation and maintenance operations. In this report, the term soil preparation will include soil maintenance from this point onward.

A heavier emphasis on soil preparation tests was also justified when extant emission factor test data were reviewed. Table 2 shows emission factors that were available for agricultural sources. When selecting the test

TABLE 2. EMISSION FACTOR VALUES AND PREDICTIVE EQUATIONS RELATING TO AGRICULTURAL SOURCES

Source	Emission factor value/ predictive equation (lb/acre)	Independent variables
I. Tilling (sweep and disc)[1]	$\frac{1.1s\,(S/5.5)}{(PE/50)^2}$ [a]	s = Silt content (%) S = Implement speed (mph) PE = Thornthwaite's precipitation-evaporation index f = Percentage of time wind speed exceeds 12 mph at 1 ft above ground e = Surface erodibility (ton/acre/year) K = Soil ridge roughness factor C = Climatic factor L = Equivalent field length (ft) V = Equivalent vegetative cover (lb/acre)
II. Cotton harvesting[2]		
A. Mechanical picker		
1. Harvesting	0.0041[b]	
2. Trailer loading	0.00062[b]	
3. Transport from field	0.0038[b]	
B. Mechanical stripper		
1. Harvesting	0.021[b]	
2. Trailer loading	0.00082[b]	
3. Transport from field	0.0025[b]	
III. Wheat harvesting[3]		
1. Harvesting with combine	0.0015[b]	
2. Truck loading	0.00013[b]	
3. Truck transport from field	0.0012[b]	
IV. Sorghum harvesting[3]		
1. Harvesting with combine	0.010[b]	
2. Truck transport from field	0.0012[b]	
V. Wind erosion[4,5]	$\frac{3400\,\frac{s}{15}\,\frac{f}{25}\,\frac{e}{50}}{(PE/100)^2}$ [a]	
	$2{,}000 \cdot e \cdot K \cdot C \cdot f(L) \cdot f(V)$ [c]	

[a] The coefficient listed here (1.1) is not identical to the coefficient listed in Reference 1 (1.4) since 1.1 represents particles smaller than 30 μm in stokes diameter while 1.4 represents TP.

[b] Represents particles smaller than 7 μm in stokes diameter.

[c] Represents all particle sizes that leave the field.

sites, it appeared that more data existed for harvesting than for soil preparation.

3.1.1 Soil Preparation Operations

Since a given soil preparation operation is performed in a similar fashion regardless of the initial crop, the crop itself was not of concern in selecting sites for testing emissions from these operations. Time schedules were important, however, since most soil preparation operations occur in the spring. The farms shown in Table 3 were selected as potential sampling sites. Since all potential sites were chosen and therefore acceptable based on the theoretical criteria, only practical considerations remained. The following conclusions were reached:

1. Soil preparation work at the U.S. Department of Agriculture (USDA) experimental farm station would be completed before MRI could be ready to test.

2. Soil preparation work at farms in Kings County would be completed before MRI could be ready to test.

3. The Norman Clark Farm seemed ideal for testing.

4. The Hamatani Farm seemed difficult for testing emissions from single agricultural operations since several different operations were performed concurrently in the field.

5. The Rice Experimental Station seemed ideal for testing.

Consequently, testing was planned at the Norman Clark Farm in the San Joaquin Valley and at the Rice Experimental Station in the Sacramento Valley.

3.1.2 Harvesting Operations

Harvesting is usually only performed once per crop (with notable exceptions like cotton and alfalfa), and the method of harvesting is highly crop dependent. Without regard to practical concerns, the harvesting operation that produces the most particulate emissions is the one that should be tested. Which operation is dustiest depends on the combination of emission factor and source extent. Harvesting operations that require digging are probably dustier than operations which require mowing or picking. On the other hand, field crops have the largest source extent, yet few of the field crops require digging as a harvesting mechanism.

The potential candidates for the testing of harvesting emissions are shown on Table 4. A process of elimination led to the decision to test sugar beet harvesting at the Hamatani Farm in Courtland, California. The various factors leading to this decision are discussed in the following paragraphs.

The cotton harvest at the USDA Experimental Farm in Shafter began so late (October 15) that problems with increasing rain frequency were of concern. In addition, other testing commitments made it difficult to test in California between October 15 and November 15.

TABLE 3. POTENTIAL TEST SITES--SOIL PREPARATION OPERATIONS

Farm name	Valley-county	Crop	Projected time period for soil preparation operations
USDA Experimental Farm Station Shafter, California	San Joaquin - Kern	Cotton	March 17 to 28
Kings County Farm Advisor Hanford, California	San Joaquin - Kings	Cotton	March 17 to 28
Norman Clark Farm Kerman, California	San Joaquin - Fresno	Hay, alfalfa	March 28 to April 7
Hamatani Farm Courtland, California	Sacramento - Sacramento	Field corn	April 1 to 14
Rice Experimental Station Biggs, California	Sacramento - Butte	Rice	April 7 to 14

TABLE 4. POTENTIAL TEST SITES - HARVESTING OPERATIONS

Farm name	Valley-county	Crop	Estimated harvesting period
USDA Experimental Farm Station Shafter, California	San Joaquin - Kern	Cotton	October 15 - November 15
Norman Clark Farm Kerman, California	San Joaquin - Fresno	Alfalfa Cotton Sugar beets	September 1-30 October 15 - November 15 November - December
Hamatani Farm Courtland, California	Sacramento - Sacramento	Field corn Sugar beets	October 6 - October 27 September 22 - October 15
Rice Experimental Station Biggs, California	Sacramento - Butte	Rice	September 25 - October 30

In a visit to the Norman Clark Farm it was observed that alfalfa mowing was not a dusty operation. Sugar beets at this site were to be harvested so late (November-December) that problems with increasing rain frequency were of concern. Testing of cotton harvesting presented a problem because it interfered with prior testing commitments.

A phone call to the Rice Experimental station in Biggs revealed that emissions would probably be low due to the wetness of the soil and the rice grains. The fields were drained prior to harvest, and the rice grains were harvested when they measured approximately 24% moisture. At this time, the soil was still moist, and little emission problem was expected.

A visit to the Hamatani Farm revealed that corn harvesting might be a good operation to test. Unfortunately, the corn harvest began on approximately October 6, and this interfered with other testing commitments.

Consequently, the harvesting of sugar beets at the Hamatani Farm in Courtland was the logical choice. It was observed to be a dusty operation, and it occurred at an acceptable time in terms of scheduling and potential rainfall problems.

3.2 SAMPLING EQUIPMENT AND TECHNIQUES

Equipment to measure concentrations and particle size distributions was employed during this study. The samples collected were handled and analyzed in the laboratory with an emphasis on quality assurance. The equipment was deployed so as to facilitate calculation of emission factors. A triplicate set of tests were performed on most sources to afford statistical significance of the emission factor measurements.

3.2.1 Emission Factor Quantification

3.2.1.1 Sampling Equipment Identification--

The primary tool for quantification of emission factors was the MRI exposure profiler, which was developed under U.S. Environmental Protection Agency (EPA) Contract No. 68-02-0619.[1] The profiler (Figure 14) consists of a portable tower (4 to 6 m height) supporting an array of sampling heads. For this study, each sampling head was operated as an isokinetic exposure sampler directing passage of the flow stream through a settling chamber which trapped larger particles and then upward through a standard 8- by 10-in. glass fiber filter positioned horizontally. Sampling intakes were pointed into the wind, and sampling velocity of each intake was adjusted at 15-min intervals to match the local mean wind speed. Throughout each test, wind speed was monitored by recording anemometers at two heights, and the vertical wind speed profile was determined by assuming a logarithmic distribution.

Sampling time was selected to provide sufficient particulate mass and to average over several units of cyclic fluctuation in the emissions, e.g., implement passes in the field. The first condition was easily met because the sampling grid was located within 5 m (16 ft) of the source.

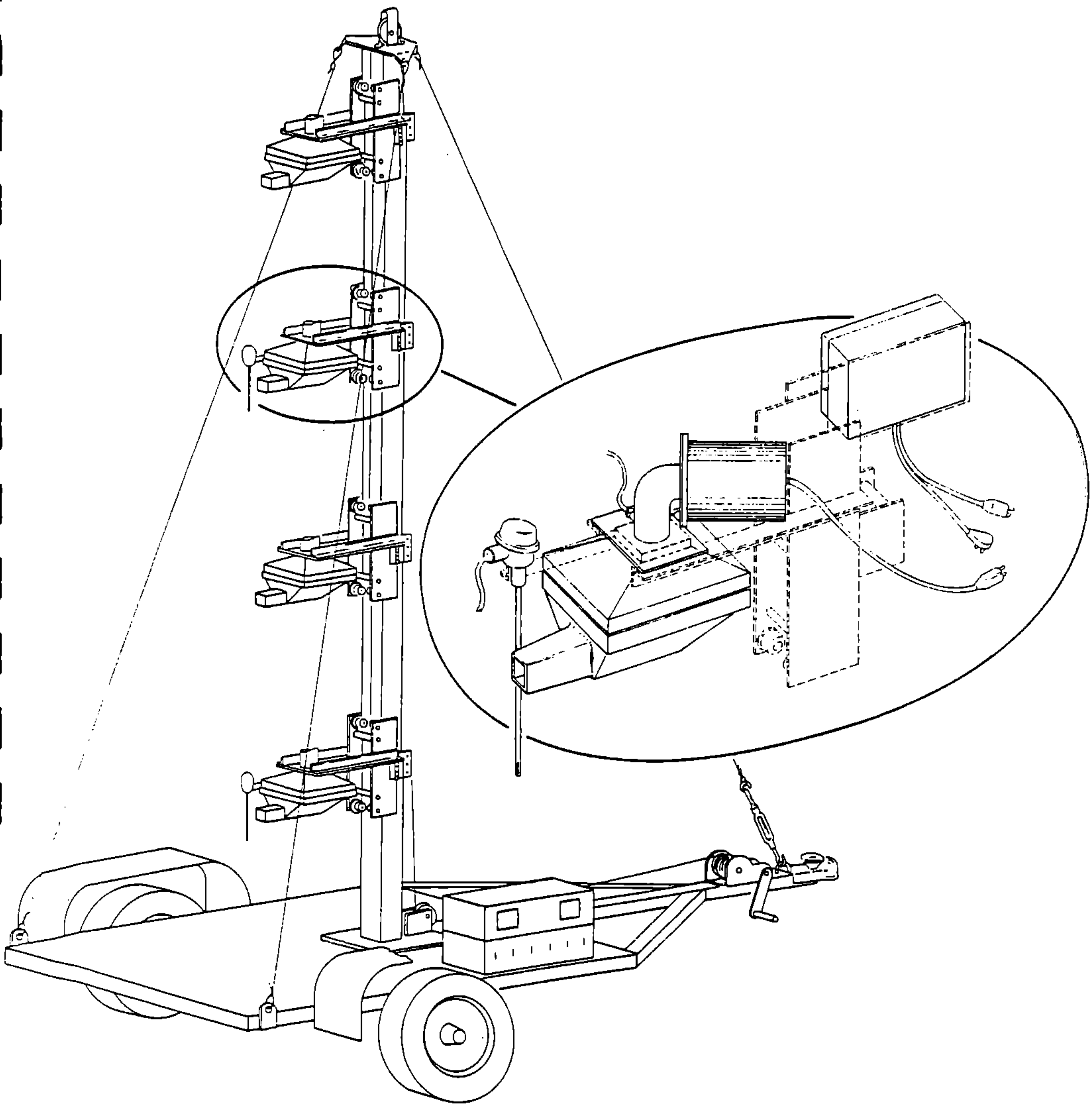


Figure 14. MRI exposure profiler.

In addition to airborne horizontal dust passage (exposure), fugitive dust parameters that were measured included total suspended dust concentration and particle size distribution. Conventional high-volume filtration units were operated upwind and downwind of the test source to provide a measure of total suspended particulate (TSP).

A Sierra Instruments high-volume parallel-slot cascade impactor (CI)[6] installed beneath a size-selective inlet (SSI) was used to measure particle size distribution alongside of the exposure profiler. The CI slotted filters were greased in order to minimize particle bounce. The SSI provided a 50% cutoff diameter of 15 μm and was used to measure IP, while the CI enabled the calculation of fine particulate (FP) concentration and also provided the size distribution of IP.

3.2.1.2 Sampling Equipment Deployment--

The equipment deployed in the field during the sampling of emissions from soil preparation operations is identified in Table 5. The exposure profiler located 5 m (16 ft) downwind of the source provided a measure of TP concentration as a function of height. The upwind equipment provided a measure of emissions not contributed from the source.
The three downwind Hi-Vols with SSIs were used to show how IP concentration decayed with downwind distance and to correlate visibility decay with IP concentration decay. The SSI/CI combination defined the particle size distribution necessary to calculate IP and FP emission factors. During one test of each triplicate set, the SSI/CI combination was deployed at two heights in order to quantify the change in particle size distribution with height. Finally, the cassette-mounted 37-mm filter provided a particle sample from which the largest particle size was determined microscopically.

In addition to the common problems associated with sampling emissions from a fugitive source, the sampling of emissions from an agricultural operation presented unique problems. Since each implement pass occurred over a different location, the sampling equipment had to be moved to maintain fixed distances from the source. This procedure was made somewhat easier by mounting the equipment on a vehicle or carriage with wheels.

The equipment deployed in the field during the sampling of emissions from sugar beet harvesting is identified in Table 6. The major difference between the equipment deployment harvesting and for soil preparation was the use of particle sizing at only one height during harvesting and the elimination of the 50- and 100-m (164 and 328 ft) downwind SSIs.

3.2.1.3 Quality Assurance Techniques--

To prevent dust losses, the filters containing the collected samples of dust were carefully transferred at the end of each run to protective containers and transported to the laboratory. In the laboratory, high-volume filters from the MRI exposure profiler and from standard high-volume units and the CI slotted filters were folded and placed in individual glycene envelopes. The 37-mm filters were transported in the cassette filter holder used in the field. Dust that collected on the interior surfaces of each exposure profiler-settling chamber was rinsed with distilled water into separate glass jars.

TABLE 5. FIELD EQUIPMENT DEPLOYMENT FOR SOIL PREPARATION OPERATIONS

Height (m)	Downwind Distance (m)	Equipment Deployment
2	(upwind)	Hi-Vol[a]
2	(upwind)	Hi-Vol with SSI[b] and CI[c]
4	(upwind)	Wind Direction and Speed Monitoring Station
1	5	Exposure Profiler Head[d]
2	5	Exposure Profiler Head
3	5	Exposure Profiler Head
4	5	Exposure Profiler Head
2	5	Hi-Vol
2	5	Cassette-mounted 37 mm millipore filter
2[e]	5	Hi-Vol with SSI and CI
1[f]	5	Hi-Vol with SSI and CI
3[f]	5	Hi-Vol with SSI and CI
2	50	Hi-Vol with SSI
2	100	Hi-Vol with SSI

[a] Make - Sierra; Model 305.

[b] SSI = size-selective inlet; Make - Anderson; Model - 7000

[c] CI = cascade impactor; Make - Sierra; Model - 235

[d] Designed by Midwest Research Institute.

[e] During two tests of each triplicate set.

[f] During one test of each triplicate set.

TABLE 6. FIELD EQUIPMENT DEPLOYMENT FOR HARVESTING OPERATIONS

Height (m)	Downwind Distance (m)	Equipment Deployment
2	(upwind)	Hi-Vol[a]
2	(upwind)	Hi-Vol with SSI[b] and CI[c]
4	(upwind)	Wind Direction and Speed Monitoring Station
1	5	Exposure Profiler Head[d]
2	5	Exposure Profiler Head
3	5	Exposure Profiler Head
4	5	Exposure Profiler Head
2	5	Hi-Vol
2	5	Hi-Vol with SSI and CI
2	5	Cassette-mounted 37 mm millipore filter

[a] Make - Sierra; Model 305.

[b] SSI = size-selective inlet; Make - Anderson; Model - 7000

[c] CI = cascade impactor; Make - Sierra; Model - 235

[d] Designed by Midwest Research Institute.

Dust samples from the field tests were returned to MRI and analyzed gravimetrically in the laboratory. Glass fiber filters and impaction substrates were conditioned at constant temperature and relative humidity for 24 hr prior to weighing, the same conditioning procedure used before taring. Water washes from the exposure profiler settling chambers were filtered. Then the tared filters were dried, conditioned at constant humidity and temperature, and reweighed.

Quality assurance techniques consisted of a 100% audit on tared filters and a 10% audit on filters with collected sample. The following audit limits were used:

Glass fiber filter size cm (in.)	Filter weight audit limits (mg)	
	Clean	Exposed
20 x 25 (8 x 10)	2.8	5.0
10 x 12 (4 x 5)	1.0	1.8

The entire lot was reweighed if any audited filter within the lot did not meet the above limits. A 100% audit for tared filters is far more than the 7% required by the "Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II, Ambient Air Specific Methods" (EPA 600/4-77-027a). Nevertheless, MRI believes this is necessary since these weights cannot be rechecked once the filters have been used.

Quality assurance was maintained in the constant temperature/humidity weighing and equilibration room by daily checking of a hydrothermograph to assure the weighing and equilibration room was within the following limits:

Temperature: 20-25°C ± 3°C maximum variation.
Relative Humidity: < 50% ± 5% maximum variation.

In addition to laboratory analysis quality assurance, procedures to assure quality in the field were also utilized. The equipment flow rates were calibrated at each regional site prior to testing and on a 2-week schedule thereafter.

3.2.1.4 Soil Collection and Analysis Techniques--

In order to determine the properties of the soil being disturbed by the action of the machinery, representative soil samples were analyzed in the laboratory. Several shovelfuls of soil collected to a depth of approximately 15 cm (6 in.) were composited for analysis.

The soil samples were analyzed for moisture, erodibility, and silt content. Moisture analysis was performed in the field since this variable could change if the sample was transported to MRI prior to analysis. Once back at MRI, soil samples were gently hand-sieved to determine erodibility. They were then mechanically screened to determine the weight fraction passing a 200-mesh screen (75 μm in diameter), which yielded the silt content. An automatic ecentric-cam-shaker was used for screening. Tables 7 through 9 show the procedure for these analyses.

TABLE 7. MOISTURE ANALYSIS PROCEDURES

1. Preheat the oven to approximately 110°C (230°F). Record oven temperature.

2. Tare the laboratory sample containers which will be placed in the oven. Tare the containers with the lids on if they have lids. Record the tare weight(s). Check zero before weighing.

3. Record the make, capacity, smallest division, and accuracy (if displayed) of the scale.

4. Weigh the laboratory sample in the container(s). Record the combined weight(s). Check zero before weighing.

5. Place sample in oven and dry overnight.[a]

6. Remove sample container from oven and (a) weigh immediately if uncovered, being careful of the hot container; or (b) place tight-fitting lid on the container and let cool before weighing. Record the combined sample and container weight(s). Check zero before weighing.

7. Calculate the moisture as the initial weight of the sample and container minus the over-dried weight of the sample and container divided by the initial weight of the sample alone. Record the value.

8. Calculate the sample weight to be used in the silt analysis as the oven-dried weight of the sample and container minus the weight of the container. Record the value.

---

[a] Dry materials composed of hydrated minerals or organic materials like coal and certain soils for only 1-1/2 hr. Because of this short drying time, material dried for only 1-1/2 hr must not be more than 2.5 cm (1 in.) deep in the container.

TABLE 8. TECHNIQUE FOR SIEVING SOIL SAMPLES TO DETERMINE ERODIBILITY[a]

1. Sieve the soil only when it is air dry. If it is not dry, bring the soil to the laboratory, dry it, and then sieve.

2. Place a 20 mesh sieve atop a receiving pan and dump the sample onto the sieve.

3. Turn the sieve by hand two turns per 5 sec. Maintain this speed by checking the second hand of a watch while turning.

4. If the soil is sand, loamy sand, or sandy loam, turn sieve 5 times; if it is loam silt loam, clay loam, or silty clay loam, turn 10 times; if it is silty clay or clay, turn 15 times.

5. Calculate the percent of the total sample that passes through the 20 mesh screen. The erodibility is related to this percentage (see Ref. b).

a From "Estimations of Wind Erodibility of Farm Field," by W.S. Chepil, Production Research Report No. 25, Agricultural Research Service, USDA, March 1959.

b Woodruff, N. P. and F. H. Siddoway. "A Wind Erosion Equation." Soil Science Society of America Proceedings, 29(5):602-608, 1965.

TABLE 9. SILT ANALYSIS PROCEDURES

1. Select the appropriate 8-in diameter, 2-in deep sieve sizes. Recommended U.S. Standard Series sizes are: 3/8 in., No. 4, No. 20, No. 40, No. 100, No. 140, No. 200, and a pan. Comparable Tyler Series sizes can also be utilized. The No. 20 and the No. 200 are mandatory. The others can be varied if the recommended sieves are not available or if buildup on one particular sieve during sieving indicates that an intermediate sieve should be inserted.

2. Obtain a mechanical sieving device such as a vibratory shaker or a Roto-Tap (without the tapping function).

3. Clean the sieves with dry compressed air and/or a soft brush. Material lodged in the sieve openings or adhering to the sides of the sieve should be removed (if possible) without handling the screen roughly.

4. Attain a scale (capacity of at least 1,600 g (3.5 lb)) and record make, capacity, smallest division, date of last calibration, and accuracy.

5. Tare sieves and pan. Check the zero before every weighing. Record weights.

6. After nesting the sieves in order from the largest to the smallest openings with pan at the bottom, dump dried laboratory sample (immediately after drying) into the top sieve. The sample should weigh between 800 and 1,600 g (1.8 and 3.5 lb). Brush fine material adhering to the sides of the container into the top sieve and cover the top sieve with a special lid normally purchased with the pan.

7. Place nested sieves into the mechanical device and sieve for 20 min. Remove pan containing minus No. 200 and weigh. Replace pan beneath the sieves and sieve for another 10 min. Remove pan and weigh. When the difference between two successive pan sample weighings spaced 10 min apart (where the tare of the pan has been subtracted) is less than 3.0%, the sieving is complete. Do not sieve longer than 40 min.

8. Weigh each sieve and its contents and record the weight. Check the zero before every weighing.

9. Collect the laboratory sample and place the sample in a separate container if further analysis is expected.

10. Calculate the percent of mass less than the 200 mesh screen (75 μm). This is the silt content.

3.3 EMISSION FACTOR CALCULATION RESULTS

Emission factors were calculated for soil preparation operations and for harvesting operations. The calculations were based on measurements of particulate concentration, size distribution, and wind speed over a given sampling time. The following sections show the measurements collected and the calculation procedure utilized to quantify emission factors.

3.3.1 Soil Preparation Operations--Measured Values

The soil preparation operations tested along with the test dates and locations are shown in Table 10. The tests were conducted in early April; seven tests were performed in the San Joaquin Valley and six tests in the Sacramento Valley.

The emissions were sampled during each pass of the tractor and implement (or car in the case of N-1) upwind of the profiling equipment. The number and quality of the passes along with the width of the pass (identical to the width of the implement) are shown in Table 11. The quality of the pass was determined by the following criteria:

- Good - The wind direction was within 45 degrees of a line perpendicular to the direction of the implement and tractor.
- Marginal - The wind direction was 45 to 90 degrees from a line perpendicular to the implement and tractor.
- Bad - The wind direction carried the plume toward the position of the upwind Hi-Vol.

From Table 11 it is clear that nearly all the implement passes were rated as good during all the tests except test N-2, when light and variable winds resulted in several bad passes. Since the results would be questionable, data from test N-2 were not used to calculate emission factors.

The measured concentrations from all the deployed equipment for each test are shown in Tables 12 to 24. Also shown on the tables is whether the exposure profiler measured total particulate (TP) concentrations in an isokinetic or nonisokinetic fashion. Samples were considered to have been sampled isokinetically if the ratio of the sampling speed to the wind speed was within the range of 0.8 to 1.2. The ratio of the sampling speed to the wind speed is called the flow ratio (FR).

The particle size distribution of IP is shown in Figures 15 through 29. The figures show only the distribution of IP and not of TP since the cascade impactor was mounted beneath the size-selective inlet. The figures show a plot of aerodynamic particle diameter versus weight percent less than the stated size. Finally, the figures show the percent of IP that is FP. This percentage was multiplied times the measured IP concentration in order to calculate the FP concentration.

TABLE 10. AGRICULTURAL FUGITIVE DUST TEST IDENTIFICATION SOIL PREPARATION OPERATIONS

Source	Run	Date	Location	Crop	Valley (County)
Unpaved roads	N-1	4/02/80	Norman Clark Farm Kerman, California	Alfalfa	San Joaquin (Fresno)
Disc[a]	N-2	4/03/80	Norman Clark Farm Kerman, California	Alfalfa	San Joaquin (Fresno)
Land plane[b]	N-3	4/04/80	Norman Clark Farm Kerman, California	Alfalfa	San Joaquin (Fresno)
Land plane[b]	N-4	4/04/80	Norman Clark Farm Kerman, California	Alfalfa	San Joaquin (Fresno)
Land plane[b]	N-5	4/04/80	Norman Clark Farm Kerman, California	Alfalfa	San Joaquin (Fresno)
Disc[b,c]	N-6	4/07/80	Norman Clark Farm Kerman, California	Alfalfa	San Joaquin (Fresno)
Disc[b,d]	N-7	4/07/80	Norman Clark Farm Kerman, California	Alfalfa	San Joaquin (Fresno)
Disc[a]	N-8	4/09/80	Rice Experimental Station Biggs, California	Rice	Sacramento (Butte)
Disc[a]	N-9	4/10/80	Rice Experimental Station Biggs, California	Rice	Sacramento (Butte)
Disc[a]	N-10	4/10/80	Rice Experimental Station Biggs, California	Rice	Sacramento (Butte)
Disc[a]	N-11	4/10/80	Rice Experimental Station Biggs, California	Rice	Sacramento (Butte)
Disc[a]	N-12	4/11/80	Rice Experimental Station Biggs, California	Rice	Sacramento (Butte)
Disc[a]	N-13	4/11/80	Rice Experimental Station Biggs, California	Rice	Sacramento (Butte)

[a] Implement towed by tractor on tracks.

[b] Implement towed by tractor on six wheels.

[c] First pass with disc to incorporate soil supplements.

[d] Second pass with disc to further incorporate soil supplements.

TABLE 11. INFORMATION ON IMPLEMENT PASSES
SOIL PREPARATION OPERATIONS

Run	Number and quality of passes				Width of passes (m)
	Good	Marginal	Bad	Total	
N-1	23	1	1	25	-
N-2	7	3	11	21	6.4 (21 ft)
N-3	15	0	0	15	4.9 (16 ft)
N-4	14	1	0	15	4.9
N-5	15	0	0	15	4.9
N-6	10	0	0	10	4.9
N-7	8	0	0	8	4.9
N-8	15	0	0	15	4.9
N-9	14	0	0	14	4.9
N-10	14	0	0	14	4.9
N-11	15	0	0	15	4.9
N-12	15	0	0	15	4.9
N-13	14	0	0	14	4.9

TABLE 12. CONCENTRATION MEASUREMENTS DURING AGRICULTURAL OPERATIONS-UNPAVED ROAD

Test Number: N-1
Location: Kerman, California
Source: Unpaved road
Test date: 4/2/80

Height (m)	Downwind distance (m)	Concentration ($\mu g/m^3$)[a] Hi-Vol	Hi-Vol with SSI	Hi-Vol with SSI and CI	Exposure profiler sampler[b]
2	10(upwind)	232			
2	10(upwind)			83	
2	5	1,403			
2	5			689	
2	55		138		
2	105		72		
1	5				2,456(N)
2	5				1,958(N)
3	5				1,467(N)
4	5				1,251(N)

[a] Actual measured concentration including contributions from background.

[b] N implies nonisokinetic sampling; I implies isokinetic sampling.

TABLE 13. CONCENTRATION MEASUREMENTS DURING AGRICULTURAL OPERATIONS - DISCING

Test Number: N-2
Location: Kerman, California
Source: Disc and tractor on tracks
Test date: 4/3/80

Height (m)	Downwind distance (m)	Concentration ($\mu g/m^3$)[a]			
		Hi-Vol	Hi-Vol with SSI	Hi-Vol with SSI and CI	Exposure profiler sampler[b]
2	10(upwind)	126			
2	10(upwind)			57	
2	5	7,199			
2	5			2,331	
2	55		296		
2	105		237		
1	5				6,624(N)
2	5				6,382(N)
3	5				7,321(N)
4	5				6,711(N)

[a] Actual measured concentration including contributions from background.

[b] N implies nonisokinetic sampling; I implies isokinetic sampling.

TABLE 14. CONCENTRATION MEASUREMENTS DURING AGRICULTURAL OPERATIONS - LAND PLANING

Test Number: N-3
Location: Kerman, California
Source: Land plane and tractor on 6 wheels
Test date: 4/4/80

Height (m)	Downwind distance (m)	Concentration ($\mu g/m^3$)[a] Hi-Vol	Hi-Vol with SSI	Hi-Vol with SSI and CI	Exposure profiler sampler[b]
2	10(upwind)	34			
2	10(upwind)			13	
2	5	3,802			
2	5			909	
2	55		293		
2	105		366		
1	5				8,504(I)
2	5				7,195(I)
3	5				4,023(I)
4	5				2,564(I)

a Actual measured concentration including contributions from background.

b N implies nonisokinetic sampling; I implies isokinetic sampling.

TABLE 15. CONCENTRATION MEASUREMENTS DURING AGRICULTURAL OPERATIONS - LAND PLANING

Test Number: N-4
Location: Kerman, California
Source: Land plane and tractor on 6 wheels
Test date: 4/4/80

Height (m)	Downwind distance (m)	Concentration ($\mu g/m^3$)[a] Hi-Vol	Hi-Vol with SSI	Hi-Vol with SSI and CI	Exposure profiler sampler[b]
2	10(upwind)	34			
2	10(upwind)			13	
2	5	6,214			
2	5			972	
2	55		504		
2	105		444		
1	5				8,113(N)
2	5				7,960(N)
3	5				4,594(I)
4	5				3,388(I)

a Actual measured concentration including contributions from background.

b N implies nonisokinetic sampling; I implies isokinetic sampling.

TABLE 16. CONCENTRATION MEASUREMENTS DURING AGRICULTURAL OPERATIONS - LAND PLANING

Test Number: N-5
Location: Kerman, California
Source: Land plane and tractor on 6 wheels
Test date: 4/4/80

Height (m)	Downwind distance (m)	Concentration ($\mu g/m^3$)[a]			
		Hi-Vol	Hi-Vol with SSI	Hi-Vol with SSI and CI	Exposure profiler sampler[b]
2	10(upwind)	34			
2	10(upwind)			13	
2	5	2,790			
1	5			457	
3	5			571	
2	55		228		
2	105		165		
1	5				5,293(N)
2	5				4,544(I)
3	5				3,588(I)
4	5				2,373(I)

[a] Actual measured concentration including contributions from background.

[b] N implies nonisokinetic sampling; I implies isokinetic sampling.

TABLE 17. CONCENTRATION MEASUREMENTS DURING AGRICULTURAL OPERATIONS - DISCING

Test Number: N-6
Location: Kerman, California
Source: Disc and tractor on 6 wheels
Test date: 4/7/80

Height (m)	Downwind distance (m)	Concentration ($\mu g/m^3$)[a]			
		Hi-Vol	Hi-Vol with SSI	Hi-Vol with SSI and CI	Exposure profiler sampler[b]
2	10(upwind)	41			
2	10(upwind)			22	
2	5	2,313			
1	5			920	
3	5			313	
2	55		647		
2	105		332		
1	5				5,806(I)
2	5				2,310(I)
3	5				806(I)
4	5				184(I)

[a] Actual measured concentration including contributions from background.

[b] N implies nonisokinetic sampling; I implies isokinetic sampling.

TABLE 18. CONCENTRATION MEASUREMENTS DURING AGRICULTURAL OPERATIONS-DISCING

Test Number: N-7
Location: Kerman, California
Source: Disc and tractor on 6 wheels
Test date: 4/7/80

Height (m)	Downwind distance (m)	Concentration (μg/m³)[a] Hi-Vol	Hi-Vol with SSI	Hi-Vol with SSI and CI	Exposure profiler sampler[b]
2	10(upwind)	41			
2	10(upwind)			22	
2	5	5,458			
2	5			1,924	
2	55		1,808		
2	105		1,470		
1	5				10,417(N)
2	5				5,130(I)
3	5				1,642(I)
4	5				1,359(I)

[a] Actual measured concentration including contributions from background.

[b] N implies nonisokinetic sampling; I implies isokinetic sampling.

TABLE 19. CONCENTRATION MEASUREMENTS DURING AGRICULTURAL OPERATIONS - DISCING

Test Number: N-8
Location: Biggs, California
Source: Disc and tractor on tracks
Test date: 4/9/80

Height (m)	Downwind distance (m)	Concentration ($\mu g/m^3$)[a]			
		Hi-Vol	Hi-Vol with SSI	Hi-Vol with SSI and CI	Exposure profiler sampler[b]
2	10(upwind)	247			
2	10(upwind)			154	
2	5	1,148			
2	5			386	
2	55		298		
2	105		166		
1	5				3,036(N)
2	5				1,462(I)
3	5				581(I)
4	5				293(I)

[a] Actual measured concentration including contributions from background.

[b] N implies nonisokinetically sampled; I implies isokinetically sampled.

TABLE 20. CONCENTRATION MEASUREMENTS DURING AGRICULTURAL OPERATIONS - DISCING

Test Number: N-9
Location: Biggs, California
Source: Disc and tractor on tracks
Test date: 4/10/80

Height (m)	Downwind distance (m)	Concentration ($\mu g/m^3$)[a] Hi-Vol	Hi-Vol with SSI	Hi-Vol with SSI and CI	Exposure profiler sampler[b]
2	10(upwind)	118			
2	10(upwind)			73	
2	5	944			
2	5			655	
2	55		468		
2	105		319		
1	5				2,405(I)
2	5				1,060(I)
3	5				363(I)
4	5				127(I)

[a] Actual measured concentration including contributions from background.

[b] N implies nonisokinetic sampling; I implies isokinetic sampling.

TABLE 21. CONCENTRATION MEASUREMENTS DURING AGRICULTURAL OPERATIONS - DISCING

Test Number: N-10
Location: Biggs, California
Source: Disc and tractor on tracks
Test date: 4/10/80

Height (m)	Downwind distance (m)	Concentration ($\mu g/m^3$)[a] Hi-Vol	Hi-Vol with SSI	Hi-Vol with SSI and CI	Exposure profiler sampler[b]
2	10(upwind)	120			
2	10(upwind)			74	
2	5	1,169			
1	5			901	
3	5			480	
2	55		555		
2	105		484		
1	5				3,621(I)
2	5				1,597(I)
3	5				579(I)
4	5				216(I)

[a] Actual measured concentration including contributions from background.

[b] N implies nonisokinetic sampling; I implies isokinetic sampling.

TABLE 22. CONCENTRATION MEASUREMENTS DURING AGRICULTURAL OPERATIONS - DISCING

Test Number: N-11
Location: Biggs, California
Source: Disc and tractor on tracks
Test date: 4/10/80

Height (m)	Downwind distance (m)	Concentration ($\mu g/m^3$)[a]			
		Hi-Vol	Hi-Vol with SSI	Hi-Vol with SSI and CI	Exposure profiler sampler[b]
2	10(upwind)	128			
2	10(upwind)			80	
1	5	1,096			
1	5			1,264	
3	5			59[c]	
2	55		473		
2	105		240		
1	5				5,692(I)
2	5				2,124(I)
3	5				598(I)
4	5				187(I)

[a] Actual measured concentration including contributions from background.

[b] N implies nonisokinetic sampling; I implies isokinetic sampling.

[c] Value is suspect since large net negative weight calculated for back-up 8 in. x 10 in. filter.

TABLE 23. CONCENTRATION MEASUREMENTS DURING AGRICULTURAL OPERATIONS - DISCING

Test Number: N-12
Location: Biggs, California
Source: Disc and tractor on tracks
Test date: 4/11/80

Height (m)	Downwind distance (m)	Concentration ($\mu g/m^3$)[a] Hi-Vol	Hi-Vol with SSI	Hi-Vol with SSI and CI	Exposure profiler sampler[b]
2	10(upwind)	189			
2	10(upwind)			103	
2	5	2,139			
2	5			1,042	
2	55		433		
2	105		1,062		
1	5				6,710(I)
2	5				2,051(I)
3	5				552(I)
4	5				213(I)

[a] Actual measured concentration including contributions from background.

[b] N implies nonisokinetic sampling; I implies isokinetic sampling.

TABLE 24. CONCENTRATION MEASUREMENTS DURING AGRICULTURAL OPERATIONS - DISCING

Test Number: N-13
Location: Biggs, California
Source: Disc and tractor on tracks
Test date: 4/11/80

Height (m)	Downwind distance (m)	Concentration ($\mu g/m^3$)[a]			
		Hi-Vol	Hi-Vol with SSI	Hi-Vol with SSI and CI	Exposure profiler sampler[b]
2	10(upwind)	189			
2	10(upwind)			103	
2	5	1,761			
2	5			48[c]	
2	55		466		
2	105		297		
1	5				5,303(I)
2	5				2,207(I)
3	5				687(I)
4	5				193(I)

[a] Actual measured concentration including contributions from background.

[b] N implies nonisokinetic sampling; I implies isokinetic sampling.

[c] Value suspect since four CI stages showed net negative weights. Most likely IP concentration value calculated as 1234 $\mu g/m^3$ assuming the same IP percent of TP at the 2m height as was measured in test N-10.

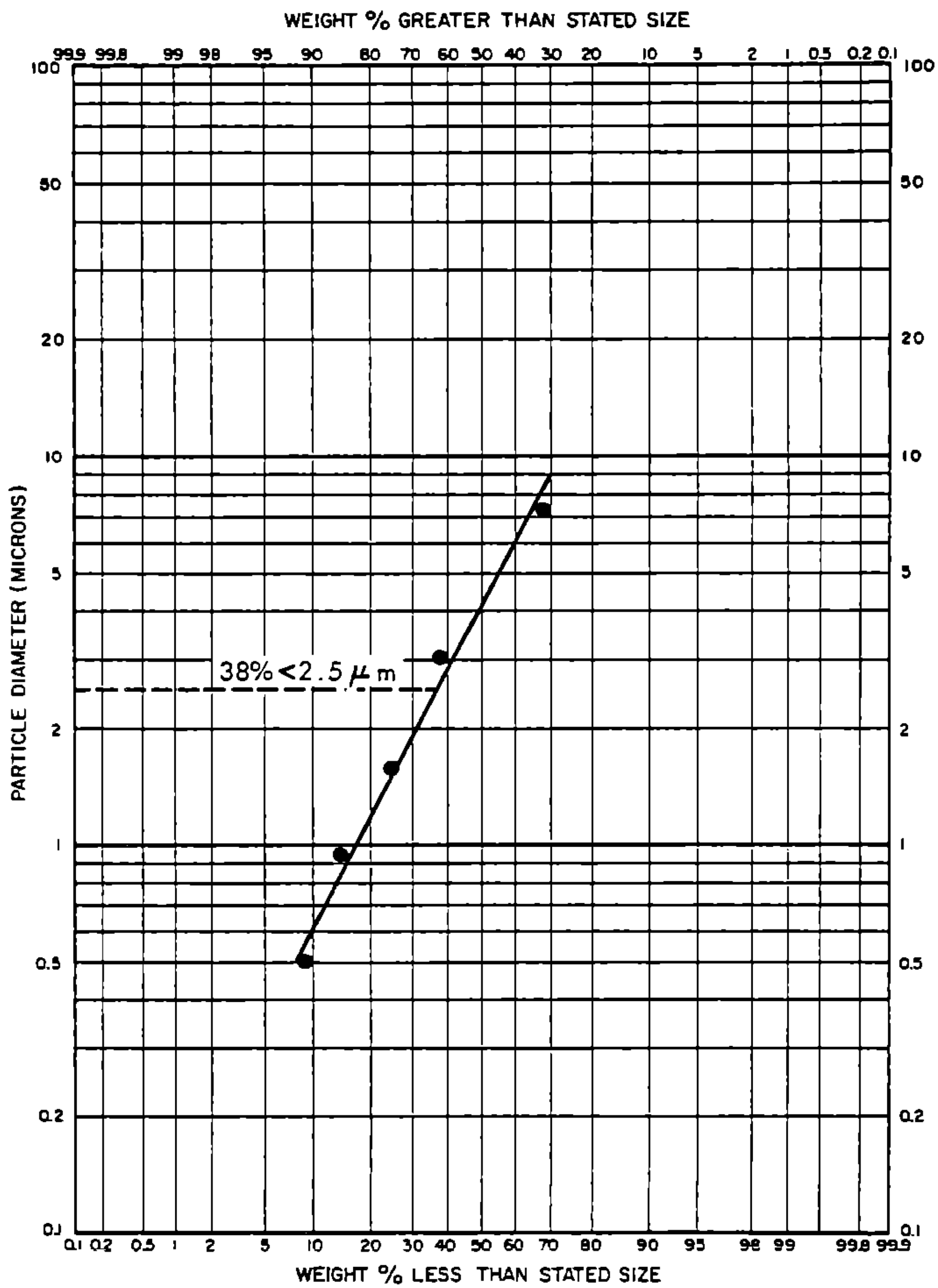


Figure 15. Particle size distribution of IP at 2 m height for test N-1.

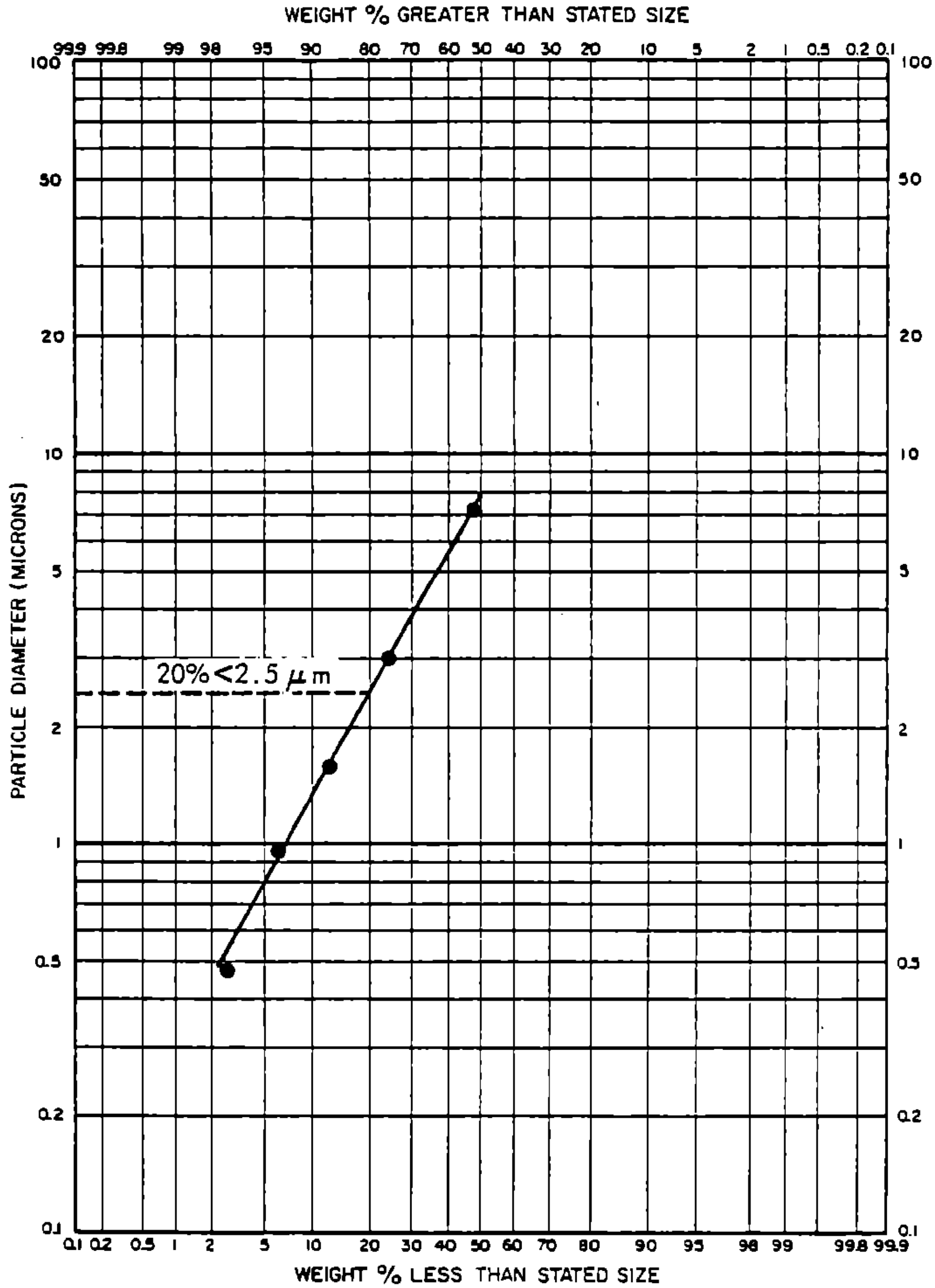


Figure 16. Particle size distribution of IP at 2 m height for test N-2.

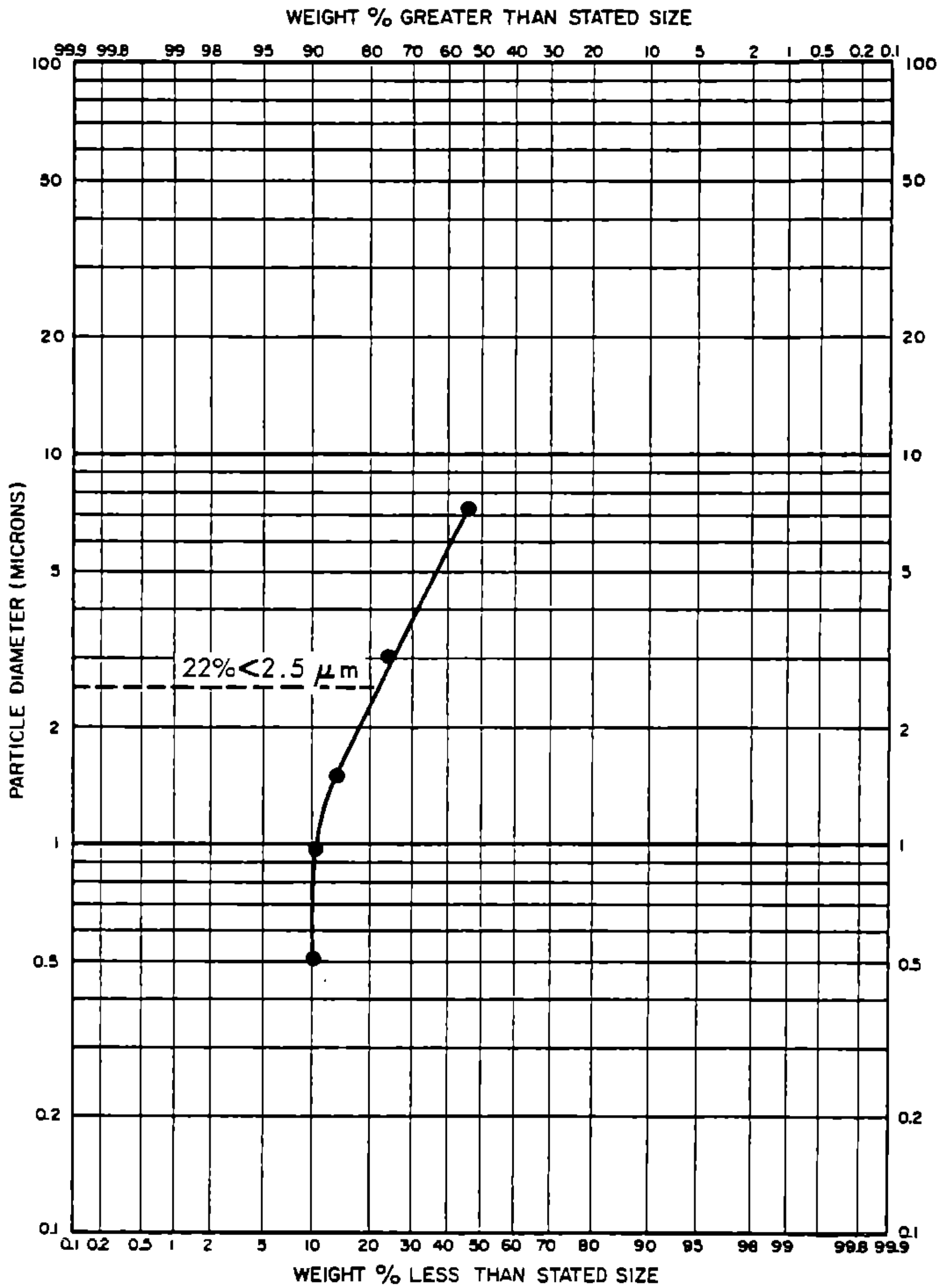


Figure 17. Particle size distribution of IP at 2 m height for test N-3.

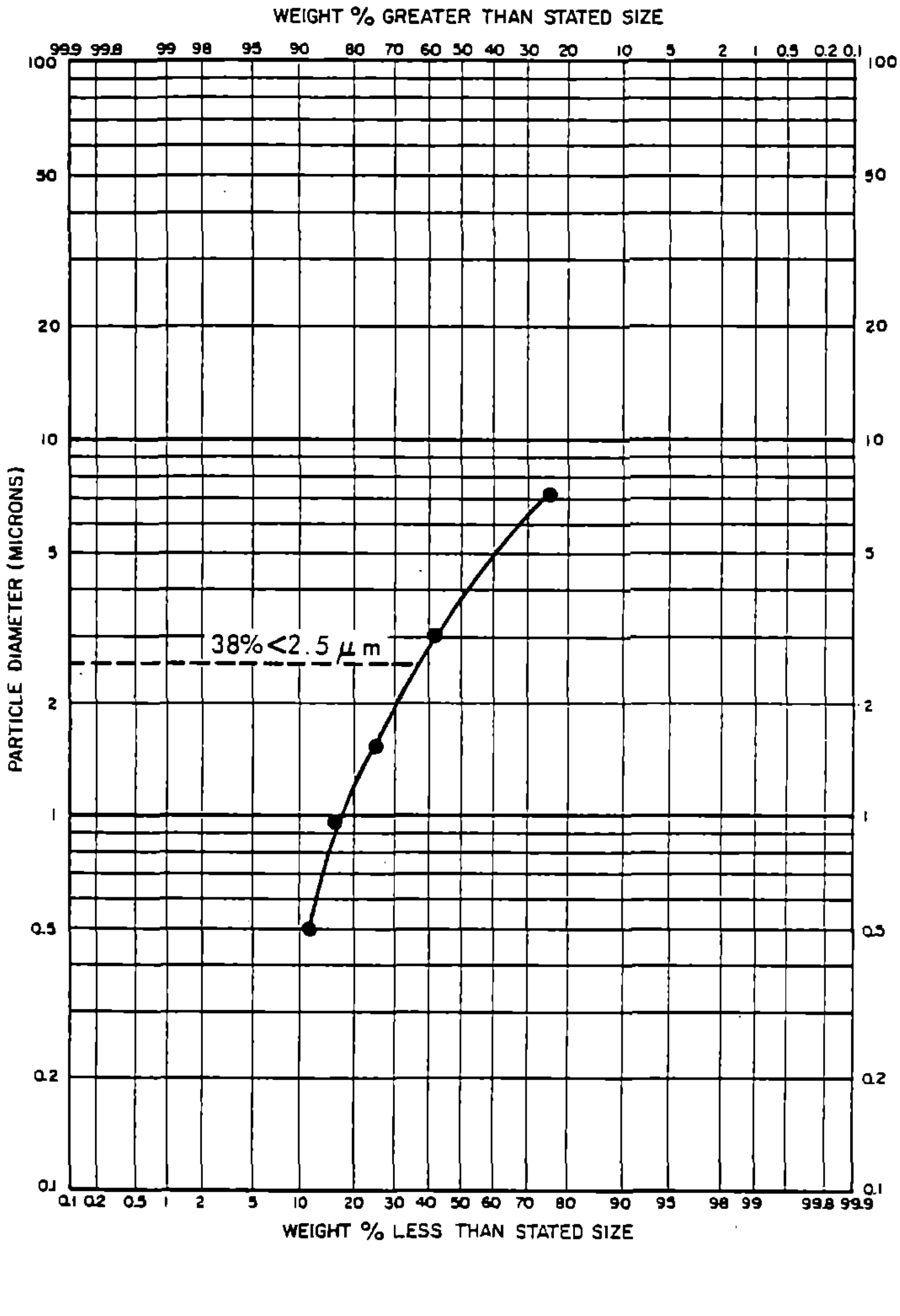


Figure 18. Particle size distribution of IP at 2 m height for test N-4.

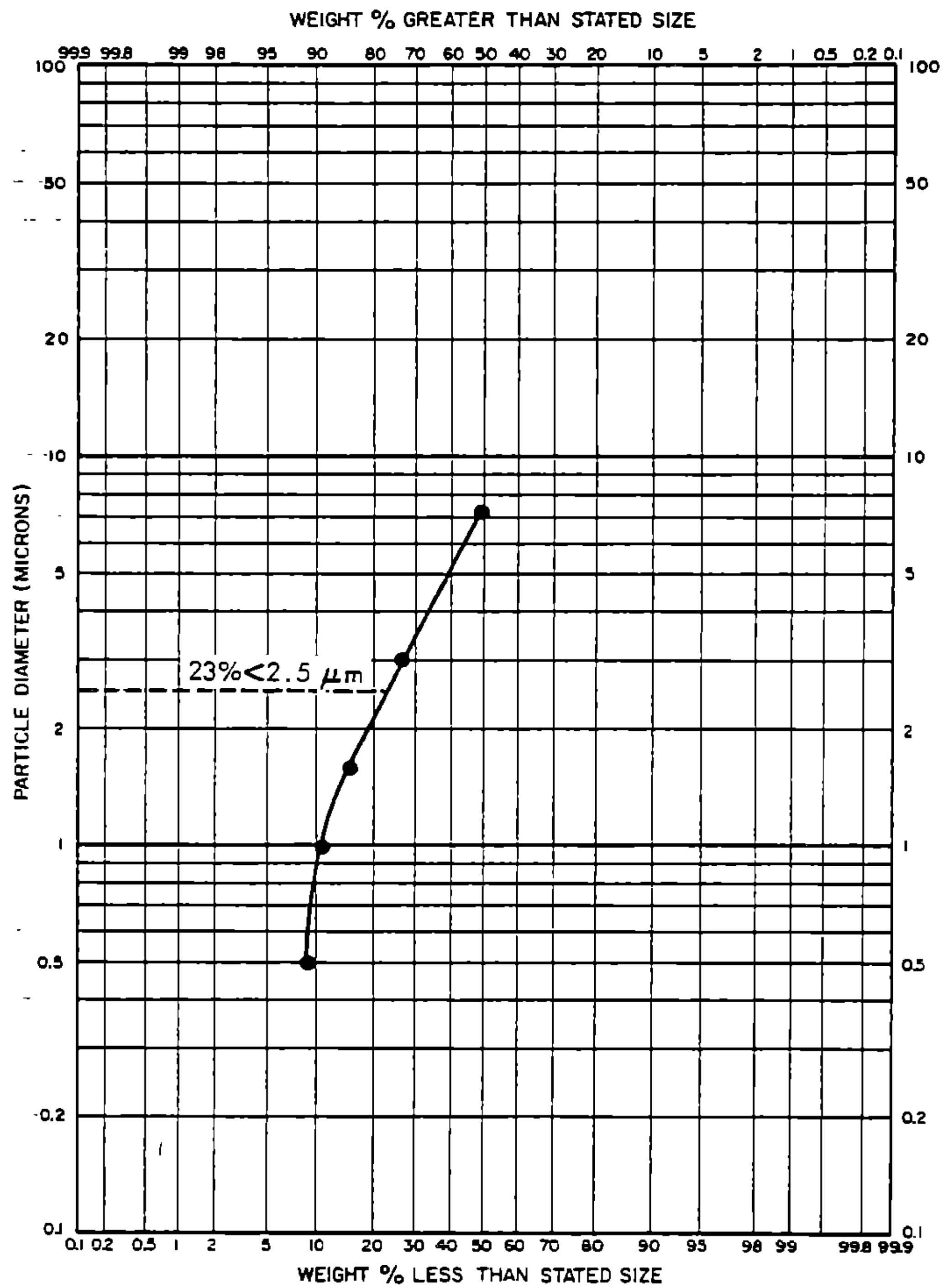


Figure 19. Particle size distribution of IP at 1 m height for test N-5.

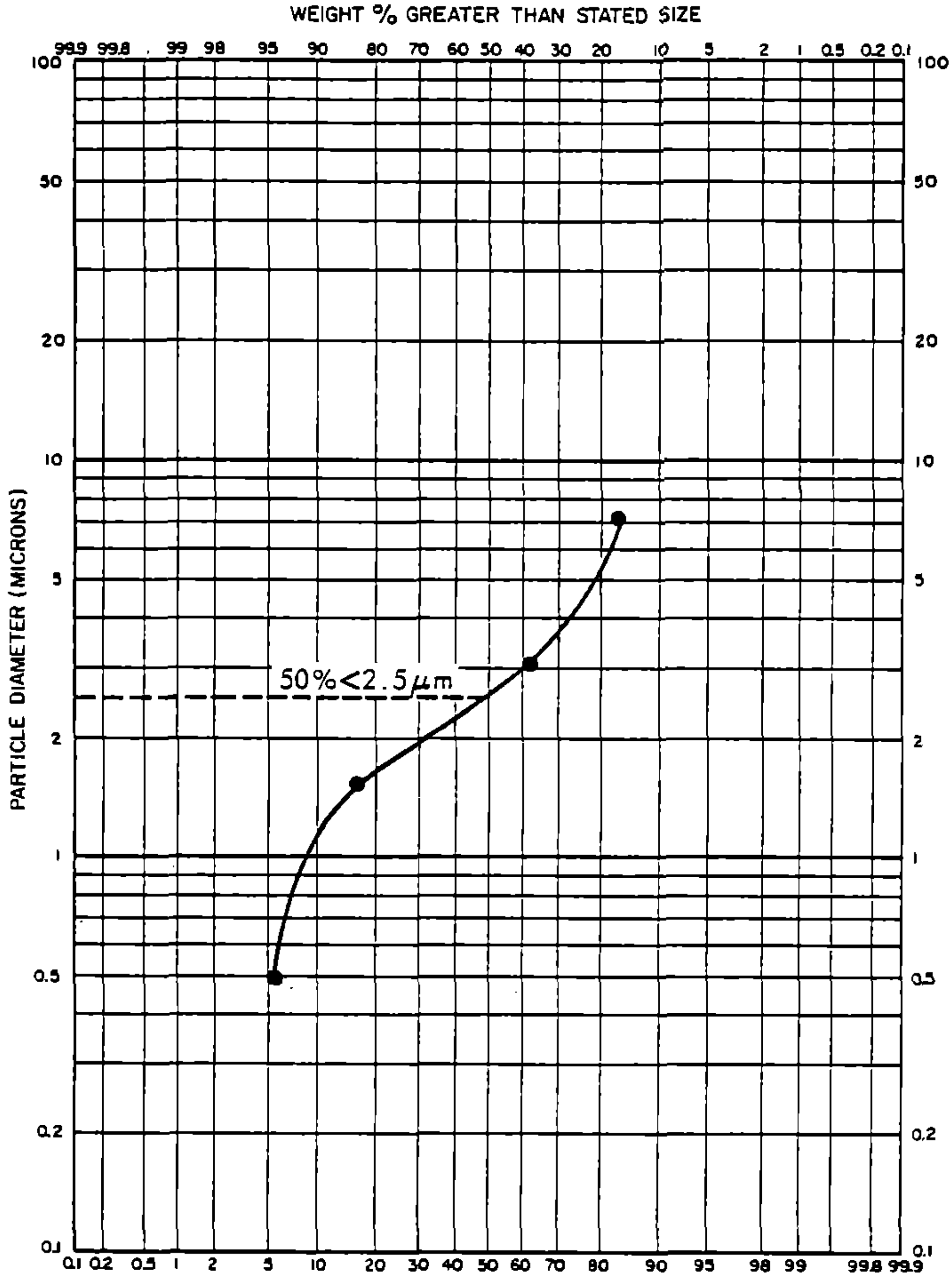


Figure 20. Particle size distribution of IP at 3 m height for test N-5.

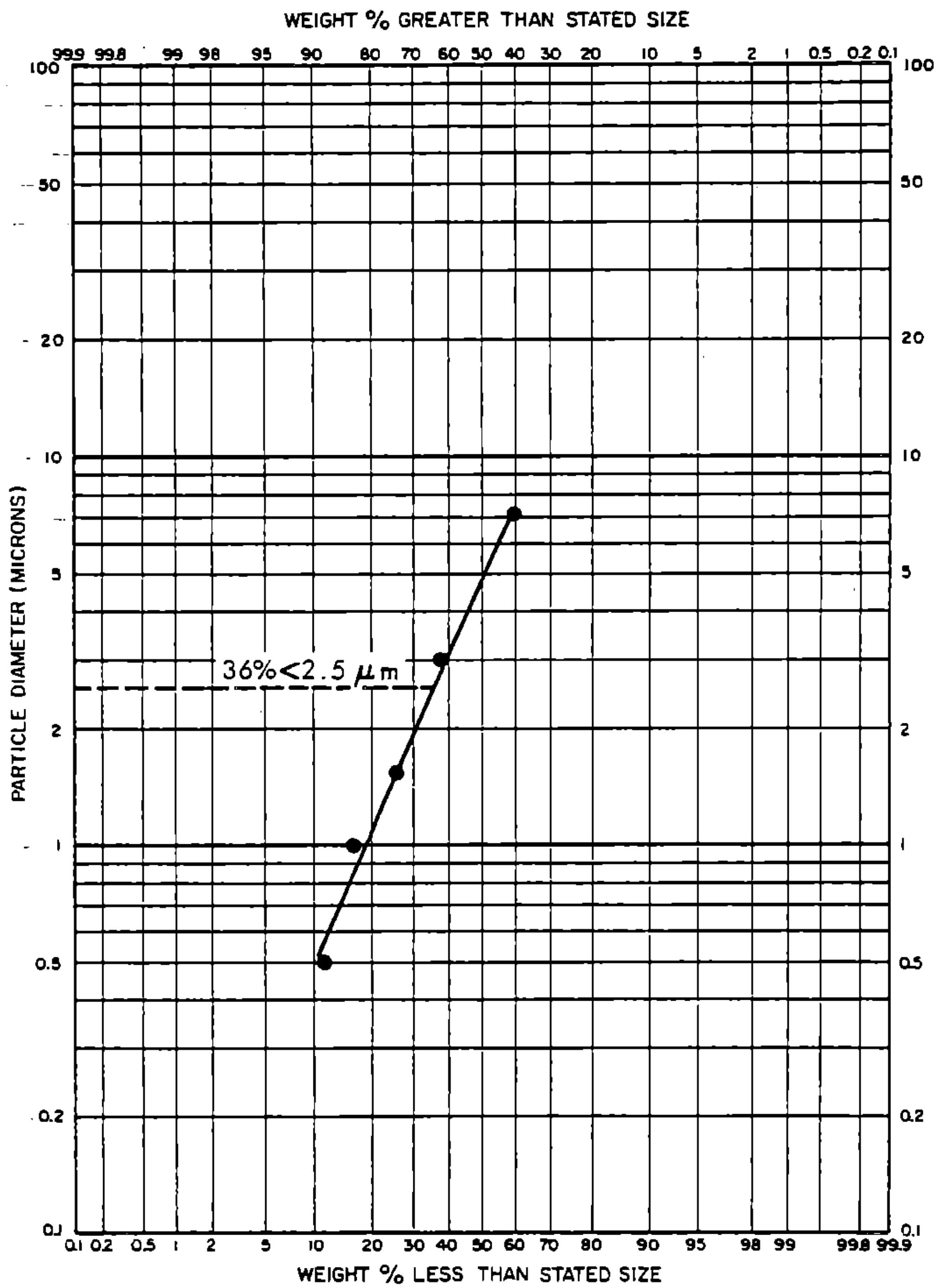


Figure 21. Particle size distribution of IP at 1 m height for test N-6.

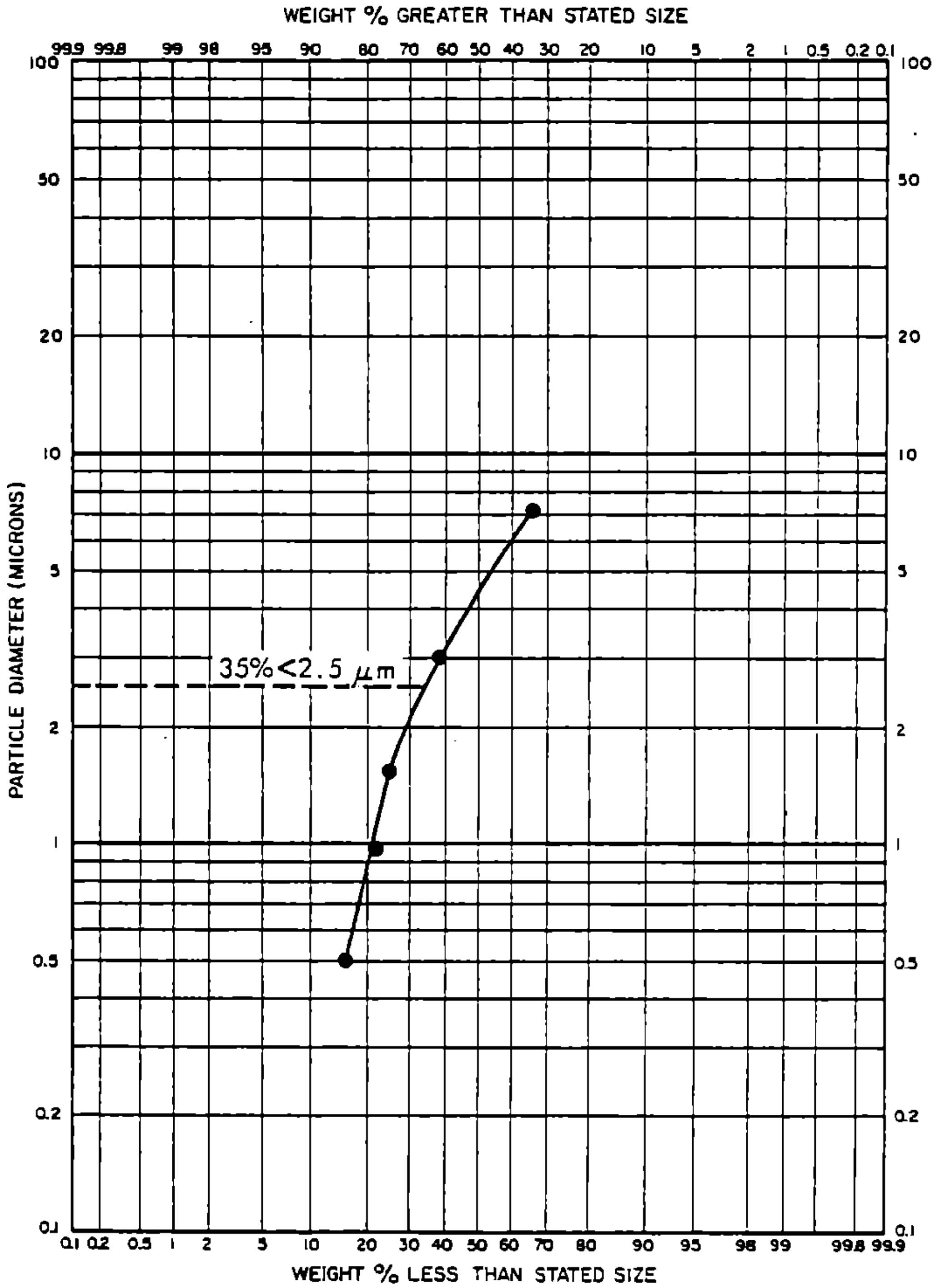


Figure 22. Particle size distribution of IP at 3 m height for test N-6.

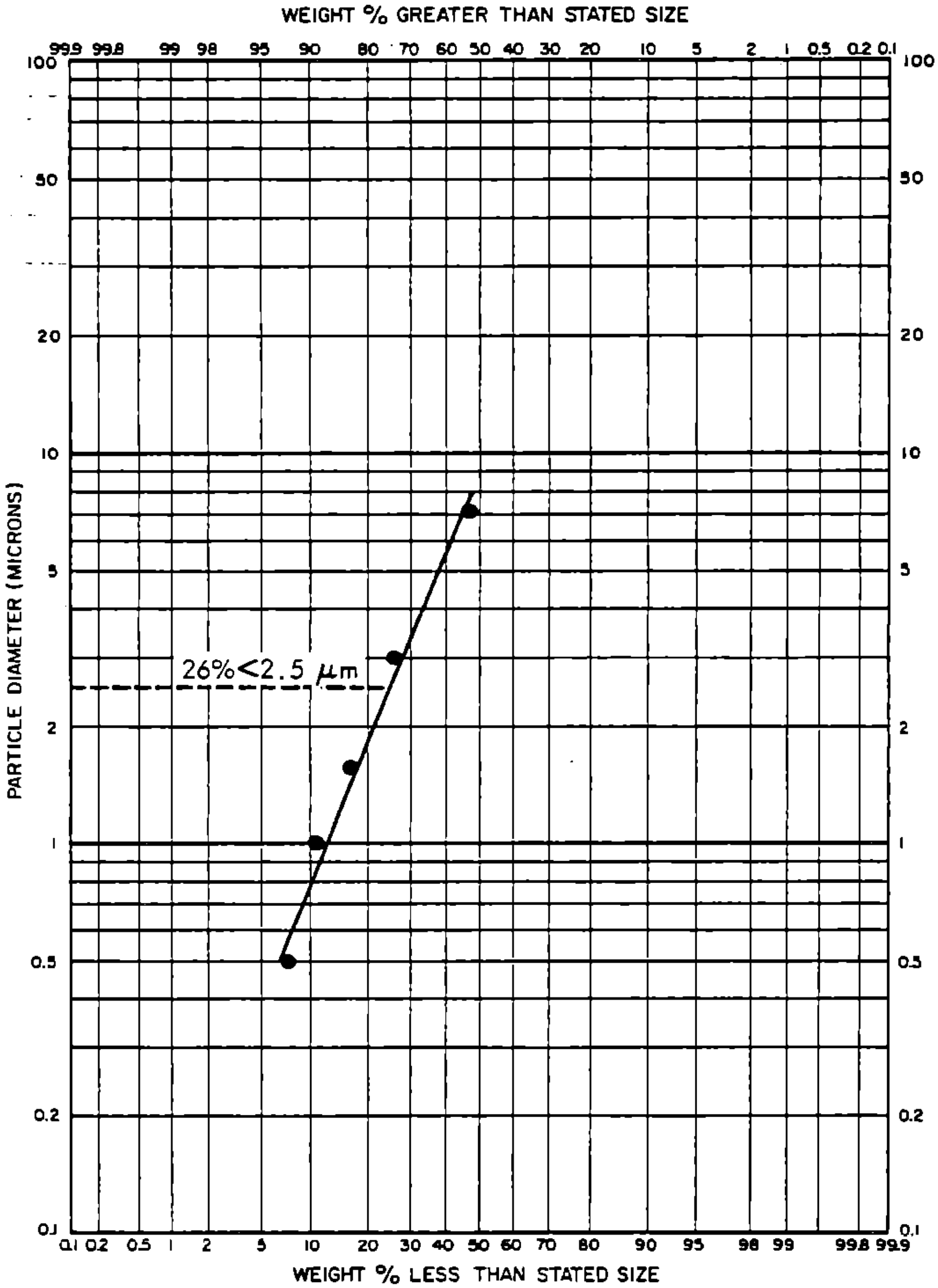


Figure 23. Particle size distribution of IP at 2 m height for test N-7.

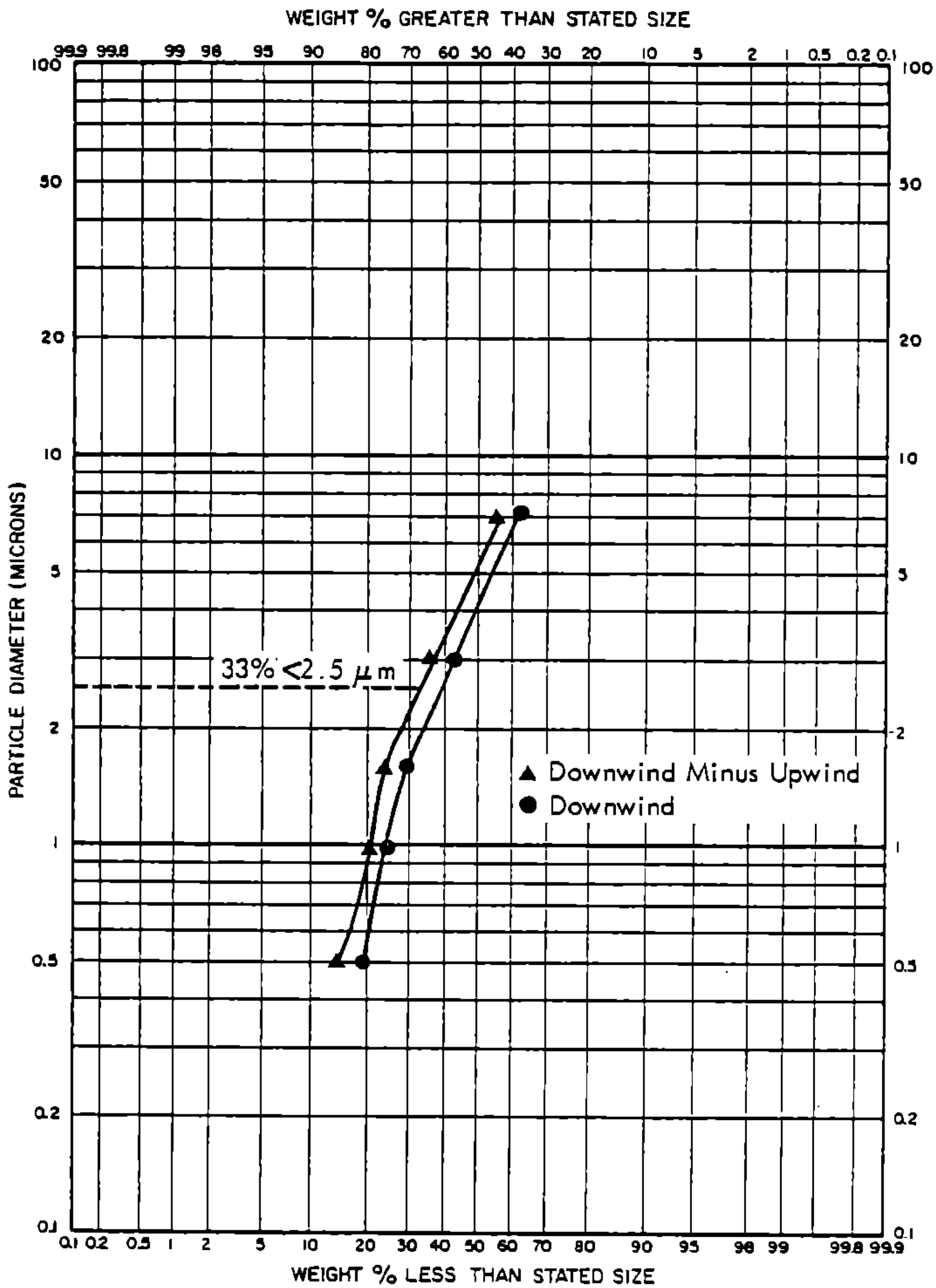


Figure 24. Particle size distribution of IP at 2 m height for test N-8.

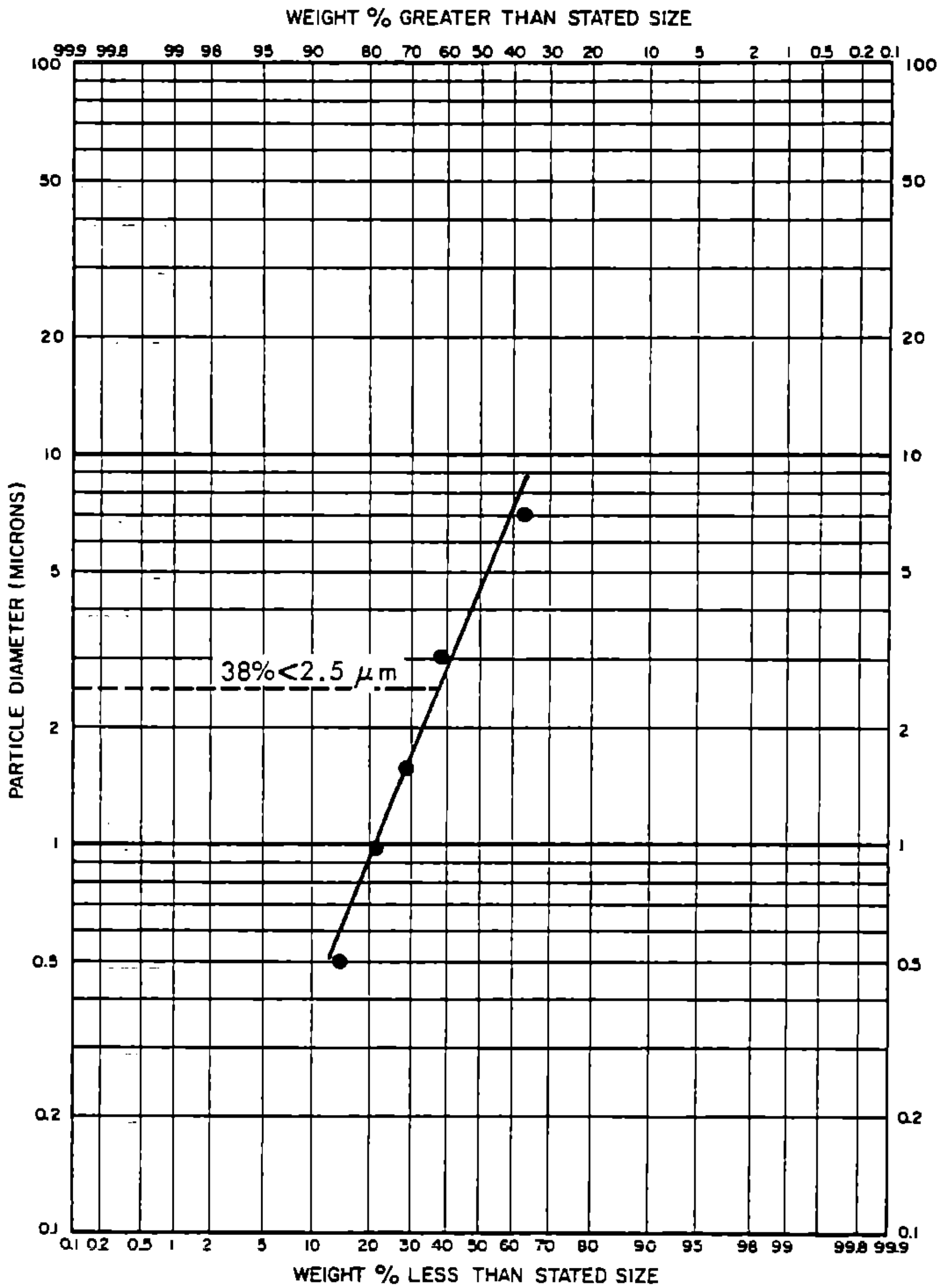


Figure 25. Particle size distribution of IP at 2 m height for test N-9.

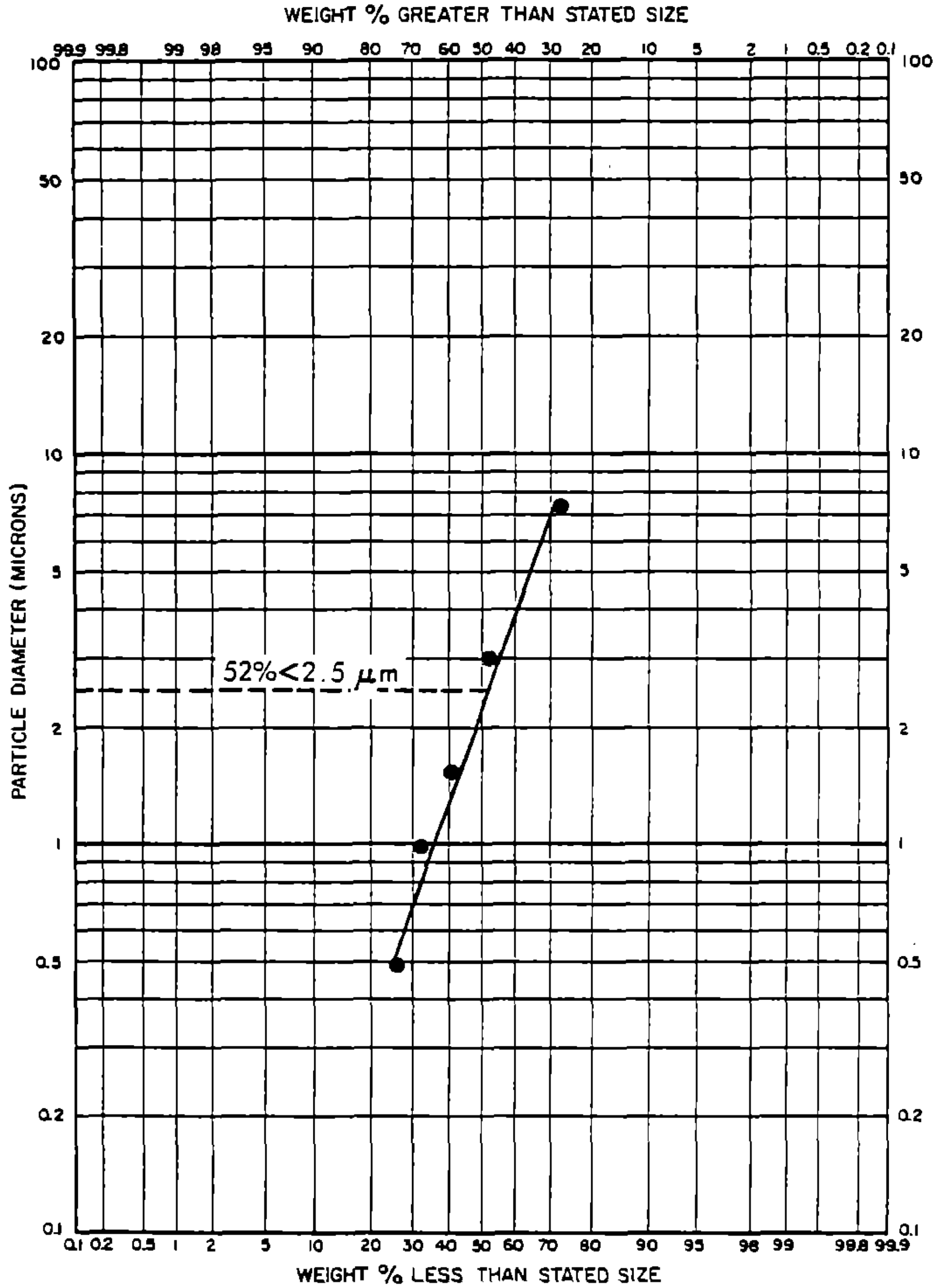


Figure 26. Particle size distribution of IP at 1 m height for test N-10.

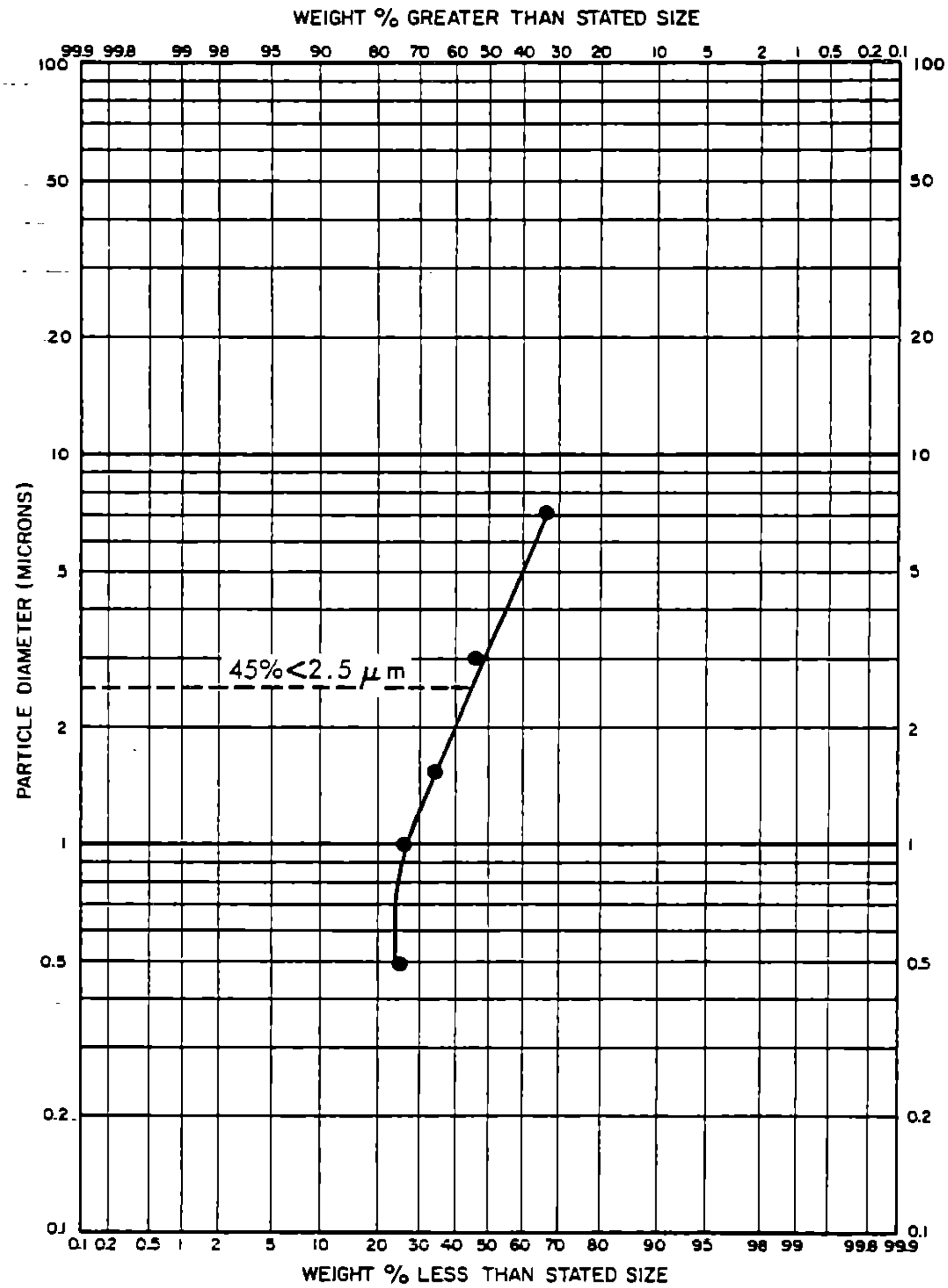


Figure 27. Particle size distribution of IP at 3 m height for test N-10.

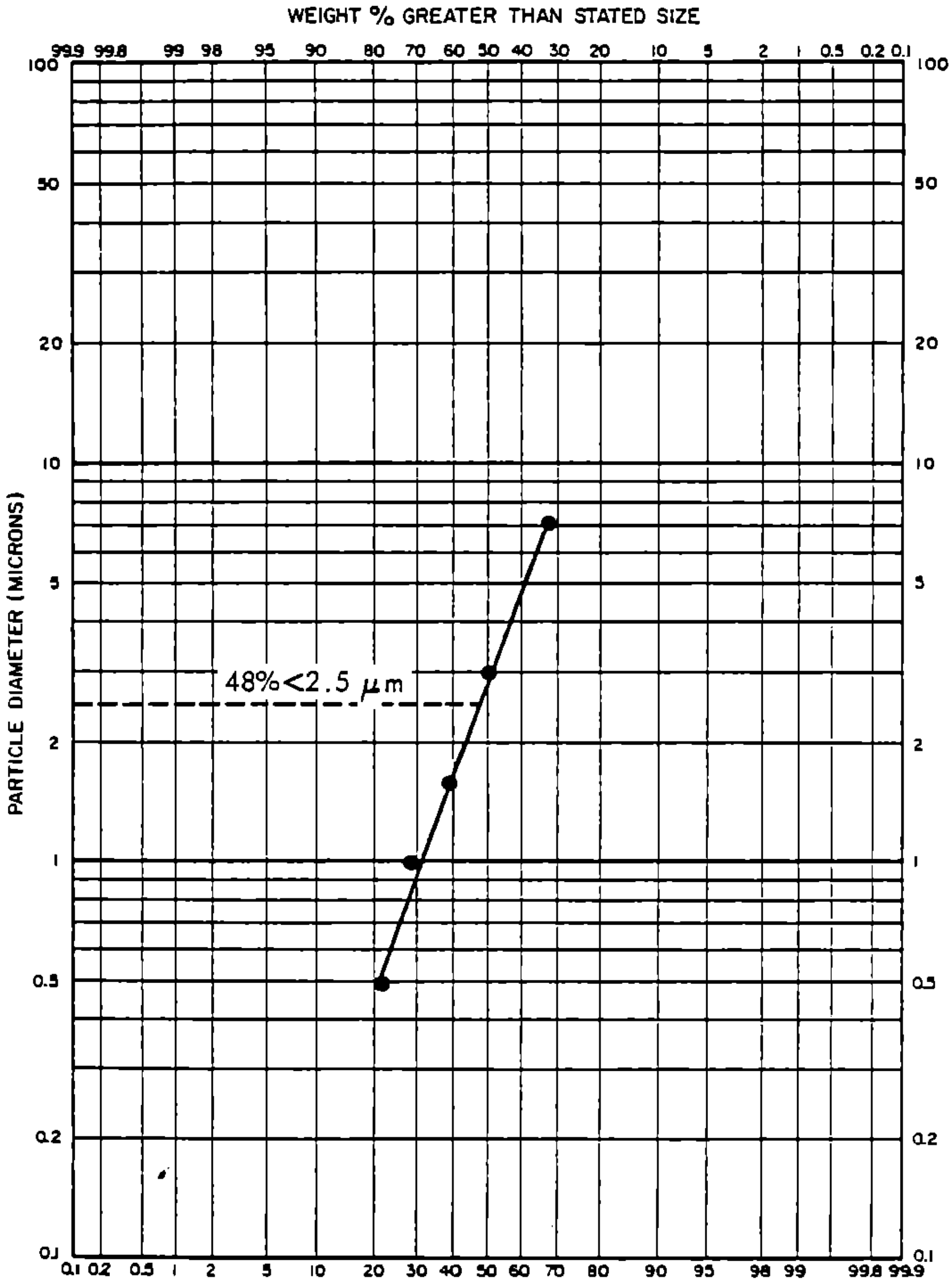


Figure 28. Particle size distribution of IP at 1 m height for test N-11.

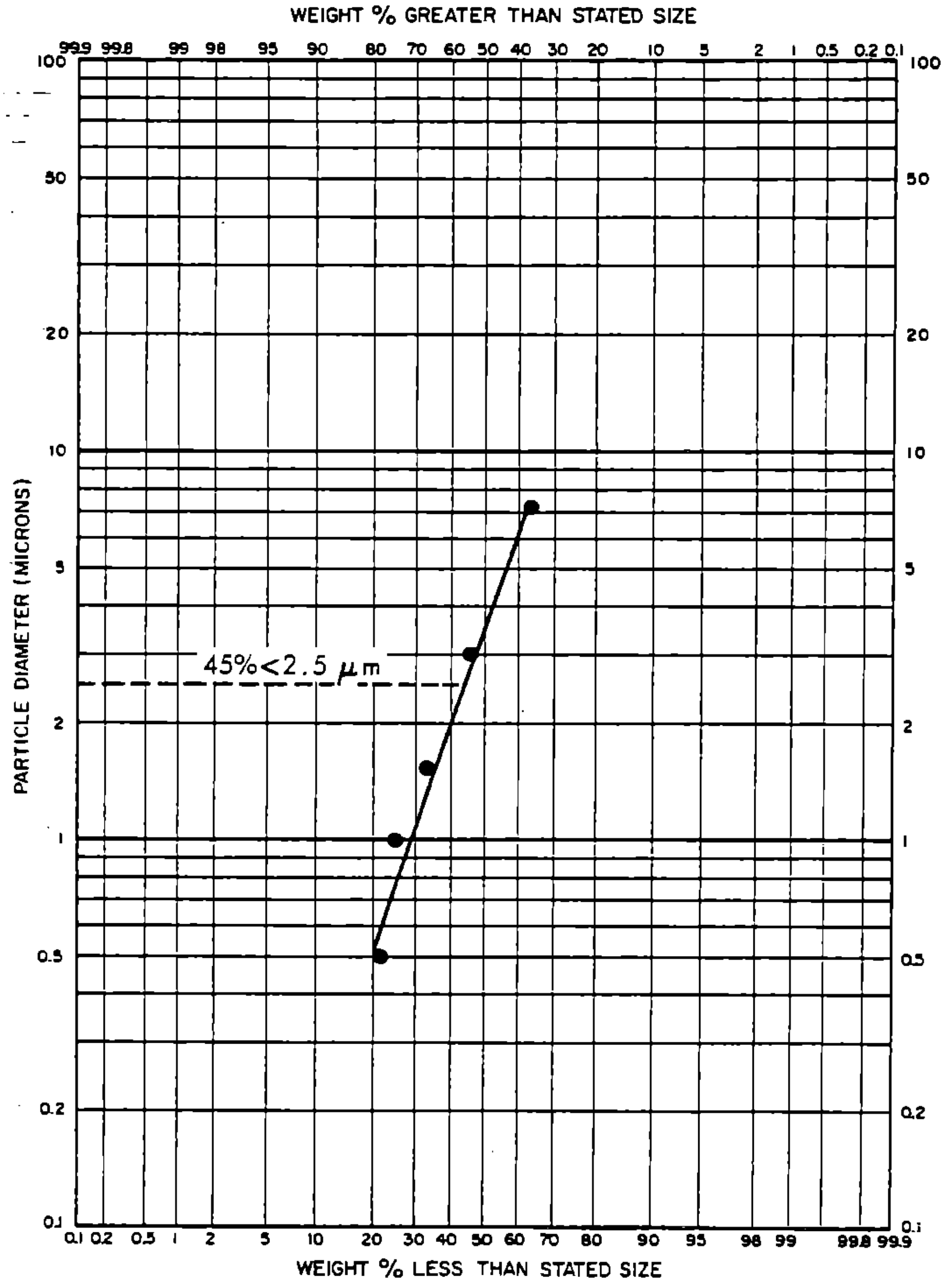


Figure 29. Particle size distribution of IP at 2 m height for test N-12.

A sample was collected on a 37-mm Millipore filter contiguous to the SSI/CI combination for the purpose of determining the largest particle by microscopic analysis. Knowledge of the largest particle size was necessary to calculate the particle size distribution of TP which was in turn necessary for determination of isokinetically correct TP concentrations. In the laboratory the Millipore filter was rendered transparent with immersion oil. The 20 particles which appeared to be among the largest were identified via a thorough scan of the filter, and their diameters were determined. The largest particle from among these 20 was then identified. Table 25 presents the results of the microscopic analysis.

3.3.2 Soil Preparation Operations--Emission Factor Calculation Procedure

Given the measured data shown in Section 3.3.1, the following calculation procedures were employed: (a) determination of the particle size distribution and the largest particle size as a function of height; (b) correction of the TP concentrations measured by the exposure profiler to represent isokinetically sampled concentrations; (c) calculation of exposure as a function of height and subsequent integration of exposure versus height; and (d) calculation of size-specific emission factors given the width of each implement pass, the total number of passes, and the size specific integrated exposure.

3.3.2.1 Determination of Particle Size as a Function of Height--

Since particle size distribution varies with height in a plume generated by an agricultural operation, the distribution measured adjacent to TP samplers located at the 2 m or at the 1 and 3 m heights had to be extrapolated to the heights at which other TP samplers were located i.e., 1, 3, 4 m, or 2 and 4 m. It was for this reason that particle size distributions were measured at two heights during one of each triplicate set of tests of emissions from soil preparation operations.

The equation for a line was calculated given the percentage of TP composed of IP at 1 and 3 m. The same procedure was performed for FP. The percent of TP composed of IP and the percent of TP composed of FP were then calculated at the two heights where they were not measured, i.e., 2 and 4 m.

The slopes of the lines were then applied to the other two tests in the triplicate set in which particle sizing was performed at only one height. Knowing the slope and the coordinates of a single point, the intercepts of the lines for percent of TP composed of IP and percent of TP composed of FP versus height were then calculated. This procedure defined the equations of two lines from which the percents of TP composed of IP and FP were calculated at 1, 3, and 4 m.

The largest particle size as a function of height also had to be estimated for heights at which there were no measurements. Since this variable was never measured at two heights during any one test, the variation with height had to be estimated. Given the largest particle size at 2 m as shown in Table 25, the largest particle size at 1, 3, and 4 m was estimated by assuming a negative slope of 10 to 25 μm per meter of height.

TABLE 25. RESULTS OF MICROSCOPIC ANALYSIS[a]

Test	Largest Particle Size[b] (μm)	Largest Aerodynamic Particle size[c] (μm)
N-1	40	56
N-2	-	47[d]
N-3	28	40
N-4	53	75
N-5	40	56
N-6	28	40
N-7	38	54
N-8	55	78
N-9	-	95[d]
N-10	-	95[d]
N-11	80	113
N-12	-	95[d]
N-13	-	95[d]

[a] Measurements taken at 5 m downwind and 2 m height.

[b] Physical diameter as observed visually.

[c] Diameter of a particle of density 1 g/cc which behaves aerodynamically in an equivalent fashion to the soil particles of density 2 g/cc and observed physical diameter.

[d] Filters did not have enough sample to perform a microscopic analysis. This value was a calculated average of the largest aerodynamic particle sizes observed in samples of a similar source.

3.3.2.2 Isokinetic Correction of TP Concentrations--

Nonisokinetically measured TP concentrations were corrected to isokinetic conditions using the following equation:

$$C_{iso} = C_{noniso} *[(FS + FI/2) + (1 - FL + FI/2)* FR] \qquad (1)$$

where C_{iso} = isokinetically corrected concentration

C_{noniso} = nonisokinetically measured concentration

FS = mass fraction of particles smaller than 5 μm in aerodynamic diameter

FI = mass fraction of particles between 5 and 50 μm in aerodynamic diameter

FL = mass fraction of particles less than 50 μm in aerodynamic diameter

FR = flow ratio which equals the sampling speed divided by the wind speed

The above equation assumes the following:

1. The concentration of particles smaller than 5 μm in aerodynamic diameter is not affected by nonisokinetic sampling.

2. The concentration of particles larger than 50 μm in aerodynamic diameter is affected by nonisokinetic sampling and is related linearly to the ratio of sampling speed to wind speed.

3. Half the mass of the particles between 5 and 50 μm in aerodynamic diameter behaves like particles less than 5 μm and half like particles greater than 50 μm.

Equation 1 is a simplified version of a much more complicated equation proposed by C. N. Davies.[7] Davies equation allowed the calculation of an isokinetic concentration (C_{iso}) given a measured nonisokinetic concentration (C_{noniso}), a flow rate (FR), and an inertial impaction parameter. The equation was basically designed to be applied to a monodisperse aerosol. Since fugitive emissions are polydisperse, the theory of Davies' equation was utilized by MRI to develop Equation 1 which is applicable to polydisperse aerosols.

From the above equation, it should be observed that the percentage less than 5 and 50 μm is needed to correct the nonisokinetic TP concentration. However, a change in the TP concentration alters the percentage less than 5 and 50 μm. Therefore, it can be seen that the correction procedure is of an iterative nature. MRI developed a computer program called NONISO to perform this iterative procedure.

3.3.2.3 Calculation and Integration of Exposure as a Function of Height--

The exposure (horizontal flux) at each height was calculated via the following equation:

$$E_i = C_i U_i T \tag{2}$$

where E_i = exposure or horizontal flux at height i (mass/area)

C_i = isokinetically measured or calculated concentration at height i (mass/volume)

U_i = horizontal wind speed at height i (length/time)

T = sampling time

The total horizontal flux per unit sampling width (E_T) is then calculated from the following equation:

$$E_T = \int_0^H E_i dh \tag{3}$$

where H = height of the plume

The height of the plume was determined by extrapolating a least-squares fit line through a plot of TP exposure versus height to the point where the exposure equaled zero. In addition to the four points where horizontal flux was measured and the extrapolated fifth point (0, H), a sixth point (0, 0) was added since the horizontal wind speed and consequently, the flux, is zero at the ground. The area under the curve was determined by integration using Simpson's Rule.

3.3.2.4 Calculation of Emission Factors--

The emission factor (EF) for agricultural operations was calculated using the following equation:

$$EF = \frac{E_T \text{ (mass/length)}}{N \times W \text{ (length)}} \tag{4}$$

where N = the number of passes
W = width of implement

The emission factor for unpaved roads was calculated as follows:

$$EF = \frac{E_T \text{ (mass/length)}}{N} \tag{5}$$

The values used to calculate the emission factors and the resulting emission factors for TP, IP, and FP are shown in Table 26.

TABLE 26. EMISSION FACTORS FOR SOIL PREPARATION OPERATIONS

Test	Integrated area under exposure profile curve (mg/cm)			No. of passes	Width of implement m (ft)	Emission factors[a]		
	TP	IP	FP			TP	IP	FP
N-1	524	185	75.3	25	-	832 (7.43)	293 (2.62)	120 (1.07)
N-2[b]	-	-	-	-	-	-	-	-
N-3	1,700	226	59	15	4.88 (16.0)	2,320 (20.7)	309 (2.76)	80.5 (0.719)
N-4	1,900	213	85	15	4.88 (16.0)	2,600 (23.2)	291 (2.60)	116 (1.04)
N-5	1,840	169	100	15	4.88 (16.0)	2,520 (22.5)	231 (2.06)	137 (1.22)
N-6	1,440	299	106	10	4.88 (16.0)	2,960 (26.4)	613 (5.47)	217 (1.94)
N-7	1,060	313	78.4	8	4.88 (16.0)	2,720 (24.3)	797 (7.12)	200 (1.79)
N-8	382	48.5	17.9	15	4.88 (16.0)	522 (4.66)	66.2 (0.591)	24.4 (0.218)
N-9	591	259	94.0	14	4.88 (16.0)	865 (7.72)	379 (3.38)	138 (1.23)
N-10	1,120	442	214	14	4.88 (16.0)	1,630 (14.6)	646 (5.77)	314 (2.80)
N-11	1,180	395	182	15	4.88 (16.0)	1,610 (14.4)	540 (4.82)	249 (2.22)
N-12	953	264	125	15	4.88 (16.0)	1,300 (11.6)	361 (3.22)	170 (1.52)
N-13	764	282	137	14	4.88 (16.0)	1,120 (9.98)	412 (3.68)	200 (1.79)

a Units are as follows: Test N-1 - kg/vehicle-km (lb/VMT), Tests N-3 through N-13 - kg/km^2 (lb/acre).

b Winds were too erratic to provide meaningful data.

3.3.3 Harvesting Operations--Measured Values

Along with the test dates and locations, the harvesting operations tested are shown in Table 27. The seven tests were conducted in early October in the Delta area of Sacramento County. The operations tested involved the beating of the leaves from sugar beets followed by the digging up of the beets.

The sugar beet leaf beater which was tested is an implement which beats the leaves from two rows of sugar beets per pass. The leaf removal is accomplished with 5 cm (1.97 in.) wide plastic strapes 3 mm (0.118 in.) thick. The strapes are attached to a rotating shaft, and the entire assembly enclosed in a box with an open bottom. The strapes were not observed to be striking the soil nor the top of the sugar beet which protruded approximately 5 cm (1.97 in.) from the soil.

Sugar beet harvesting was accomplished by an implement which used dual discs to dig up the sugar beet and convey it to an adjacent trailer being pulled by a truck tractor at the same speed as the implement was being pulled by the farm tractor.

The emissions were sampled during each pass of the tractor and implement upwind of the profiling equipment. The number and quality of the passes along with the width of the pass (identical to the width of the implement) are shown in Table 28. The quality ratings for the winds during each pass were described in Section 3.3.1. Since the winds were very light and variable (much of the state was under atmospheric stagnation conditions), a few of the tests had a large percentage of marginal or bad passes.

The measured concentrations from all the deployed equipment for each test are shown in Tables 29 through 35. Also shown is whether the TP samples were collected isokinetically ($0.8 \leqq FR \leqq 1.2$).

The particle size distribution of IP is shown in Figures 30 through 35. The figures show only the distribution of IP and not of TP, since the cascade impactor was mounted beneath a size-selective inlet. The figures show a plot of aerodynamic particle diameter versus weight percent less than the stated size. Finally, the figures show that approximately half of the IP generated by sugar beet harvesting operations is FP.

A sample was collected on a 37-mm Millipore filter contiguous to the SSI/CI combination for the purpose of determining the largest particle by microscopic analysis. The analytical procedure was described in Section 3.3.1 and is, therefore, not repeated here. The results are shown in Table 36.

3.3.4 Harvesting Operations--Emission Factor Calculation Procedure

Given the measured data shown in Section 3.3.3, the calculation procedures described in Section 3.3.2 were employed. A slight deviation from the procedure was utilized to determine the variation of particle size distribution with height. None of the harvesting tests had particle sizing

TABLE 27. AGRICULTURAL FUGITIVE DUST TEST IDENTIFICATION--SUGAR BEET HARVESTING

Source	Run	Date	Location	Valley (county)
Leaf beater[a]	R-1(Pre)[b]	10/3/80	Hamatani Farm Walnut Grove, CA	Sacramento (Sacramento)
Leaf beater[a]	R-1	10/4/80	Hamatani Farm Walnut Grove, CA	Sacramento (Sacramento)
Leaf beater[a]	R-2	10/4/80	Hamatani Farm Walnut Grove, CA	Sacramento (Sacramento)
Lead beater[a]	R-3	10/4/80	Hamatani Farm Walnut Grove, CA	Sacramento (Sacramento)
Beet harvester[c]	R-4	10/5/80	Hamatani Farm Walnut Grove, CA	Sacramento (Sacramento)
Beet harvester[c]	R-5	10/5/80	Hamatani Farm Walnut Grove, CA	Sacramento (Sacramento)
Beet harvester[c]	R-6	10/5/80	Hamatani Farm Walnut Grove, CA	Sacramento (Sacramento)

[a] Two-wheel leaf beater pulled by four-wheel tractor at about 3 to 4 mph. The process is also called scalping (see the Glossary).

[b] During run R-1(Pre), only background concentrations were obtained since leaf beating operations were suspended before downwind concentrations could be measured.

[c] Two-wheel beet harvester (digs up sugar beets) pulled by four-wheel tractor at about 5 mph. An 18-wheel tractor trailer moved alongside the beet harvester.

TABLE 28. INFORMATION ON IMPLEMENT PASSES--HARVESTING OPERATIONS

Run	Number and quality of passes				Width of pass m (ft)
	Good	Marginal	Bad	Total	
R-1(Pre)[a]	0	0	0	0	-
R-1	6	3	1	10	2.1 (7)
R-2	7	0	0	7	2.1 (7)
R-3	5	2	0	7	2.1 (7)
R-4	5	0	0	5	4.6 (15)
R-5	5	6	0	11	4.6 (15)
R-6	3	0	1	4	4.6 (15)

[a] Obtained background sample only. Equipment did not make any passes.

TABLE 29. CONCENTRATION MEASUREMENTS DURING AGRICULTURAL OPERATIONS--BACKGROUND

Test Number: Pre R-1
Location: Walnut Grove, California
Source: Background measurement[a]
Test date: 10/3/80

Height (m)	Downwind distance (m)	Concentration ($\mu g/m^3$)	
		Hi-Vol	Hi-Vol with SSI and CI
2	485 (background)	144	
2	485 (background)		118

[a] During Run Pre R-1, only background concentrations were obtained since leaf beating operations were suspended before downwind concentrations could be measured.

TABLE 30. CONCENTRATION MEASUREMENTS DURING AGRICULTURAL OPERATIONS--LEAF BEATING

Test Number: R-1
Location: Walnut Grove, California
Source: Sugar beet leaf beater and tractor
Test date: 10/4/80

Height (m)	Downwind distance (m)	Concentration ($\mu g/m^3$)[a]		
		Hi-Vol	Hi-Vol with SSI and CI	Exposure profiler sampler[b]
2	485 (background)	219		
2	485 (background)		152	
2	5	1,594		
2	5		692	
1	5			2,833
2	5			6,064
3	5			1,164
4	5			1,482

[a] Actual measured concentration including contributions from background.

[b] Nonisokinetic concentration.

TABLE 31. CONCENTRATION MEASUREMENTS DURING AGRICULTURAL OPERATIONS--LEAF BEATING

Test Number: R-2
Location: Walnut Grove, California
Source: Sugar beet leaf beater and tractor
Test date: 10/4/80

Height (m)	Downwind distance (m)	Concentration ($\mu g/m^3$)[a] Hi-Vol	Hi-Vol with SSI and CI	Exposure profiler sampler[b]
2	485 (background)	219		
2	485 (background)		152	
2	5	2,661		
2	5		1,378	
1	5			3,539
2	5			2,054
3	5			1,203
4	5			707

[a] Actual measured concentration including contributions from background.

[b] Nonisokinetic concentration.

TABLE 32. CONCENTRATION MEASUREMENTS DURING AGRICULTURAL OPERATIONS--LEAF BEATING

Test Number: R-3
Location: Walnut Grove, California
Source: Sugar beet leaf beater and tractor
Test date: 10/4/80

Height (m)	Downwind distance (m)	Concentration ($\mu g/m^3$)[a] Hi-Vol	Hi-Vol with SSI and CI	Exposure profiler sampler[b]
2	485 (background)	219		
2	485 (background)		152	
2	5	2,560		
2	5		1,140	
1	5			6,615
2	5			2,703
3	5			1,645
4	5			1,149

[a] Actual measured concentration including contributions from background.

[b] Nonisokinetic concentration.

TABLE 33. CONCENTRATION MEASUREMENTS DURING AGRICULTURAL OPERATIONS--HARVESTING VIA DIGGING

Test Number: R-4
Location: Walnut Grove, California
Source: Sugar beet harvester and tractor
Test date: 10/5/80

Height (m)	Downwind distance (m)	Concentration ($\mu g/m^3$)[a]		
		Hi-Vol	Hi-Vol with SSI and CI	Exposure profiler sampler[b]
2	485 (upwind background)	49[c]		
2	485 (upwind) background		69	
2	5	849		
2	5		387	
1				3,220
2	5			1,147
3	5			966
4	5			782

a Actual measured concentration including contributions from background.

b Nonisokinetic concentration.

c Value suspect since filter was mounted incorrectly in sampling cartridge.

TABLE 34. CONCENTRATION MEASUREMENTS DURING AGRICULTURAL OPERATIONS--HARVESTING VIA DIGGING

Test Number: R-5
Location: Walnut Grove, California
Source: Sugar beet harvester and tractor
Test date: 10/5/80

Height (m)	Downwind distance (m)	Concentration ($\mu g/m^3$)[a]		
		Hi-Vol	Hi-Vol with SSI and CI	Exposure profiler sampler[b]
2	485 (upwind background)	49[c]		
2	485 (upwind background)		69	
2	5	1,365		
2	5		661	
1	5			2,178
2	5			1,796
3	5			1,316
4	5			1,292

a Actual measured concentration including contributions from background.

b Nonisokinetic concentration.

c Value suspect since filter was mounted incorrectly in sampling cartridge.

TABLE 35. CONCENTRATION MEASUREMENTS DURING AGRICULTURAL OPERATIONS--HARVESTING VIA DIGGING

Test Number: R-6
Location: Walnut Grove, California
Source: Sugar beet harvester and tractor
Test date: 10/5/80

Height (m)	Downwind distance (m)	Concentration ($\mu g/m^3$)[a]		
		Hi-Vol	Hi-Vol with SSI and CI	Exposure profiler sampler[b]
2	485 (background)	49[c]		
2	485 (background)		69	
2	5	1,819		
2	5		1,274	
1	5			3,285 (N)
2	5			2,955 (I)
3	5			2,518 (I)
4	5			1,647 (I)

[a] Actual measured concentration including contributions from background.

[b] N implies nonisokinetic sampling; I implies isokinetic sampling.

[c] Value suspect since filter was mounted incorrectly in sampling cartridge.

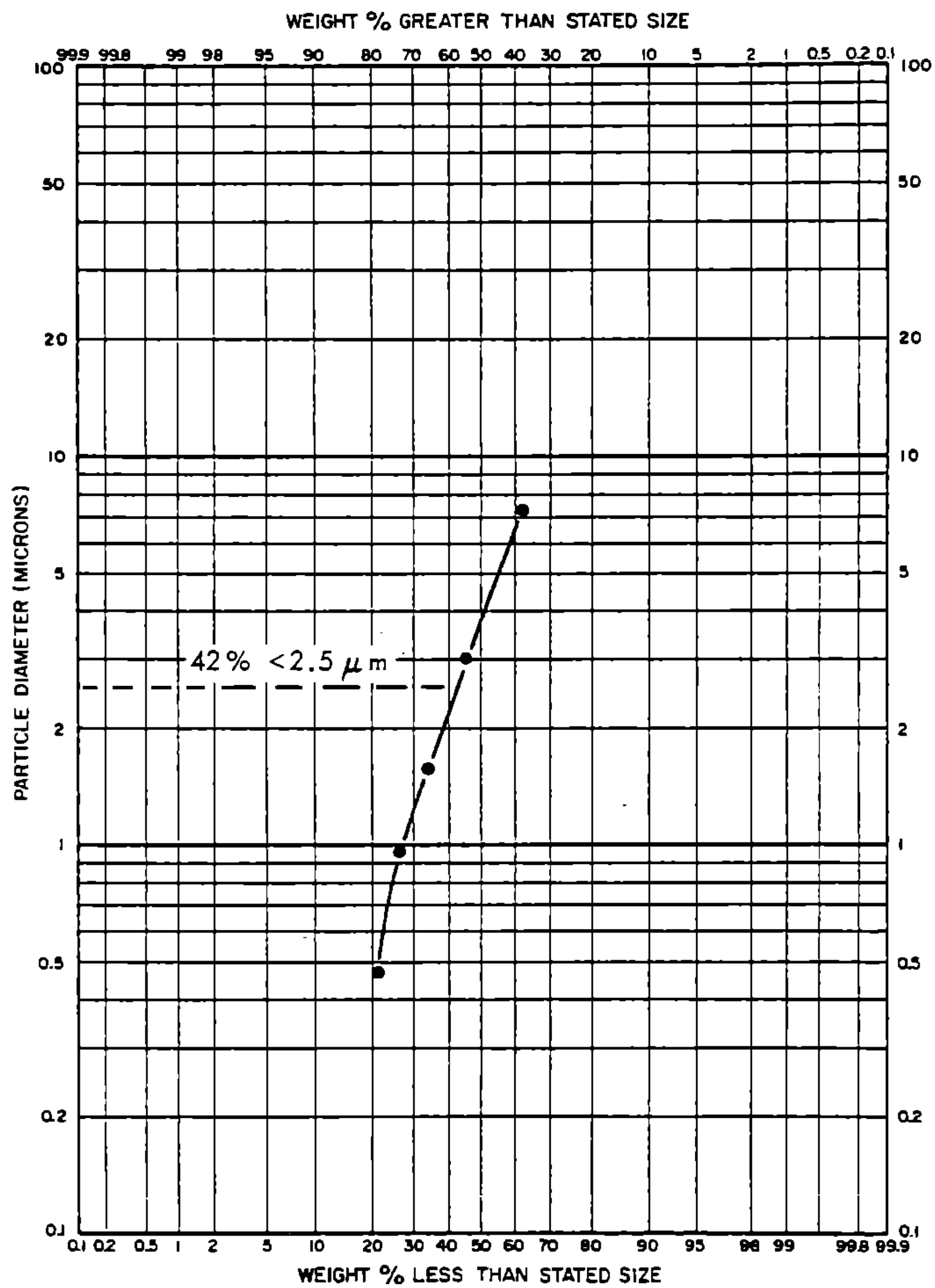


Figure 30. Particle size distribution of IP at 2 m height and 5 m downwind for test R-1.

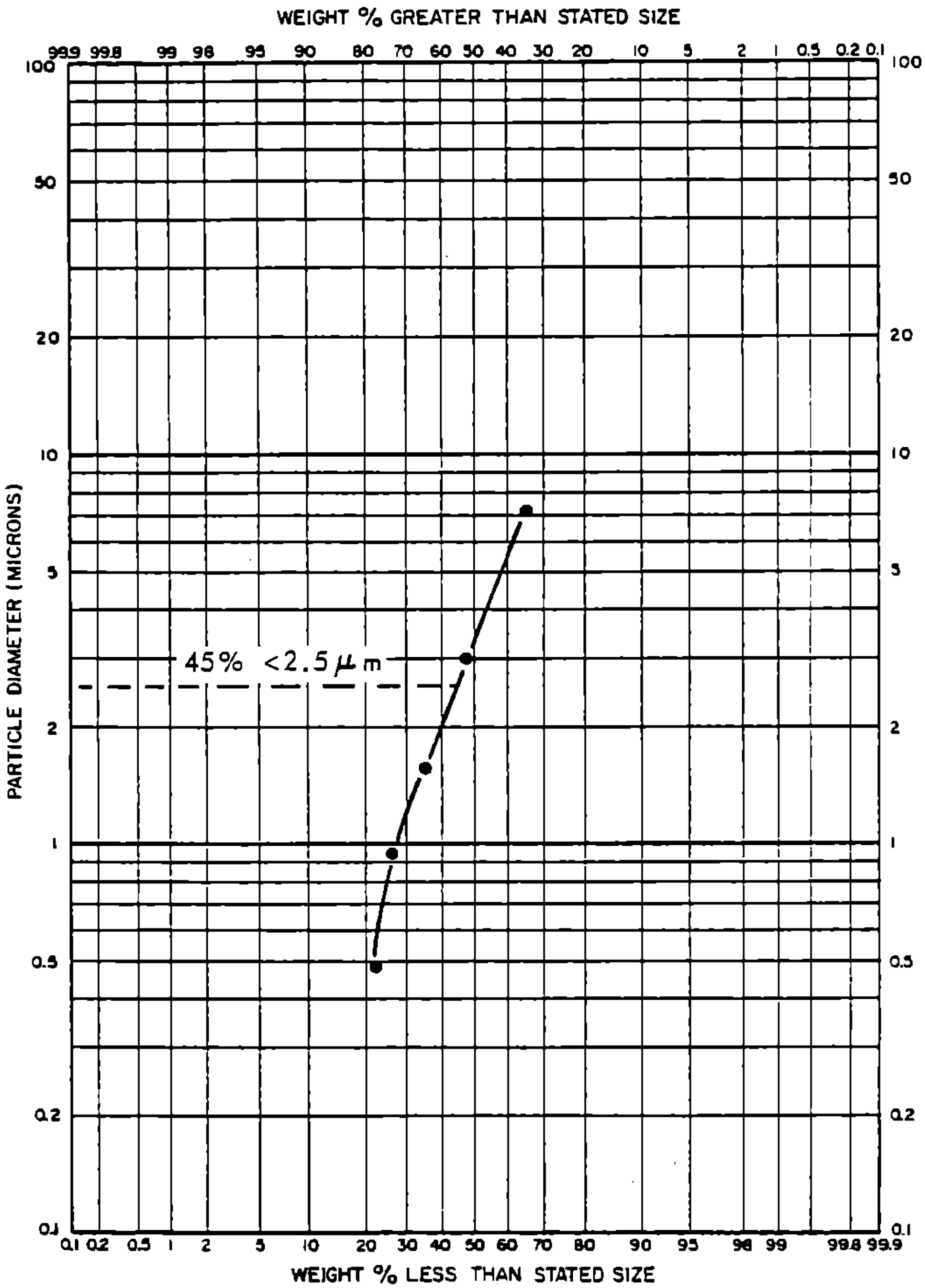


Figure 31. Particle size distribution of IP at 2 m height and 5 m downwind for test R-2.

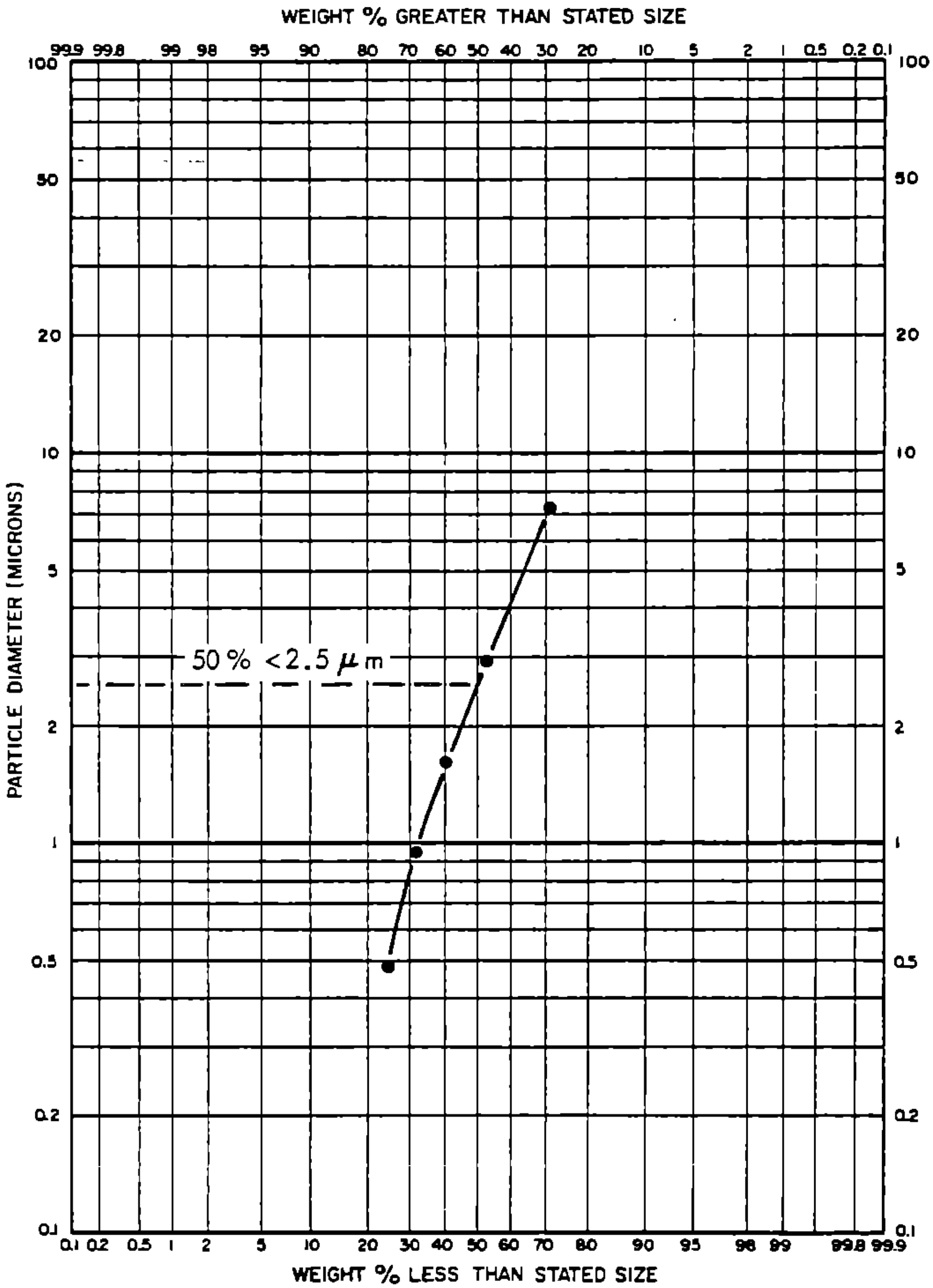


Figure 32. Particle size distribution of IP at 2 m height and 5 m downwind for test R-3.

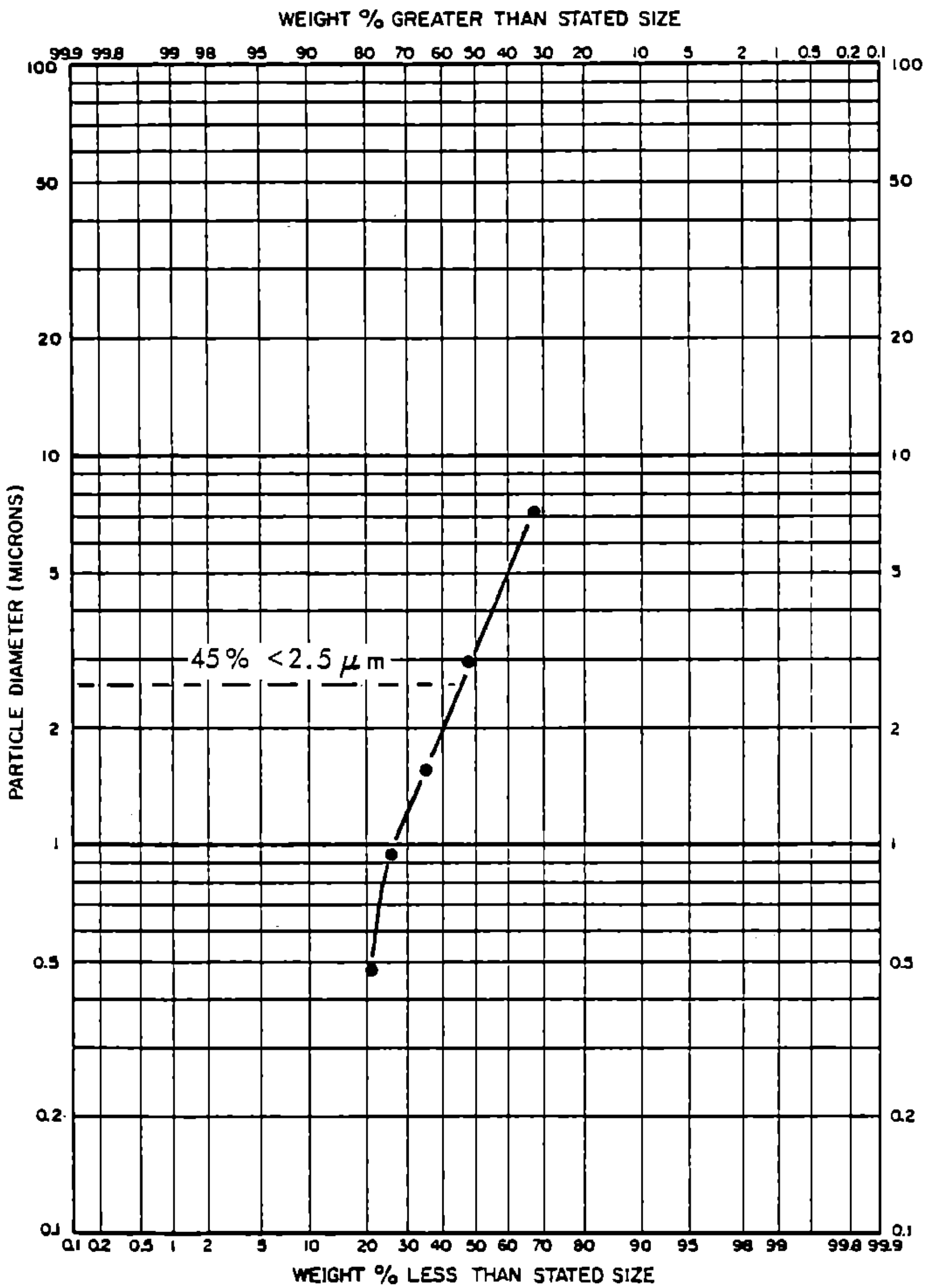


Figure 33. Particle size distribution of IP at 2 m height and 5 m downwind for test R-4.

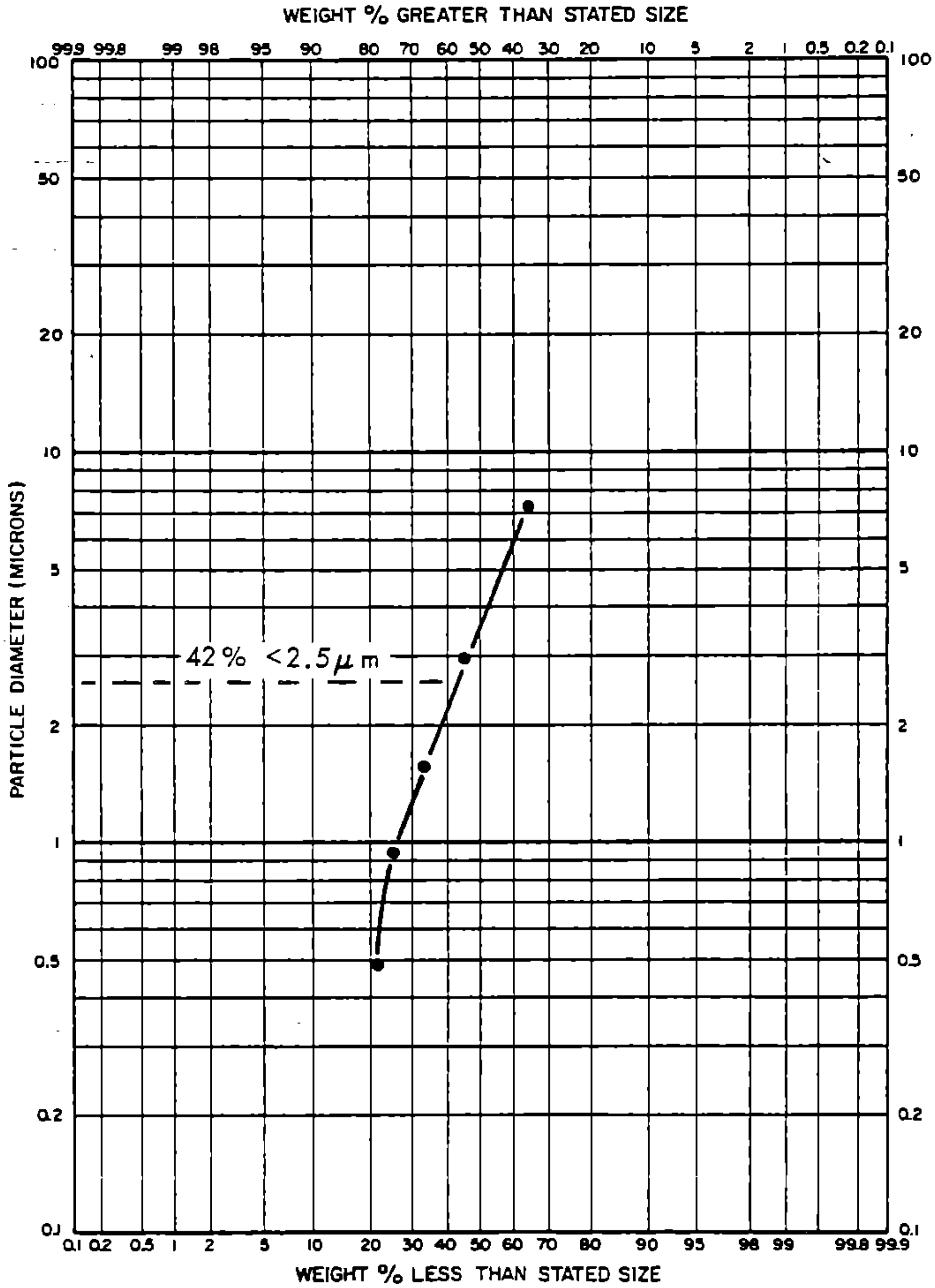


Figure 34. Particle size distribution of IP at 2 m height and 5 m downwind for test R-5.

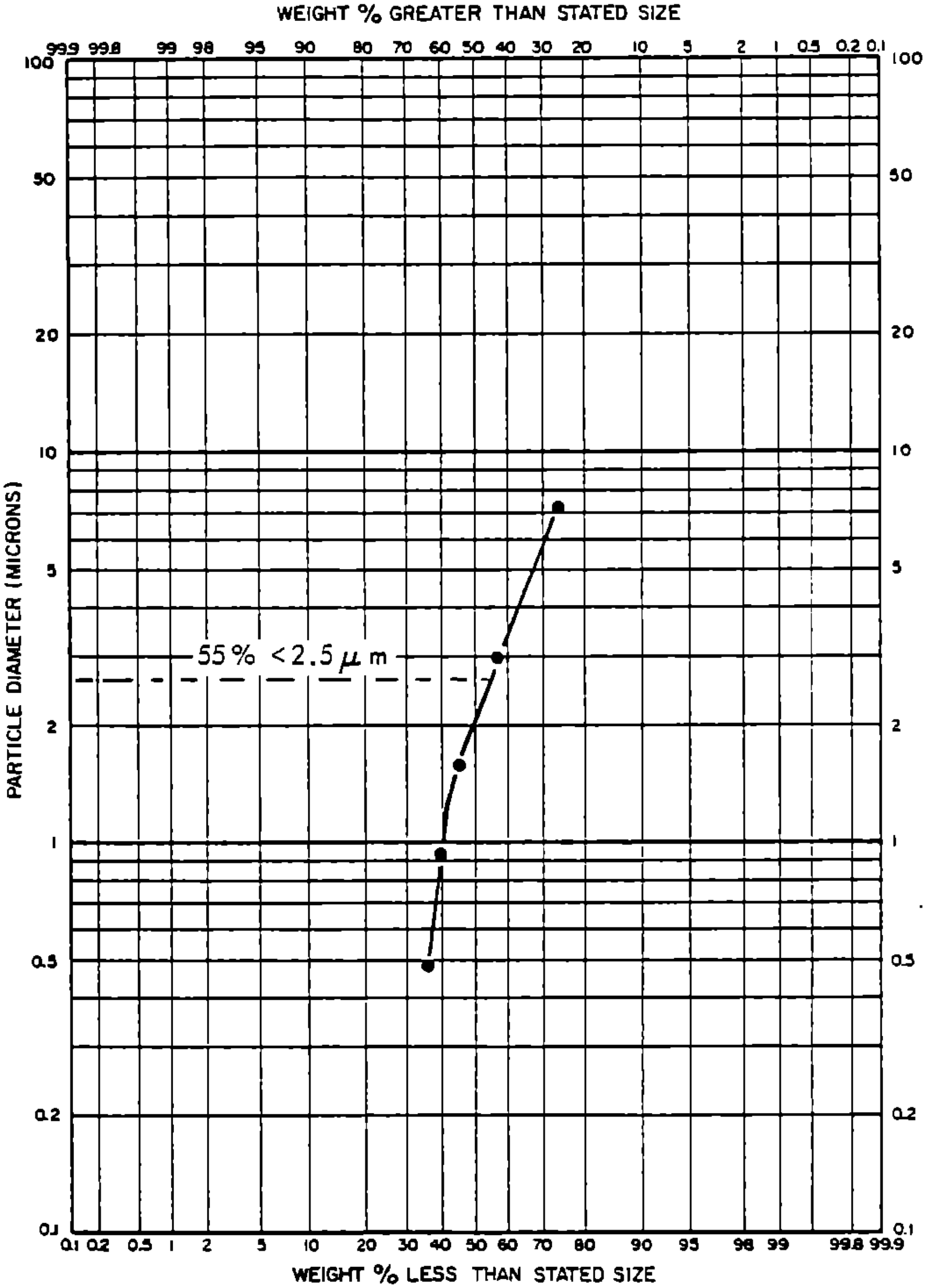


Figure 35. Particle size distribution of IP at 2 m height and 5 m downwind for test R-6.

TABLE 36. RESULTS OF MICROSCOPIC ANALYSIS[a]

Test	Largest particle size[b] (μm)	Largest Aerodynamic particle size[c] (μm)
R-1	19	27
R-2	20	28
R-3	62	88
R-4	78	110
R-5	32	45
R-6	38	54

[a] Measurements taken at 5 m downwind and 2 m height.

[b] Physical diameter as observed visually.

[c] Diameter of a particle of density 1 g/cc which behaves aerodynamically in an equivalent fashion to the soil particles of density 2 g/cc and observed physical diameter.

devices at two heights, so the slopes of the lines describing the variation with height in percentage of TP that was IP and FP were determined from the soil preparation tests.

A study of the spring soil preparation tests showed a definite correlation between the wind speed and the slope of the linear equation describing the percent IP and FP as a function of height. The higher the wind speed, the larger the slope of the line. This is in keeping with the theory that under unstable conditions, the wind speed is light and there is much mixing, which causes minimal variations with height, i.e., a small slope. As the stability increases, so does the wind speed (during the day). Consequently, there is less mixing with height and a larger slope in the linear equation. The data supporting this theory are shown in Table 37.

Since winds during harvesting tests R-1, R-2, R-3, R-5, and R-6 were similar to those during test N-5, the slopes shown in Table 37 for test N-5 were applied to these five harvesting tests. Since the winds during test R-4 were similar to those during test N-6, the slopes shown in Table 37 for test N-6 were applied to test R-4.

The emission factors for the harvesting of sugar beets were calculated using Eq. 4 in Section 3.3.2.4. The values used to calculate the emission factors and the resulting emission factors for TP, IP, and FP are shown in Table 38.

TABLE 37. VARIATION OF SIZE DISTRIBUTION WITH HEIGHT AND WIND SPEED

Tests containing particle size measurements at two heights	Wind speed at 2 m m/sec (ft/min)	Slope of % IP versus height (%/m)	Slope of % FP versus height (%/m)
N-5	1.83 (361)	4.6	3.15
N-6	3.72 (733)	11.15	3.8
N-10	6.76 (1,330)	32.3	13.7
N-11[a]	-	-	-

[a] Measurement at 3 m height was suspect; therefore, no slope was determined for this test.

TABLE 38. EMISSION FACTORS FOR SUGAR BEET HARVESTING OPERATIONS

Test	Integrated area under exposure profile curve (mg/cm)			No. of good passes[a]	Width of implement m (ft)	Emission factor kg/km^2 (lb/acre)		
	TP	IP	FP			TP	IP	FP
R-1	590	21.1	11.1	7	2.13 (7.00)	3,940 (35.2)	141 (1.26)	74.3 (0.663)
R-2	322	149	66.3	7	2.13 (7.00)	2,150 (19.2)	997 (8.90)	444 (3.96)
R-3	512	122	59.2	7	2.13 (7.00)	3,430 (30.6)	816 (7.29)	396 (3.54)
R-4	816	160	74.3	5	4.57 (15.0)	3,560 (31.8)	699 (6.24)	325 (2.90)
R-5	366	103	43.9	7	4.57 (15.0)	1,140 (10.2)	321 (2.87)	137 (1.22)
R-6	454	200	108	3	4.57 (15.0)	3,300 (29.5)	1,460 (13.0)	786 (7.02)

[a] 3 marginal passes = 1 good pass.

SECTION 4.0

DETERMINATION OF PREDICTIVE EMISSION FACTOR EQUATIONS

Fugitive emission generation is highly dependent on such generic classes of variables as: (a) climate, (b) soil properties, and (c) equipment characteristics. Consequently, any given set of emission factor measurements most likely will not be applicable to a geographic or climatic setting different from the measured setting. Therefore, the most reliable method to assure usefulness from fugitive emission measurements is to quantify the independent variables along with the dependent variables and to develop a predictive equation. This section presents predictive equations for TP, IP, and FP emission factors.

4.1 PREDICTIVE EMISSION FACTOR EQUATIONS

The specific variables which could affect emissions from agricultural operations are shown in Table 39. These variables are not all independent. Precipitation, wind speed, evaporation, solar radiation, cloud cover, and frequency of condensation all affect the soil moisture content. Likewise, the implement speed and implement weight per unit width affect the energy imparted to the soil by the implement. Of the variables listed in Table 39, the independent ones seem to be: (a) implement speed, (b) implement weight per unit width, (c) the soil silt content, and (d) the soil moisture. Using various combinations of these variables, separate predictive emission factor equations were developed for soil preparation and for harvesting operations.

4.1.1 Soil Preparation Operations

MRI believed that the variables upon which emissions from soil preparation operations might have the strongest dependence were soil silt and moisture contents. Consequently, the data base shown in Table 40 was constructed for soil preparation operations. Not only were data from testing in California included in the data base, but also data from seven tests of discing and plowing at four sites in Kansas in 1974. Only TP emission factors were available for the Kansas data.

Two forms of a predictive equation were examined:

TABLE 39. EFFECTS OF EQUIPMENT, SOIL, AND METEOROLOGICAL PARAMETERS ON EMISSIONS

Parameters affecting emissions	Effect of increasing parameter value on emissions in mass/area
1. Equipment characteristics	
a. Energy imparted to soil by implement	Increase
b. Implement width	None
c. Implement speed	Increase
d. Implement weight per unit width	Increase
2. Soil characteristics	
a. Silt	Increase
b. Moisture	Decrease
3. Meteorological parameters	
a. Wind speed	Increase
b. Precipitation amount and frequency	Decrease
c. Evaporation	Increase
d. Solar radiation	Increase
e. Cloud cover	Decrease
f. Frequency of condensation	Decrease

TABLE 40. DATA BASE FOR PREDICTIVE EQUATION DEVELOPMENT--
SOIL PREPARATION OPERATIONS

Run	Source	Silt (%)	Moisture (%)	Measured emission factors kg/km² (lb/acre) TP	IP	FP
N-3	Land plane	24.7	4.0	2,320 (20.7)	309 (2.76)	80.5 (0.719)
N-4	Land plane	24.7	4.0	2,600 (23.2)	291 (2.60)	116 (1.04)
N-5	Land plane	22.5	3.1	2,520 (22.5)	231 (2.06)	137 (1.22)
N-6	Disc	18.9	2.1	2,960 (26.4)	613 (5.47)	217 (1.94)
N-7	Disc	17.5	2.9	2,720 (24.3)	797 (7.12)	200 (1.79)
N-8	Disc	1.7	13.3	522 (4.66)	66.2 (0.591)	24.4 (0.218)
N-9	Disc	2.6[a]	12.6[a]	865 (7.72)	379 (3.38)	138 (1.23)
N-10	Disc	3.5	12.0	1,630 (14.6)	646 (5.77)	314 (2.80)
N-11	Disc	4.9	10.8	1,610 (14.4)	540 (4.82)	249 (2.22)
N-12	Disc	3.6	13.0	1,300 (11.6)	361 (3.22)	120 (1.52)
N-13	Disc	3.2	10.7	1,120 (9.98)	412 (3.68)	200 (1.79)
5[b]	Disc	54	10.5	6,270 (56)	-	-
6[b]	Disc	54	10.5	5,820 (52)	-	-
7[b]	Disc	54	10.5	6,720 (60)	-	-
9[b]	Disc	71	11.0	4,700 (42)	-	-
11[b]	Sweep plow	88	15.9	7,170 (64)	-	-
12[b]	Sweep plow	87	13.4	9,520 (85)	-	-
14[b]	Disc	73	12.3	8,740 (78)	-	-
		$\bar{X} = 17.5$				

[a] Assumed average of N-8 and N-10.

[b] Tests performed in Kansas (see Ref. 1).

$$EF_i = a\ s^b\ M^c \tag{6}$$

$$EF_i = a\ s^b \tag{7}$$

where i = particle size category (TP, IP, or FP)

s = silt content (%)

M = unbound surface moisture content (%)

a, b, c = regression coefficients (the values vary as i varies)

The correlation coefficients (r) for various combinations of tests and for each particle size category are shown in Tables 41 for Eq. 6, and Table 42 for Eq. 7. The regression coefficients (a, b and c) for various combinations of tests and for each particle size category are shown in Table 43 for Eq. 6 and Table 44 for Eq. 7.

Figures 36, 37, and 38 show a plot of the measured, TP, IP, and FP emission factors versus silt content. Also portrayed on the figures are the various potential predictive equations from Table 44. The plots of the potential predictive equations aid in visualizing why some of the correlation coefficients of Table 42 are better than others. Unfortunately, this visualization process is impossible for the correlation coefficients in Table 41 since this would require three axis plots on the two dimensional page. These types of plots normally produce more confusion than clarification.

The question can be raised whether the moisture content range tested in this study extended over the expected range of moistures in California. There is little statewide surface moisture data available to answer such a question.

A study of soil moisture in the 0 to 2-cm surface layer was performed by Dr. Jerry L. Hatfield of University of California Department of Land, Air, and Water Resources at Davis. Measurements of natural soil surface moisture in Yolo Loam at Davis, California, during parts of 1977 and 1978, were included in a report entitled "Investigations into the Prediction of Soil Moisture from Surface Measurements" under Contract No. NCA2-OR180-607 for NASA's Ames Research Center.

The surface moisture measurements collected by Dr. Hatfield are shown in Figure 39. The circles in Figure 39 identify the mean values of moisture obtained from 4 to 10 measurements per month while the bar represents ± 1 standard deviation around the mean.

Using Dr. Hatfield's data, one can see that the range of moistures tested by MRI, (2.1 to 15.9%) extended over nearly the entire range of mean monthly values measured by Dr. Hatfield (2.1 to 19.3%).

While little can still be said about whether testing assumed over the expected range of moisture in the entire state over 30 years, for example, one can at least say that based on a small amount of data in time and

TABLE 41. SUMMARY OF CORRELATION COEFFICIENTS FOR THE EQUATION OF THE FORM $EF_i = a\ s^b\ M^c$

Sources and sites included	Tests included	Correlation coefficients by particle size category i		
		TP	IP	FP
Discing and land planing - 2 sites	N3-N13	0.916	0.277	0.171
Discing - 2 sites	N6-N13	0.974	0.683	0.827
Discing - 1 site	N8-N13	0.953	0.867	0.889
Discing, land planing, and plowing - 6 sites	N3-N13 and seven Kansas tests	0.969	-	-

TABLE 42. SUMMARY OF CORRELATION COEFFICIENTS FOR THE EQUATION OF THE FORM $EF_i = a\ s^b$

Sources and sites included	Tests included	Correlation coefficients by particle size category i		
		TP	IP	FP
Discing and land planing - 2 sites	N3-N13	0.915	0.278	0.152
Discing - 2 sites	N6-N13	0.931	0.683	0.503
Discing - 1 site	N8-N13	0.950	0.868	0.888
Discing, land planing, and plowing - 6 sites	N3-N13 and seven Kansas tests	0.941	-	-

TABLE 43. SUMMARY OF REGRESSION COEFFICIENTS FOR THE EQUATION OF THE FORM $EF_i = a\ s^b\ M^c$

Sources and sites included	Tests included	Particle size category	Regression coefficients[a] a	b	c
Discing and land planing - 2 sites	N3-N13	TP	554	0.504	0.034
		IP	267	0.167	-0.0185
		FP	60.7	0.234	0.206
Discing - 2 sites	N6-N13	TP	45.6	1.20	0.730
		IP	164	0.59	-0.0211
		FP	0.0312	2.34	2.32
Discing - 1 site	N8-N13	TP	98.1	1.23	0.414
		IP	107	1.91	-0.413
		FP	64.3	2.16	-0.656
Discing, land planing, and plowing - 6 sites	N3-N13 and seven Kansas tests	TP	364	0.600	0.162

[a] The values of the regression coefficients assume silt and moisture contents in percent and the emission factor in kg/km^2.

TABLE 44. SUMMARY OF REGRESSION COEFFICIENTS FOR THE EQUATION OF THE FORM $EF_i = a\ s^b$

Sources and sites included	Tests included	Particle size category	Regression coefficients[a] a	b
Discing and land planing - 2 sites	N3-N13	TP	618	0.481
		IP	251	0.179
		FP	116	0.101
Discing - 2 sites	N6-N13	TP	532	0.611
		IP	153	0.607
		FP	77.2	0.456
Discing - 1 site	N8-N13	TP	297	1.16
		IP	35.1	1.99
		FP	11.1	2.27
Discing, land planing, and plowing - 6 sites	N3-N13 and seven Kansas tests	TP	538	0.601

[a] The values of the regression coefficients assume silt content in percent and the emission factor in kg/km^2.

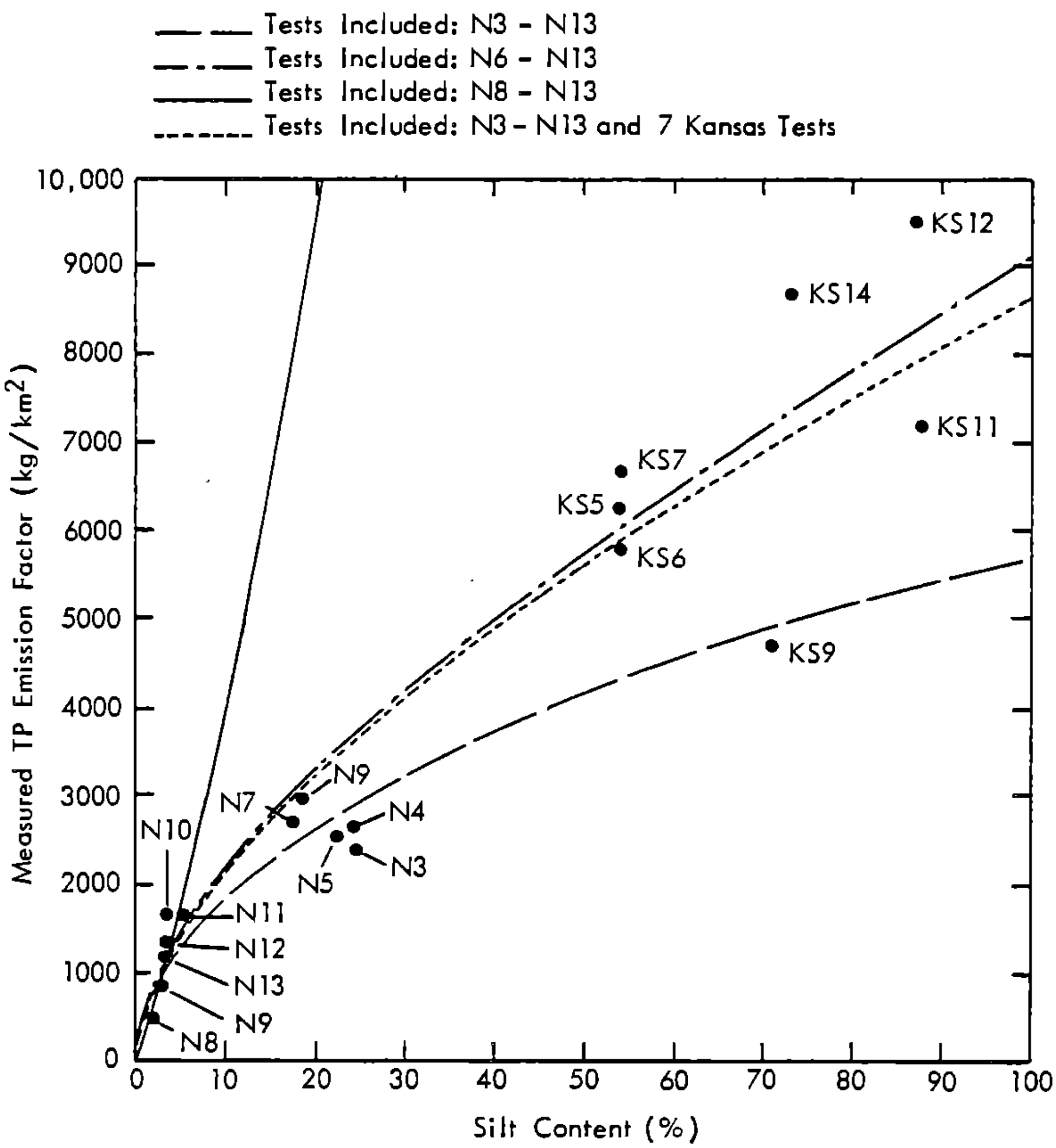


Figure 36. Plot of Measured TP Emission Factor Versus Silt Content with Potential Predictive Equations Depicted.

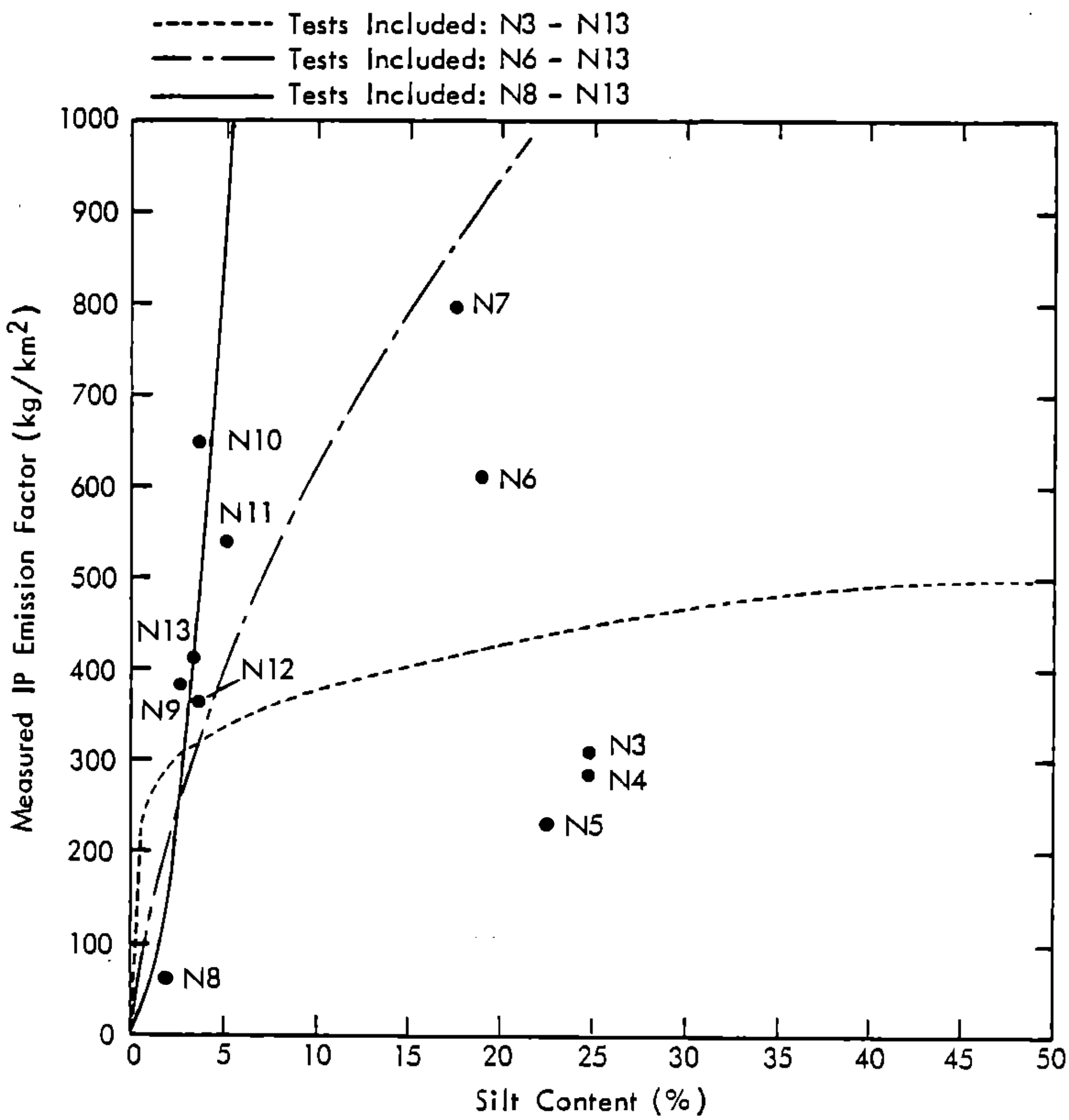


Figure 37. Plot of Measured IP Emission Factor Versus Silt Content with Potential Predictive Equations Depicted.

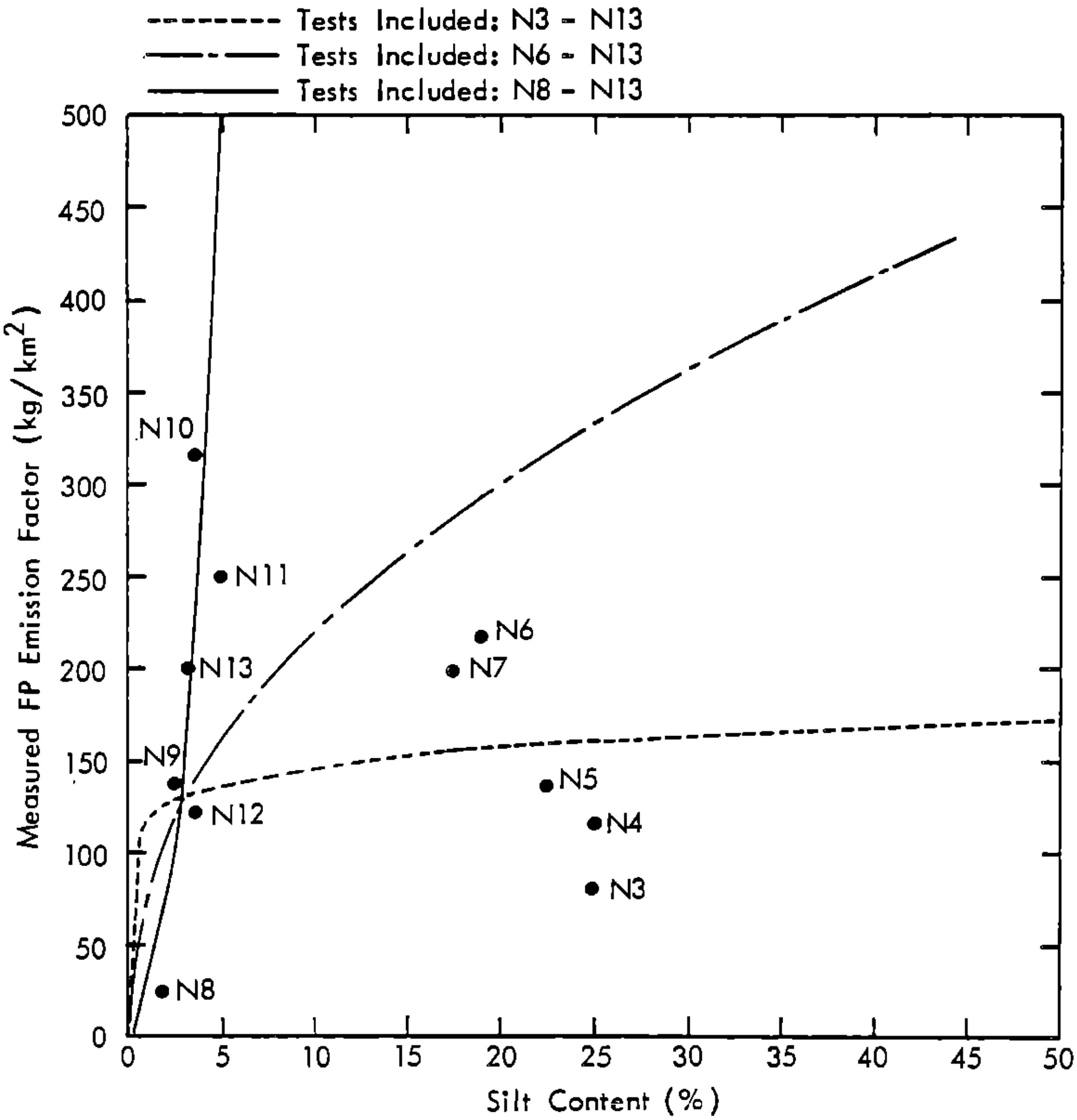


Figure 38. Plot of Measured FP Emission Factor Versus Silt Content with Potential Predictive Equations Depicted.

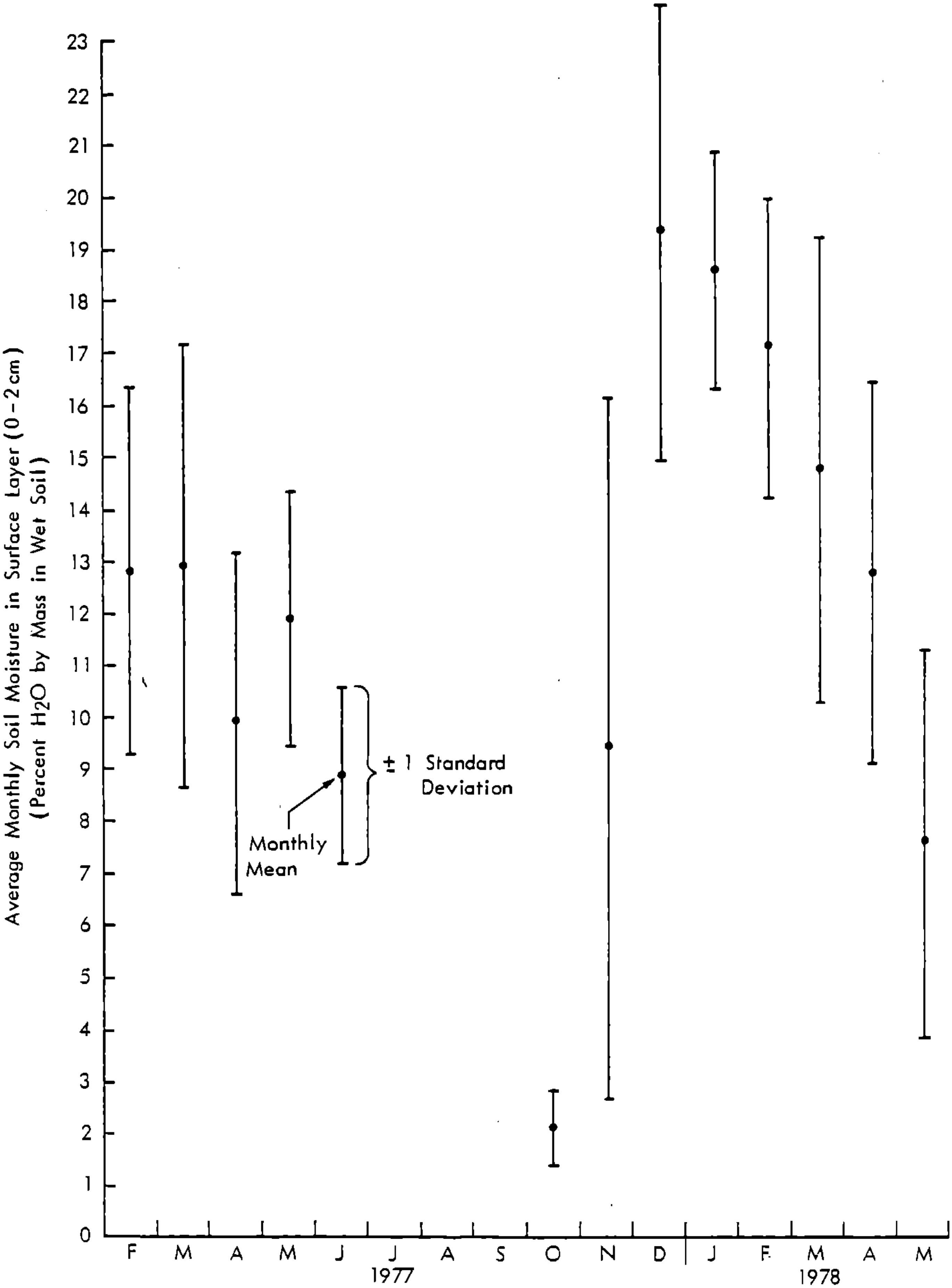


Figure 39. Surface Soil Moisture of Yolo Loam in Davis, California.

space, it appears that MRI has tested over nearly the entire range of surface moisture conditions presently known to exist in California.

One interesting conclusion gleaned from analyzing Tables 41 and 42 is that the dependence of the emission factor on moisture content of the soil produced an almost unobservable improvement in the correlation coefficient. This leads to an interesting hypothesis which relies on an analogy with findings into the nature of wind erosion.

It has been shown for wind erosion of soils that at a given energy input level (related to wind speed), there is a threshold moisture above which erosion ceases.[8] The higher the energy input level, the higher the threshold moisture. There is little effect of moisture on wind erosion until this threshold moisture is approached at which point erosion drops off quickly to zero. Values of the wind erosion moisture threshold at a friction velocity of 60 cm/s were measured by Dr. F. J. Vechmeyer of the University of California at Davis for certain California soils.[9] These values are shown in Table 45 under the name "permanent wilting point."

Now let us extend these findings from wind-erosion-generated to agricultural-implement-generated emissions. The energy input to the soil now originates from the implement instead of the wind. If the same relation between emission magnitude, energy input level, and threshold moisture exists for agricultural operations, then it may be that farmers inadvertently perform their soil preparation operations when the soil moisture is well below the threshold moisture that corresponds to the energy input into the soil from the moving implement. If the analogy holds, then one would expect little relationship between the measured emission factors and the soil moisture. Only when the threshold moisture is approached would one expect to see a dramatic drop in emissions due to an increase in moisture.

Since moisture as an independent variable does not improve the predictability of the equation, MRI concluded that Eq. 7, relating the emission factor to just the silt content, is sufficient. The most significant equation in Table 42 is the one that applies to discing, land planing, and plowing at six sites in California and Kansas. This is an amazing range of applicability considering the simplicity and the accuracy of the equation, which is shown below:

$$EF_{TP} = 538\ (s)^{0.6} \qquad (8)$$

where EF_{TP} is in kg/km^2 and s is in percent

The overall correlation coefficient for the above equation is $r = 0.941$ which means that 88% of the variation in EF_{TP} can be explained by the variation in silt content. This relationship is more than 99% significant; that is, only one time in 100 could this value of r occur by chance. The one-sigma precision factor is 1.29, which means that 68% of the predicted values lie within a factor of 1.29 of the measured value. The two-sigma precision factor is 1.67, which means that 95% of the predicted values lie within a factor of 1.67 of the measured values.

TABLE 45. MEASURED THRESHOLD MOISTURES FOR CALIFORNIA SOILS[a]

Soil type	Permanent wilting point moisture (%)
Columbia silt loam	8.61
Delano silt loam	4.17
Farwell silt loam	14.14
Fresno sandy loam	3.05
Stockton clay adobe	9.28
Harford fine sandy	3.99
Columbia sand	5.53
San Joaquin loam	6.34
Sierra sandy loam	5.09
Yolo fine sand loam	9.11
Placentia loam	3.70
Madera and Gridley loam	10.25
Okley fine sand	1.33
Brockton clay	11.55
Wooster silt loam	6.12
Plainfield fine sand	1.36
Yolo silt loam	10.13
Tehama loam	4.51
Catherine loam	19.03
Yolo fine sandy loam	8.93
Yolo clay	13.98
Aiken clay loam	20.75
Yuma sand	3.17
Brazito fine sand	1.58
San Joaquin sandy loam	3.93
Madera sandy loam	3.62

[a] Based on a friction velocity of 60 cm/s.

The predictive equations for IP and FP emissions from soil preparation operations were determined by multiplying the TP equation by the average IP/TP and FP/TP ratios, respectively. The following predictive equations were determined.

$$EF_{IP} = 0.25 \times 538 \times (s)^{0.6} = 135 \ (s)^{0.6} \quad (9)$$

$$EF_{FP} = 0.1 \times 538 \times (s)^{0.6} = 53.8 \ (s)^{0.6} \quad (10)$$

where EF_{IP} and EF_{FP} are in kg/km^2 and s is in percent

The one-sigma precision factor for the IP emission factor equation is 2.17; the two-sigma precision factor is 4.7. The one-sigma precision factor for the FP emission factor equation is 2.33; the two-sigma precision factor is 5.42.

The IP and FP emission factor equations are not as precise as the TP emission factor equation. One theory to explain this is that the IP and FP emissions may be related to a soil-sizing parameter finer than silt. It may be that IP and FP correlate better with the percent of soil particles less than 50 or 40 or 30 μm in diameter, for example. Nevertheless, for the small data base available and the range of applicability utilized, the relationships are useful.

4.1.2 Harvesting Operations

The data base shown in Table 46 was constructed for harvesting operations. Since there were only three runs on each of the two types of harvesting operations tested, the development of a significant equation for harvesting was not possible. Table 47 shows the correlation coefficients for equations relating emission factor to silt and moisture content. Table 48 shows correlation coefficients for equations relating emission factor to silt content alone.

The reason that r = 1.0 in some cases shown on Table 47, is that there are three unknown regression coefficients and only three runs per operation. This is similar to fitting a straight line to two points in that one must get a perfect fit. Unfortunately, the significance and the precision of the equations are undefined.

When considering all six runs together, the equations which include silt and moisture perform better than the equations which include only silt content. However, even the equation which has the highest r value and relates the TP emission factor to silt and moisture is only 84% significant; that is, 16 times out of 100, one could get this value of r by chance for the form of the equation chosen and only six data points.

TABLE 46. DATA BASE FOR PREDICTIVE EQUATION DEVELOPMENT--
HARVESTING OPERATIONS

Run	Source	Silt (%)	Moisture[a] (%)	Measured emission factors kg/km^2 (lb/acre) TP	IP	FP
R-1	Leaf beating	1.7	15.0	3,940 (35.2)	141 (1.26)	74.3 (0.663)
R-2	Leaf beating	1.2	16.1	2,150 (19.2)	997 (8.90)	444 (3.96)
R-3	Leaf beating	1.8	14.3	3,430 (30.6)	816 (7.29)	396 (3.54)
R-4	Digging	2.5	13.5	3,560 (31.8)	699 (6.24)	325 (2.90)
R-5	Digging	1.7	14.0	1,140 (10.2)	320 (2.87)	137 (1.22)
R-6	Digging	2.1	13.6	3,300 (29.5)	1,460 (13.0)	786 (7.02)

[a] Soil was dried for 24 hr; therefore, some of the evaporated water may have been hydration molecules and not truly representative of unbound surface moisture.

TABLE 47. SUMMARY OF CORRELATION COEFFICIENTS FOR THE EQUATION OF THE FORM $EF_i = a\ s^b\ M^c$

Sources and sites included	Tests included	Correlation coefficients (r) by particle size category i		
		TP	IP	FP
Leaf beating - 1 site	N1-N3	1.0	1.0	1.0
Beet digging - 1 site	N4-N6	1.0	1.0	1.0
Leaf beating and beet digging - 1 site	N1-N6	0.841	0.231	0.216

TABLE 48. SUMMARY OF CORRELATION COEFFICIENTS FOR THE EQUATION OF THE FORM $EF_i = a\ s^b$

Sources and sites included	Tests included	Correlation coefficients (r) by particle size category i		
		TP	IP	FP
Leaf beating - 1 site	N1-N3	0.938	-0.538	-0.466
Beet digging - 1 site	N4-N6	0.917	0.327	0.281
Leaf beating and beet digging - 1 site	N1-N6	0.418	0.130	0.187

SECTION 5.0

EVALUATION OF PROMISING MODIFICATIONS TO AGRICULTURAL PRACTICES TO MINIMIZE FUGITIVE DUST

The purpose of this section is to suggest potential control techniques which might minimize fugitive dust from agricultural operations. These control techniques can take the form of separate, additional equipment, or they can consist simply of operational modifications. This section contains a list of potential techniques to minimize dust from soil preparation and crop harvesting operations and also from wind erosion of fallow or partially vegetated soil. Finally, an estimate of the 1978 inhalable particulate (IP) fugitive dust emissions from soil preparation and maintenance and crop harvesting is provided along with an estimate of the future emissions reduction which could be expected from various control techniques.

5.1 MODIFICATION TO AGRICULTURAL OPERATIONS

This subsection presents potential modifications to agricultural operations which might minimize fugitive dust. The modifications are of two forms: (1) additional equipment, and (2) alteration of agricultural practices.

5.1.1 Additional Equipment--The Fogger

Historically speaking, various types of watering techniques have been suggested as a means to settling the dust created during agricultural operations. In this particular application, the dispensing of copious quantities of water by spray nozzles located at the rear of a moving vehicle is usually neither practical nor effective. A supply of water adequate for the operation of such a system is simply not available on commercial agricultural equipment.

There is, however, another potential means for effectively controlling such emissions with a minimum water consumption. The use of electrostatics for the precipitation of fine suspended particulate matter is common engineering practice. Recently, electrostatics have been used to augment traditional wet dust collectors (scrubbers) of various designs. Since 1977, Dr. Stuart Hoenig, at the University of Arizona, has been studying a new approach for the application of electrostatically augmented water sprays (charged fog) on a bench scale for the control of fugitive dust generated by various industrial processes.[10,11] Commercial devices (foggers) resulting from this work are now available from the Ritten Corp. in Ardmore, Pennsylvania.[12] These foggers offer significant economic advantages over more traditional fugitive dust control technology, in that they use only a minimum amount of water to achieve a good degree of control. The only major problems with the commercially available foggers are that they require high pressure air or water for proper atomization, they cannot tolerate a water supply with a high suspended solids content, and only a portion of the water drops generated are electrostatically charged. Nevertheless, a recent test at a primary rock crusher has shown that the Fogger IV (the largest of the commercial foggers) is capable of reducing the dust generated by 65 to 75%.[13]

To solve the problems with the existing electrostatic fogging equipment, a second generation fogger is currently being developed under USEPA sponsorship. It is being designed especially for use on moving vehicles. This device, called the Spinning Cup Fog Thrower (SCFT), has already shown itself capable of applying a greater electrostatic charge to the water drops, does not require high pressure air or water for atomization, and is essentially insensitive to a water supply with a high suspended solids content, while still achieving a good degree of dust control.[14] Preliminary wind tunnel tests have shown a control efficiency in the same range as that reported above for the commercial foggers (65 to 75%) with a substantially improved version SCFT currently undergoing field tests.[15]

It is anticipated that either the already commercially available foggers and/or the SCFT when available, could be applied to the control of fugitive dust from agricultural operations. A small water tank, power supply, and other necessary electrostatic fogging equipment could be installed on existing vehicles to effectively control dust emissions. Due to the foggers inherently low water consumption, (anticipated at 5 to 10 gal./hr for the SCFT), a large water supply or frequent stops to refill the water tank would not be necessary thereby making such a system much more practical than watering. A large implement would probably require a minimum of three SCFT and would require 15 to 30 gal./hr. All in all, the use of electrostatically charged fog does seem to be a viable alternative to controlling agricultural fugitive dust.

5.1.2 Operational Modifications

Operational modifications include the use of novel implements or the alteration of cultural techniques to eliminate some operations altogether. All operational modifications will affect soil preparation or seed planting operations, but none will affect harvesting. Harvesting implements are already designed to garnish the crop in the most effective manner, and there is no cultural technique to substitute for harvesting. Therefore, harvesting controls must take the form of the additional control equipment discussed in Section 5.1.1.

The suggested operational modifications are crop specific. The major crops in each valley in terms of acreage and emissions were selected for investigation with respect to operational modification. The following list of crops was compiled: (a) cotton, (b) barley, (c) alfalfa, (c) rice, (d) corn, (e) wheat, (g) processing tomatoes, and (h) lettuce. Field crops are dominant in all three valleys, so processing tomatoes and lettuce were added to the list to afford a look at vegetable crops. The operational modifications listed below were obtained from interviews with California crop specialists who are experts in the production of the respective crop.

The punch planter is a novel implement which might have applications for emissions reduction from planting cotton, corn, and lettuce. The punch planter is already being used in sugar beet production. The punch planter punches a hole and places the seed into it, as opposed to conventional planters, which make a trough and drop the seeds in at a specified spacing. The advantage is that punch planters can leave much of the surface soil and surface crop residues undisturbed. Large-scale use of the punch planters would require initial capital investments by the farming industry for new equipment.

A novel cultural practice which might have applications for emissions reduction from cotton and processing tomato production is the low energy crop production system. This system is truly a minimum tillage technique, whereby all vehicular traffic is confined to traffic corridors within the fields. These traffic corridors are spaced approximately 6 to 9 m (20 to 30 ft) apart. It is intended that farm vehicle wheels never come in contact with the crop-producing portion of the field. This system eliminates all land preparation and preplant operations (plowing, discing, land planning) and reduces production operations to planting, fertilizing, and harvesting. This practice amounts to a 60 to 80% reduction in energy input and a large reduction in dust emissions. However, this system would require capital investments in wide span equipment.

The major reason the need for tillage is reduced in the low energy system, is that compaction caused by the farm equipment itself is eliminated. In cotton cropping, farm equipment is the principal source of soil compaction. Even though this system has been under development since 1940, its widespread use is still projected to be 15 years away.

Another advantage of the low energy system is that less weed control is necessary because the soil is not disturbed. Weeds normally grow in areas which are disturbed or in transition. The low energy system is an advantage since the use of herbicides and/or cultivation can be reduced.

The plug planter is a novel implement which may have applications for emission reduction for process tomato production. Similar to the punch planter, the plug planter punches plugs, which contain carbon, peat moss, and the seed, into furrows. Because this method spaces plants more exactly than do the current planting methods, the need for thinning, which is often done by hand, is eliminated. Since people will not be working long hours in the field, stronger herbicides for weed control can be used.

Herbicides for weed control is a cultural practice which could reduce emissions from cultivation for most new crops with wide enough spacing for cultivation and for some close-grown crops like wheat. Much of the preplant tillage of wheat soil is for weed control. The use of herbicides, however, must be balanced against potential increased herbicide emissions caused by wind and by water runoffs.

Sprinkler irrigation is an existing cultural technique which could produce fugitive emission control for any crop which is currently irrigated by surface watering systems. Sprinkler irrigation eliminates the need for extensive land planing operations which surface irrigation requires. However, the capital investment for sprinkler irrigation equipment and the increased costs of pumping the water are major deterrents.

The laser-directed land plane is a novel implement which might yield some emissions controls for surface-irrigated crops. Laser-guided grading equipment has been used in construction for years and can be expected to reduce the amount of land planing required due to its more precise leveling-blade. This device might be retrofitted to existing land planes, but capital investment funds are required.

One cultural technique which might reduce fugitive emissions from process tomato production is to list in the fall. This technique eliminates the need to harrow and roll in the spring. One-third to one-half of the farmers in the Sacramento Valley currently follow this practice.

The development of long lasting varieties of alfalfa with high leaf protein content would help to reduce emissions, because present practices require replanting every 3 to 5 years. New varieties already exist which can last up to 20 years, but the protein content is low. If longevity and quality could be combined, the soil would not have to be prepared so often, thus yielding a subsequent reduction in emissions.

Double cropping corn with wheat or other grain instead of corn with corn might reduce fugitive emissions. Since corn provides so much stubble, it must be plowed or disced under. The beds must then be formed and shaped for the next corn seed planting. If wheat or another grain were grown on a bedded field, then corn could be planted on the beds after the wheat harvest and stubble removal. The beds would require only reshaping. This would eliminate a plowing or discing operation and a bed forming operation while adding a less dusty wheat stubble removal operation.

Finally, aerial seeding which is already used in rice production, would probably reduce emissions somewhat from alfalfa and wheat production. However, at least in the case of wheat, the aerially applied seed must be covered. This covering operation will produce dust, but it may be less dust than a ground planting operation would produce.

5.2 MINIMIZATION OF WIND EROSION EMISSIONS

5.2.1 Introduction

Wind erosion control is accomplished by stabilizing erodible soil particles. The stabilization process is accomplished in three major successive stages: (a) trapping of moving soil particles; (b) consolidation and aggregation of trapped soil particles; and (c) revegetation of the surface.[16]

The trapping of eroding soil is termed "stilling" of erosion. This may be effected by roughening the surface, by placing barriers in the path of the wind, or by burying the erodible particles during tillage. Trapping is accomplished naturally by soil crusting resulting from rain followed by a slow process of revegetation. It should be stressed that the stilling of erosion is only temporary; to effect a permanent control, plant cover must be established or plant residues must be maintained.

In bare soils containing a mixture of erodible and nonerodible fractions, the quantity of soil eroded by the wind is limited by the height and number of nonerodible particles that become exposed on the surface. The removal of erodible particles continues until the height of the nonerodible particles that serve as barriers to the wind is increased to a degree that affords complete shelter to the erodible fractions. If the nonerodible barriers are low, such as fine gravel, a relatively large number of pieces is needed for protection of soil from wind erosion. The gravel in such a case would protect the erodible portion more by covering than by sheltering from the wind. Thus, all nonerodible materials on the ground that control erosion have an element of cover in addition to the barrier principle which protects the soil. The principles of surface barriers and cover are, therefore, inseparable.

The above principles extend to almost all elements used in wind erosion control. All of these control methods are designed to: (a) take up some or all of the wind force so that only the residual force, if any, is taken up by the erodible soil fractions; and (b) trap the eroded soil, if any, on the lee side or among surface roughness elements or barriers, thereby reducing soil avalanching and intensity of erosion.

In the sections that follow, various control methods are discussed with respect to their characteristics and effectiveness in controlling erosion. Methods include vegetative cover, soil ridges, windbreaks, crop strips, chemical stabilizers, and irrigation.

5.2.2 Vegetative Cover

Natural vegetative cover is the most effective, easiest, and most economical way to maintain an effective control of wind erosion. In addition to the crops such as grasses, wheat sorghum, corn legumes, and cotton, crop residues are often placed on fallow fields until a permanent crop is started. All of these methods can remove 5 to 99% of the direct wind force from the soil surface.[17]

5.2.2.1 Effectiveness--

Grasses and legumes are most effective because they provide a dense, complete cover. Wheat and other small grains are effective beyond the crucial 2 or 3 months after planting. Corn, sorghum, and cotton are only of intermediate effectiveness because they are planted in rows too far apart to protect the soil.

After harvesting, vegetative residue should be anchored to the surface.[18] Duley found that legume residues decay rapidly, while corn and sorghum stalks are durable.[19] He found wheat and rye straw more resistant to decay than oat straw.[19]

Some effects of density and orientation of residue on wind erosion control are shown in Table 49. The more erect, finer, and denser the residue, the less the erosion.

TABLE 49. AVERAGE EFFECTS OF KIND AND ORIENTATION OF CROP RESIDUE ON EROSION OF SANDY LOAM SOIL BY WIND OF UNIFORM VELOCITY[16]

Quantity of crop residue above soil surface kg/km^2 (lb/acre)	Quantity of soil eroded in a wind tunnel: Covered with wheat residue Mg/km^2 (tons/acre): Standing, 25.4 cm (10 in.) high	Covered with wheat residue: Flat	Covered with sorghum residue Mg/km^2 (tons/acre): Standing, 25.4 cm (10 in.) high	Covered with sorghum residue: Flat
0	2,370 (10.6)	3,580 (16.0)	3,580 (16.0)	3,580 (16.0)
56,000 (500)	627 (2.8)	1,900 (8.5)	2,910 (13.0)	3,250 (14.5)
112,000 (1,000)	22.4 (0.1)	560 (2.5)	1,810 (8.1)	2,330 (10.4)
224,000 (2,000)	T[a]	22.4 (0.1)	874 (3.9)	1,190 (5.3)
336,000 (3,000)	T	T	314 (1.4)	490 (2.2)
672,000 (6,000)	T	T	T	44.8 (0.2)

[a] T = trace, insignificant.

5.2.2.2 Maintenance--

Excessive tillage, tillage with improper implements, and overgrazing are the major causes of crop cover destruction. Effective land management practices must be instituted if wind erosion is to be controlled.

For grazing, the number of animals per acre should be controlled to maximize the use of grass and still maintain sufficient vegetative cover.

Stubble mulching and minimum tillage or plow-plant systems of farming tend to maintain vegetative residues on the surface when the land is fallow. Stubble mulching is a year-round system in which all tilling, planting, cultivating, and harvesting operations are performed to provide protection from erosion. This practice requires the use of tillage implements which undercut the residue without soil inversion. The effectiveness of various tillage implements on residue maintenance is shown in Table 50.

TABLE 50. RESIDUE MAINTENANCE WITH TILLAGE IMPLEMENTS[16]

Type of implement	Average residue remaining after each tillage operation (%)	Range of residue remaining (%)
Subsurface implements		
Blades (36 in. or wider)	90	70-113
Sweeps (24 to 36 in.)	90	60-112
Rodweeders, plain rod[a]	90	80-115
Rodweeders, with semichisels[a]	85	55-105
Mixing implements		
Heavy duty cultivator (16 to 18-in. sweeps)	80	50-100
Heavy duty cultivator (2-in. chisels, 12 in. apart)	75	-
One-way disc (24 to 26-in. pans)	50	30-90
Tandem or offset disks	50	-

[a] The rodweeder involves the insertion of a horizontal rod no more than 3 in. below the soil surface. As the rod is pulled through the soil it is also rotated. This action uproots weeds and loosens the surface soil.

5.2.3 Asphalt Cover

Chepil experimented with cutback asphalt and asphalt in-water emulsion.[20] Tests were performed to demonstrate: (a) effectiveness and stability of asphalt films against erosion by wind when sprayed on surface; (b) effects of the film on seed germination; and (c) effects of asphalt on erosion and seed growth when mixed into the soil.

The conclusions of the study were as follows:

- From 100 to 200 gal. of asphalt per acre protected highly erodible soil again erosion by wind.
- The finer the spray, the better the surface coverage; hence, a smaller amount of asphalt was needed.
- Dilution of the cutback asphalt or the asphalt-in-water emulsion increased depth of penetration and stability of film.
- Amount of dilution needed depended on soil and climate conditions.

* Surface film disintegrated most rapidly on clay soils.

* Erosion was controlled for at least 2 months with 200 gal./acre of cutback or 400 gal./acre of emulsion.

* Asphalt contains sticky substances which consolidate soil particles. However, mechanical tillage and differential expansion and contraction by alternate wetting and drying or freezing and thawing broke up the soil crust. The resultant aggregates were water-stable but were too small to resist wind erosion.

Table 51 shows the effects of asphalt-in-water emulsion on erodibility, and Table 52 illustrates its effect on crop yield.

5.2.4 Tillage Practices

The soil surface can be made cloddy and rough in order to control erosion by developing a surface barrier. Such practices include: (a) regular tillage processes to prepare seedbeds and to control weeds for crop production; and (b) emergency tillage practices used specifically to bring clay to the surface for possible increased cloddiness and to roughen the land to prevent wind erosion.

5.2.4.1 Regular Tillage--

It is important that all tillage operations be conducted sparingly because tillage leads to soil surface smoothing and clod pulverization. Soil moisture at time of tillage has an effect on cloddiness. Different soils have differing moisture contents at which soil pulverization is most severe. More clods are produced if the soil is either extremely dry or moist than if it contains an intermediate moisture content.[21]

The type of tillage implement used also has an influence on soil cloddiness and surface roughness.[21] A study conducted with a moldboard plow, a one-way disc, and a subsurface sweep in controlled soil moisture conditions demonstrated that cloddiness is more dependent on the type of machinery than soil moisture content. The moldboard plow produced a rougher, more cloddy surface with higher mechanical stability of clods than the one-way disk or subsurface sweeps. Tillage implements used in stubble-mulch farming, with the exception of chisel cultivators, usually do not leave a ridged, rough surface. Subsurface sweeps provide a smooth surface and are advantageous insofar as they allow the vegetation to remain erect.

It is important that planting and seeding equipment preserve as much residue as possible, keep the soil surface rough and cloddy, and also, place the seed in moist, firm soil to promote rapid germination. Major types of planters available for small grains include hoe, single and double disk, deep furrow drills, and seeding attachments on one-ways and cultivators.

TABLE 51. AVERAGE EFFECTS OF ASPHALT-IN-WATER EMULSION AND TIME PERIOD AFTER TREATMENT ON SOIL ERODIBILITY BY WIND[20]

Amount of asphalt added (by weight) (%)	Time elapsed after treatment (months)	Soil erodibility by wind Mg/km² (tons/acre)
0 (check)	4	134 (0.6)
3		44.8 (0.2)
6		44.8 (0.2)
12		11.2 (0.05)[a]
0 (check)	18	112 (0.5)
3		44.8 (0.2)
6		44.8 (0.2)
12		22.4 (0.1)
0 (check)	36	89.6 (0.4)
3		202 (0.9)
6		336 (1.5)[a]
12		89.6 (0.4)
0 (check)	60	112 (0.5)
3		426 (1.9)[a]
6		2,020 (9.0)[a]
12		470 (2.1)[a]

TABLE 52. EFFECTS OF ASPHALT-IN-WATER EMULSION ON YIELD OF CROPS IN GREENHOUSE[20]

Amount of asphalt added (by weight) (%)	Yields of dry forage[a] Mg/km² (tons/acre)		
	6 months after treatment		5 years after treatment
	Corn	Oats	sorghum
0 (check)	1,720 (7.70)	822 (3.67)	228 (1.02)
3	1,240 (5.52)	721 (3.22)	181 (0.81)
6	1,080 (4.82)	661 (2.95)	220 (0.98)
12	797 (3.56)	186 (0.83)	235 (1.05)

[a] N, P, and K at 11,200, 22,400, and 11,200 kg/km² (100, 200, and 100 lb/acre), respectively, were added to corn and oat crops, but no fertilizer was applied to sorghum. Amount of soil available for growth of corn and oats was 3.6 kg (8 lb) and for sorghum 1.5 kg (3.3 lb) for each duplicated sample.

5.2.4.2 Emergency Tillage--

Emergency tillage to provide a rough, cloddy surface is a temporary measure, and its only purpose is to create an erosion-resistant soil surface in a short period of time. It is a last resort measure to be implemented when vegetative cover is depleted by excessive grazing, drought, improper or excessive tillage, or by growing crops that produce little or no residue or when potentially severe erosive conditions are expected.

The most common implements used are listers, duckfoot cultivators, and narrow-tooth chisel cultivators. The effectiveness of any of the above in creating cloddiness depends upon soil moisture, texture, and density. Cloddiness of soil is increased markedly by increasing density; also, the cloddiness potential of soils with a high clay content is greater than for sandy soils. Speed of travel, depth of tillage, spacing between tillage point-carriers, and type of part also influence the degree of cloddiness. Speeds of 5.6 to 6.4 km/hr (3.5 to 4.0 miles/hr) provide the optimum degree of cloddiness.

As for depth, 7.6 to 15.2 cm (3 to 6 in.) brings up compact clods. Spacing of lister and chisel must be governed by severity of erosion and the presence or absence of crops. Close spacing creates a rougher surface; however, if a crop is involved and there is a possibility of saving part of it, then wide spacings of 122 to 137 cm (48 to 54 in.) should be used to both provide roughness for control and permit the crop to grow.

Listers and narrow chisels are most effective types of tillage points. Listers produce a high degree of roughness and are especially effective in sandy soils where clods can be produced by deep tillage. Chisel cultivators require less power and destroy less crop than do listers.

5.2.5 Windbreaks and Wind Barriers

Windbreaks consist of trees or shrubs in 1 to 10 rows, crops in narrow rows, snowfences, solid wooden or rock walls, and earthen banks. Windbreaks function as surface barriers to control wind erosion; i.e., they take up or deflect a sufficient amount of the wind force to lower the wind velocities to the leeward below the threshold required to initiate soil movement. The effectiveness of any barrier depends on the wind velocity and direction, shape, width, height, and porosity of the barrier.

Nearly all barriers provide maximum reduction in wind velocity at leeward locations near the barrier, gradually decreasing downwind. Percentage reductions in wind velocities for rigid barriers remain constant no matter what the wind velocity.[16]

Direction of wind influences the size and location of the protected areas. Area of protection is greatest for perpendicular winds to the barrier length and least for parallel winds.

The shape of the windbreak indicates that a vertically abrupt barrier will provide large reductions in velocity for relatively short leeward distances, whereas porous barriers provide smaller reductions in velocity but for more extended distances.

Height of the barrier is, perhaps, the most important factor influencing effectiveness. Expressed in multiples of barrier height, the zone of wind velocity reduction on the leeward side may extend to 40 to 50 times the height of the barrier; however, such reductions at those distances are insignificant for wind erosion control. If complete control is desired, then barriers must be placed at close intervals.

Tree windbreaks, crop barriers, and various artificial barriers are discussed below.

5.2.5.1 Tree Windbreaks--

One-, two-, three-, and five-row barriers of trees are found to be the most effective arrangement for planting to control wind erosion. The type of tree species planted also has a considerable influence on the effectiveness of a windbreak. The rate of growth governs the extent of protection that can be realized in later years.

Figure 40 shows the reduction of wind velocity of a windbreak.

Table 53 illustrates the amount of area protected as a function of the length of the tree windbreak.

Table 54 shows the effect of the number of rows and season on wind erosion control afforded by tree windbreaks.

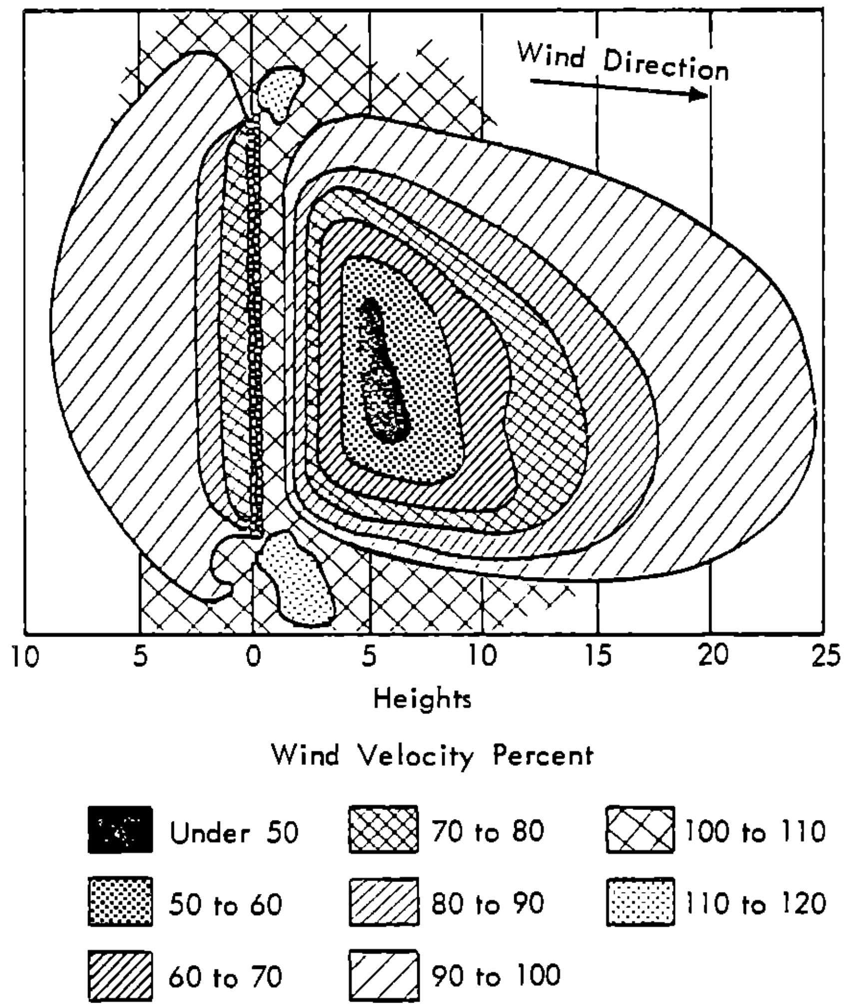
5.2.5.2 Artificial Barriers--

Snowfences, fences constructed of board or lath, bamboo and willow fences, earthen banks, hand-inserted straw rows, and rock walls have been used for wind erosion control on a rather limited scale. Because of the high cost of both material and labor required for construction, their use has been limited to where high value crops are grown or where overpopulation requires intensive agriculture.

In the United States, the application of artificial barriers for wind erosion control has been limited. Snowfences constructed from strips of lath held together with wire have been used for protecting vegetable crops. Such fences provide only a relatively short zone of protection against erosion, approximately 10 times the height of the barrier.

5.2.5.3 Crop Barriers--

Annual crops can be interplanted in narrow strips or rows so that one crop provides protection to the other. In California, interrow planting of barley protects the asparagus crop. Table 55 gives test results showing how effective a row of Sudan grass, grain or forage sorghum, or broomcorn would be as an interplanted row. This table illustrates their height, effectiveness index, and afforded protected distance.



Note - The actual field of protection of a windbreak 19 heights long, with an average density of 50 percent but more open in the lower than in the upper half. The air pushes through the opening at the bottom and shoots upward on the leeward side. The wind was measured 16 inches above ground.

Figure 40. Effectiveness of tree windbreak.

TABLE 53. PROTECTED AREA AS A FUNCTION OF WIND BARRIER LENGTH[22]

Length, m (rods)[a]	Area protected, km^2 (sq rods)
30 (6)	0.000228 (9)
60 (12)	0.000911 (36)
362 (72)	0.0328 (1,296)
805 (160)	0.113 (4,464)

[a] One rod = 16.5 ft.

TABLE 54. EFFECT OF NUMBER OF ROWS AND SEASON ON AMOUNT OF WIND EROSION PROTECTION PROVIDED BY TREE WINDBREAKS[16]

Windbreak	Effectiveness index[a]	Protected distance[b] (H units)[c]
	Summer conditions	
2-Row mulberry	55.9	18.0
5-Row plum, cedar, mulberry, elm, olive	42.6	15.0
1-Row osage orange	32.4	-
3-Row cedar (2), shrub	30.8	11.0
1-Row Siberian elm	27.1	9.5
1-Row jackpine	19.7	-
	Winter conditions	
10-Row cedar (1), deciduous (9)	46.6	-
5-Row plum, elm (2), cedar, honeysuckle	24.9	9.2
1-Row osage orange	24.9	12.0
7-Row ash (2), elm, cottonwood (2), osage orange, coffee	7.2	-

[a] Effectiveness index is computed by summing the products (velocity-reduction ratio at a given leeward location times the distance of the location from the barrier expressed in H units).

[b] Based on 64 km/hr (40 mile/hr) wind at 15 m (50 ft) height and a 40 km/hr (25 mile/hr) threshold velocity at the 15 m (50 ft) height.

[c] H = average height of trees in a single-row windbreak and average height of tallest trees in a multiple-row windbreak.

TABLE 55. EFFECTIVENESS OF SOME ANNUAL CROP BARRIERS FOR WIND EROSION CONTROL[16]

Crop	Height[a] m (ft)	Effectiveness index[b]	Protected distance[c] m (ft)
Kochia	1.1 (3.5)	17.0	12.8 (42.0)
Sudan grass	0.91 (3.0)	11.4	6.86 (22.5)
Grain sorghum	0.61 (2.0)	10.7	3.66 (12.0)
Forage sorghum	0.46 (1.5)	7.9	1.8 (6.0)
Broomcorn	1.2 (4.0)	3.9	1.2 (4.0)

[a] Harvested height.

[b] Effectiveness index equals sum of product (velocity-reduction ratio at a given leeward location times the distance of the location from the barrier expressed in H units).

[c] Based on 64 km/hr (40 mile/hr) wind at 15 m (50 ft) height and a 40 km/hr (25 mile/hr) threshold velocity at the 15 m (50 ft) height.

5.2.6 Strip Cropping and Row Crop Spacing

Crop strips function as soil traps designed to reduce soil avalanching. Strip cropping is a method of farming, usually involving two or more crops, whereby strips of erosion-resistant crops are planted between strips of erosion-susceptible crops. The strips are generally all the same width.

Row crop spacing involves only one crop and consists of planting crops at different row spacings to trap erodible soil.

These two farming practices as they relate to wind erosion control are discussed in the next two sections.

5.2.6.1 Strip Cropping--

The practice of strip cropping consists of dividing a field into alternate strips of erosion-resistant crops and erosion-susceptible crops or fallow. Erosion-resistant crops are the small grains and other crops that cover the ground rapidly. Erosion-susceptible crops are cotton, tobacco, sugar beets, peas, beans, potatoes, peanuts, asparagus, and most truck crops.

Strip cropping controls erosion by reducing soil avalanching, which increases with width of eroding field. Since avalanching depends on field erodibility, the appropriate width of strips required varies with factors that influence erodibility, such as soil texture, wind velocity and direction, quantity of crop residue, and degree of soil cloddiness and surface roughness.

Table 56 indicates the effectiveness of crop strips in relation to soil texture and direction of erosive winds. These data indicate that directional deviation of erosive winds from the perpendicular requires narrower strips, and that required width of the strip increases as soil texture becomes finer, except for clays and silty clays subject to granulation.

Strip cropping alone will not fully control wind erosion; it must be used in conjunction with other measures, such as stubble mulching, to be fully effective. In combination with strip cropping, the supplementary practices need not be as intensive as they would have to be for large fields.

5.2.6.2 Row Crop Spacing--

The relative effectiveness of different row spacings for wind erosion control has not been fully evaluated. In theory, the closer the row spacing, the more effective is the protection afforded against erosion. Most close-spaced crops are erosion-resistant once they are established. Sorghum, corn, cotton, and other crops normally planted in rows 102 to 107 cm (40 to 42 in.) apart are not so resistant. Experiments have shown that some of these crops can be grown in closer spaced rows without being detrimental to crop yield.

Orientation of crop rows to the prevailing erosive winds has an effect on erosion. The relative amount of erosion from soil planted to wheat in rows 25.4 cm (10 in.) apart is six times greater when the wind is blowing parallel to rows than when it blows perpendicular to the rows.[16]

5.2.7 Limited Irrigation of Fallow Field

The periodic irrigation of a barren field controls blowing soil by adding moisture which consolidates soil particles and creates a crust upon the soil surface when drying occurs.[23] The amount of water and frequency of each irrigation during fallow to maintain a desired level of control would be a function of the season and of the crusting ability of the soil. The drawback to irrigation control concerns the availability of water, cost of water, and interference with farming activities on the cropland.[24]

5.3 PROJECTED IMPACTS OF MODIFICATIONS IN AGRICULTURAL PRACTICE ON IP EMISSION INVENTORY

5.3.1 Baseline Emissions Calculation

In order to estimate the impact of implementing the control techniques described in Section 5.1, a baseline must first be established. Table 57 displays an IP emissions inventory based on the 1978 data provided in Appendix A. The detailed emission rate calculations on a crop-by-crop basis are shown in Appendix B.

The following criteria were used to perform the IP emissions inventory:

TABLE 56. AVERAGE WIDTH OF STRIPS REQUIRED TO CONTROL WIND EROSION EQUALLY ON DIFFERENT SOIL CLASSES AND FOR DIFFERENT WIND DIRECTIONS[16]

Soil class	Width of strips[a]		
	Wind at right angles to strips, m (ft)	Wind deviating 20 degrees from right angles, m (ft)	Wind deviating 45 degrees from right angles, m (ft)
Sand	6.1 (20)	5.5 (18)	4.3 (14)
Loamy sand	7.6 (25)	6.7 (22)	5.5 (18)
Granulated clay	24 (80)	23 (75)	16 (54)
Sandy loam	30.5 (100)	28 (92)	21 (70)
Silty clay	45.7 (150)	42.7 (140)	33.5 (110)
Loam	76.2 (250)	71.6 (235)	51.8 (170)
Silt loam	85.4 (280)	79.3 (260)	57.9 (190)
Clay loam	107 (350)	99.1 (325)	76.2 (250)

[a] For negligible surface roughness, average soil cloddiness, no crop residue, 1-ft high erosion-resistant stubble on windward, 64 km/hr (40 mile/hr), wind velocity at 15 m (50 ft) height, and a tolerance maximum rate of soil flow of 36 Mg/km width/hr (0.2 ton/rod width/hr).

TABLE 57. 1978 AGRICULTURAL IP EMISSIONS INVENTORY

Valley	Crop type	Operation	IP emissions, Mg/yr (tons/yr)
San Joaquin	Field	Soil preparation	31,000 (34,200)
		Cultivation	10,800 (11,900)
		Harvesting	29,000 (32,000)
	Vegetable	Soil preparation	3,100 (3,430)
		Cultivation	996 (1,100)
		Harvesting	850 (938)
	Fruit and nut	Soil preparation	7,230 (7,960)
		Cultivation	8,000 (8,820)
		Harvesting	1,060 (1,170)
Sacramento	Field	Soil preparation	20,100 (22,100)
		Cultivation	2,870 (3,170)
		Harvesting	14,000 (15,400)
	Vegetable	Soil preparation	2,090 (2,300)
		Cultivation	474 (522)
		Harvesting	357 (393)
	Fruit and nut	Soil preparation	693 (763)
		Cultivation	2,130 (2,340)
		Harvesting	280 (309)
Imperial	Field	Soil preparation	6,250 (6,900)
		Cultivation	1,260 (1,390)
		Harvesting	3,690 (4,070)
	Vegetable	Soil preparation	846 (933)
		Cultivation	424 (467)
		Harvesting	282 (311)
	Fruit and nut	All operations	Negligible
			148,000 (163,000)

1. Only agricultural operations in the 18 counties of concern were considered. These counties comprise the three largest agricultural valleys of the state.

2. Only crops with greater than 10,000 acres per agricultural valley were inventoried.

3. Operations thought to produce little dust were not listed in the inventory in Appendix B.

4. The inventory was performed only for IP emissions.

5. The IP emission factor for soil preparation in the San Joaquin Valley was calculated as the average of the measured IP emission factors for tests N-3 through N-6 as 393 kg/km^2 (3.5 lb/acre).

6. The IP emission factor for soil cultivation in the San Joaquin Valley was estimated as one-half of the soil preparation emission factor.

7. The IP emission factor for soil preparation in the Sacramento Valley was calculated as the average of the measured IP emission factors for tests N-8 through N-13 as 393 kg/km^2 (3.5 lb/acre).

8. The IP emission factor for soil cultivation in the Sacramento Valley was estimated as one-half of the soil preparation emission factor.

9. The IP emission factors for soil preparation and cultivation in the Imperial Valley were estimated to be the same as for the San Joaquin and Sacramento valleys.

10. The IP emission factor for harvesting emissions via digging for all the valleys was calculated as the average of the measured IP emission factors for tests R-1 through R-6.

11. The IP emission factor for harvesting via methods other than digging for all the valleys was calculated as one-half the average of the measured IP emission factors for tests R-1 through R-6.

The results of the inventory are summarized in Tables 57 through 61. The following conclusions are gleaned from the tables:

1. Soil preparation is the largest agricultural source of emissions in each of the three valleys comprising 44.9% of the total in the San Joaquin Valley, 53.3% of the total in the Sacramento Valley, and 55.7% of the total in the Imperial Valley.

2. The San Joaquin Valley yields the largest portion of agricultural emissions from the three valleys combined with 62.2% originating in the San Joaquin Valley, 29.1% originating in the Sacramento Valley, and 8.7% originating in the Imperial Valley.

TABLE 58. 1978 IP EMISSION RATES IN MG/YR BY OPERATION AND BY CROP FOR ALL THREE VALLEYS

	Soil preparation	Cultivation	Harvesting	Total
Field crops	57,400	14,900	46,700	119,000 (80.5%)
Vegetables	6,040	1,890	1,490	9,420 (6.4%)
Fruit and nuts	7,920	10,100	1,340	19,400 (13.1%)
Total	71,400 (48.3%)	26,900 (18.2%)	49,500 (33.55)	148,000 (100%)

TABLE 59. 1978 IP EMISSION RATES IN MG/YR BY OPERATION AND BY CROP FOR THE SAN JOAQUIN VALLEY

	Soil preparation	Cultivation	Harvesting	Total
Field crops	31,000	10,800	29,000	70,800 (77.0%)
Vegetables	3,100	996	850	4,950 (5.3%)
Fruit and nuts	7,230	8,000	1,060	16,300 (17.7%)
Total	41,300 (44.9%)	19,800 (21.5%)	30,900 (33.6%)	92,000 (100%)

TABLE 60. 1978 IP EMISSION RATES IN MG/YR BY OPERATION AND BY CROP FOR THE SACRAMENTO VALLEY

	Soil preparation	Cultivation	Harvesting	Total
Field crops	20,100	2,870	14,000	37,000 (86.0%)
Vegetables	2,090	474	357	2,920 (6.8%)
Fruit and nuts	693	2,130	280	3,100 (7.2%)
Total	22,900 (53.3%)	5,470 (12.7%)	14,600 (34.0%)	43,000 (100%)

TABLE 61. 1978 IP EMISSION RATES IN MG/YR BY OPERATION AND BY CROP FOR THE IMPERIAL VALLEY

	Soil preparation	Cultivation	Harvesting	Total
Field crops	6,250	1,260	3,690	11,200 (87.8%)
Vegetables	846	424	282	1,550 (12.2%)
Fruit and nuts	0	0	0	0 (0%)
Total	7,100 (55.7%)	1,680 (13.2%)	3,970 (31.1%)	12,800 (100%)

3. Field crop operations yield the largest portion of emissions in each of the three valleys comprising 77% of the total in the San Joaquin Valley, 86% of the total in the Sacramento Valley, and 87.8% of the total in the Imperial Valley.

4. The total IP emission rate from agricultural operations in the three valleys combined is 148,000 Mg/year (163,000 tons/year).

5.3.2 Estimation of Emission Reduction Due to Control

The control efficiences of the techniques discussed in Section 5.3.1 were estimated. It should be emphasized that these are crude estimates made simply to give a feel for the range of emission reduction values one might expect. The estimates of control efficiency for each technique are shown in Table 62.

The emission reductions for each control technique by crop and by valley were calculated using the control efficiences of Table 62 and the uncontrolled emission estimates of Appendix B. Tables 63 through 65 showed the emissions reduction attributable to each control technique on each crop in each valley. As discussed in Section 5.1.2, only eight crops were selected as candidates for study in terms of control techniques.

Tables 63 through 65 can be used by the reader to calculate an emission reduction given various combinations of controls. For example, control of cotton production in the San Joaquin Valley by a combination of punch planting and sprinkler irrigation would yield an estimated emission reduction of 4,550 Mg/year. Since cotton production in the San Joaquin Valley is currently estimated to contribute 23,200 Mg/year to the atmospheric particulate burden, this example combination of controls would effect an estimated 20% reduction in emissions.

In conclusion, novel control concepts do exist for agricultural fugitive dust and at present, their impact on air quality can be estimated. However, much more testing to quantify control efficiencies should yet be done. These and other conclusions and recommendations are developed in the front of this report.

TABLE 62. ESTIMATED VALUE OF CONTROL EFFICIENCIES FOR IP

Control technique	Operation affected	Estimated control efficiency (%) by crop for applicable techniques							
		cotton	barley	alfalfa	rice	corn	wheat	Process tomatoes	lettuce
1. Punch planter	Planting	50				50			50
2. Low energy system	All soil preparation operations	60						60	
3. Plug planter	Planting							50	
4. Herbicides	Cultivation or soil preparation	100	25[a]	25[a]	[b]	100	25[a]	100	100
5. Sprinkler irrigation	Land planing	90	90	90	[c]	90	90	90	90
6. Laser-directed land plane	Land planing or floating	30	30	30	30	30	30	30	30
7. List tomato acreage in the fall	Rolling and harrowing							100	
8. Develop high quality alfalfa	All soil preparation operations			75					
9. Double crop corn with wheat	Discing or plowing					50[d]			

TABLE 62. (concluded)

Control technique	Operation affected	Estimated control efficiency (%) by crop for applicable techniques							
		cotton	barley	alfalfa	rice	corn	wheat	Process tomatoes	lettuce
10. Aerial seeding	Planting			50	[e]		50		
11. Fogger	All operations	50	50	50	50	50	50	50	50

[a] Eliminates only some soil preparation operations, whereas in other cases, all cultivation operations are eliminated.

[b] Herbicides already applied by airplane for majority of acreage.

[c] Flood irrigation necessary.

[d] Fifty percent control only for double-cropped acreage.

[e] Seeding already performed by airplane for majority of acreage.

TABLE 63. ESTIMATED IP EMISSION REDUCTION POTENTIAL IN THE SAN JOAQUIN VALLEY

	Estimated emission reduction in Mg/yr for the San Joaquin Valley							
Control technique	cotton	barley	alfalfa	rice	corn	wheat	Process tomatoes	lettuce
1. Punch planter	556				70.4			6.67
2. Low energy system	7,980							912
3. Plug planter							34.4	
4. Herbicides	4,450	1,360	234		422	370	206	66.7
5. Sprinkler irrigation	3,990	699	210		254	190	249	48.1
6. Laser-directed land plane	1,330	233	70.0	75.6	84.7	63.3	83.0	16.0
7. List tomato acreage in the fall							138	
8. Develop high quality alfalfa			700					
9. Double crop corn with wheat					141			
10. Aerial seeding			147			52.5		
11. Fogger	11,600	4,050	5,600	439	1,610	1,100	1,060	165

TABLE 64. ESTIMATED IP EMISSION REDUCTION POTENTIAL IN THE SACRAMENTO VALLEY

Control technique	Estimated emission reduction in Mg/yr for the Sacramento Valley							
	cotton[a]	barley	alfalfa	rice	corn	wheat	process tomatoes	lettuce
1. Punch planter	0				56.9			Neg.
2. Low energy system	0						1,250	
3. Plug planter							47.4	
4. Herbicides	0	433	88.8		341	693	284	Neg.
5. Sprinkler irrigation	0	222	79.9		206	356	342	Neg.
6. Laser-directed land plane	0	74.0	26.6	846	68.7	119	114	Neg.
7. List tomato acreage in the fall							190	
8. Develop high quality alfalfa			266					
9. Double crop corn with wheat					114			
10. Aerial seeding			55.5			99.0		
11. Fogger	0	1,290	2,110	4,860	1,130	2,060	1,460	Neg.

[a] There is no cotton in the Sacramento Valley.

TABLE 65. ESTIMATED IP EMISSION REDUCTION POTENTIAL IN THE IMPERIAL VALLEY

Control technique	Estimated emission reduction in Mg/yr for the Imperial Valley							
	cotton	barley	alfalfa	rice[a]	corn[a]	wheat	process tomatoes	lettuce
1. Punch planter	26.6				0			16.3
2. Low energy system	383						Neg.	
3. Plug planter							Neg.	
4. Herbicides	159	Neg.	743		0	333	Neg.	163
5. Sprinkler irrigation	192	Neg.	802		0	399	Neg.	117
6. Laser-directed land plane	64	Neg.	267	0	0	133	Neg.	38.9
7. List tomato acreage in the fall							Neg.	
8. Develop high quality alfalfa			2,230					
9. Double crop corn with wheat					0			
10. Aerial seeding			74			55.5		
11. Fogger	632	Neg.	2,800	0	0	986	Neg.	610

[a] There is no rice or corn grown in the Imperial Valley.

REFERENCES

1. Cowherd, C., Jr., K. Axetell, Jr., C. M. Guenther (Maxwell), and G. Jutze. Development of Emission Factors for Fugitive Dust Sources. EPA 450/3-74-037, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, June 1974. 190 pp.

2. Monsanto Research Corporation. Source Assessment: Mechanical Harvesting of Cotton - State of the Art. EPA 600/2-77-107d, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, July 1977. 105 pp.

3. Monsanto Research Corporation. Source Assessment: Harvesting of Grain - State of the Art. EPA 600/2-77-107f, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, July 1977. 99 pp.

4. Woodruff, M. P., and F. H. Siddoway. A Wind Erosion Equation. Soil Science Society of America Proceedings, 29(5):602-608, 1965.

5. Cowherd, Chatten, Jr., Russel Bohn, and Thomas Cuscino, Jr.. Iron and Steel Plant Open Source Fugitive Emission Evaluation. EPA 600/2-79-103, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, May 1979. 139 pp.

6. Willeke, Klaus. Performance of the Slotted Impactor. J. of the Amer. Industrial Hygiene Assoc., September 1975. pp. 683-691.

7. Davies, C. N. The Entry of Aerosols in Sampling Tubes and Heads. British Journal of Applied Physics, 1968.

8. Chepil. W. J. Influence of Moisture on Erodibility of Soil by Wind. Soil Science Society of America Proceedings, 20:288-292, 1956.

9. Bouyoucos, G. J. The Dilatometer as an Indirect Means of Determining the Permanent Wilting Point of Soils. Soil Science, 43:217-223, 1936.

10. Hoenig, S. A. Use of Electrostatically Charged Fog for Control of Fugitive Dust Emissions. EPA-600/7-77-131, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, 1977.

11. Hoenig, S. A. Fugitive and Fine Particle Control Using Electrostatically Charged Fog. EPA-600/7-79-078, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, 1979.

12. Ritten Corporation. Stop Dust Pollution. Brochure, Ardmore, Pennsylvania, 1980.

13. Brookman, E. T. Demonstration of the Use of Charged Fog in Controlling Fugitive Dust from Large-Scale Industrial Sources. Symposium on Iron and Steel Pollution Abatement Technology for 1980, Philadelphia, Pennsylvania, November 1980.

14. Mathai, C. V. and Lyle Rathbun. New Concepts of Control Applied to Urban Inhalable Particulates. Phase I Report, EPA Contract No. 68-02-3145, AeroVironment, Inc., Pasadena, California, December 1980.

15. Kinsey, John Scott, Carol E. Lyons, Stuart A. Hoenig, and Dennis Drehmel. A New Concept for the Control of Urban Inhalable Particulate by the Use of Charged Fog. Technical Paper 80-68.5, 73rd Annual Meeting of the APCA, Montreal, Quebec, June 1980.

16. Chepil, N. S., and N. P. Woodruff. The Physics of Wind Erosion and Its Control. In: Advances in Agronomy, Volume 15, A. G. Norman, Ed., Academic Press, New York, New York, 1963.

17. Zingg, A. W. The Wind Erosion Problem in the Great Plains. Trans. Geophysics Union, 35:252-258, 1954.

18. Chepil, N. S. N. P. Woodruff, F. H. Siddoway, and L. Lyles. Anchoring Vegetative Mulches. Agricultural Engineering, 41:754-755, 1960.

19. Duley, F. L. U.S. Department of Agriculture Agronomy Handbook, 136:1-31, 1958.

20. Chepil, N. S. Effects of Asphalt on Some Phases of Soil Structure and Erodibility by Wind. Soil Science Society of America Proceedings, 19: 125-128, 1955.

21. Lyles, L., and N. P. Woodruff. How Moisture and Tillage Affect Soil Cloddiness for Wind Erosion Control. Agricultural Engineering, 43:150-153, 159, 1962.

22. Bates, C. G. The Windbreak as a Farm Asset. U.S. Department of Agriculture, Farmer's Bulletin, Volume 1405, 1944.

23. Guideline for Development of Control Strategies in Areas with Fugitive Dust Problems. OAQPS No. 1.2-071, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, October 1977.

24. Jutze, G., and K. Axetell. Investigation of Fugitive Dust, Volume I - Sources, Emissions, and Control. EPA 450/3-74-036a, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, June 1974.

GLOSSARY

Baler - A machine drawn by a tractor, or can be self-propelled, used to bale (bind with wire or bands) alfalfa, oat, grass, or any type of hay. Activity is called baling.

Bankout - Term used in rice production; means hauling the rice from fields out to the road.

Bedding - See List.

Block - To make borders or ridges with a blocking machine (a triple disc type machine) to enable the water to spread out more evenly over the beds.

Border disc - A small disc with three blades on each side (usually); set so that when it is pulled by a tractor it throws up a border or ridge; also see Block.

Broadcast - A method of applying seed or fertilizer to a field by using a broadcast spreader which runs off of the power takeoff of a tractor. This machine applies the materials on the surface of the soil.

Brush rake - A rake used for piling brush, usually mounted on the front of a tractor. Many different types; some are drawn behind the tractor, others pushed in front.

Brush shredder - A shredding machine used to shred pruned limbs from citrus, walnut, prunes, or any type of tree or vine crop. The brush is run through the machine, or the machine may pick the brush up and shred it. The small chips then come out of the machine and are fine enough to be turned under.

Buck brush - To pile brush in stacks (see also Brush rake).

Burn stubble - To burn grain stubble or any crop residue.

Check breaker - A small disc with two gangs set opposite each other that throw the soil in different directions so that when it passes over the check (an obstruction), it smoothes the soil.

Chisel - An implement used on the back of a tractor that has shanks set 1 to 3 ft apart; used to break the upper surface of the soil to a depth of 10 to 18 in.

Cleaning ditches - May be done by burning, by using a V-plow, or a scraper attached to a tractor; done to free the ditch of weeds so that irrigation water may pass more freely.

Clipping pasture - May be done by using a self-propelled swather, a sickle bar mower attached to a tractor, or by a shredder which is pulled by a tractor (like a rotary lawn mower). New pastures are clipped so that the pasture plants will stool out and become thicker, and to reduce week growth.

Combine - A machine used to harvest small grains such as wheat, barley, oats, and milo. Has a sickle mower attached to the front which cuts the grains, which go through the machine and through a series of screens. The grain is separated from the stems of the plants and goes into a storage bin; the stems go out the back onto the ground.

Cultivator - A machine attached to a tractor; used on row crops to loosen up soil for the following purposes: (a) to retain moisture (by killing weeds, mulching the surface); (b) to develop plant food; (c) to aerate soil by allowing oxygen to penetrate; and (d) to promote activity of microorganisms.

Cultural drag - See Drag.

Disc - An implement that is used to break up the soil at a shallow depth, for weed control and to leave residue to prevent erosion. Pulled behind a tractor to prepare grain fields and to break up clods after plowing.

Drag - An implement pulled behind a tractor to crush clods, level beds, level land, or firm the soil around the seeds that have just been planted; it is usually homemade from wood to fit a farmer's particular needs.

Dress (side) - This is a method of applying fertilizer to the sides of the beds in row crops; it is applied as a gas (or liquid) into the soil; is put on a tractor and the material goes through a cultivator shank into the soil.

Drill - A machine pulled behind a tractor to plant seeds in furrows.

Duster - A machine used to dust crops such as grapes, oranges, walnuts, and some vegetable crops; usually self-powered; used basically for applying sulfur.

Fertilizer - Four basic types: (a) barnyard; (b) commercial; (c) liquid; and (d) grass. Application is by: (a) manure spreader; (b) broadcasting (by truck, tractor, or airplane); (c) putting into irrigation water; and (d) side dressing (see Dress).

Float - A type of a drag used to water level land.

Furrow - The bottom of a narrow trench made in the soil by a lister (see List).

Girdling - The cutting of a ring around a tree or branch with a knife.

Harrow - An implement pulled behind a tractor; used for seedbed preparation; stirs the soil, breaks up clods, smooths the soil, and kills weeds. Three types: spring tooth, spike toothed, and disc.

Heaters (or smudge pots) - Used to hold oil and are set afire to protect many types of fruit trees from frost damage; sometimes used in vegetable production as well.

Hot capping - Paper caps that are put over young plants such as tomatoes for protection from the climatic elements, including providing more warmth for them.

Land plane - A large machine on wheels pulled behind a tractor for leveling land. Has a blade or bucket across the middle to carry the soil. This blade or bucket can be preset for the level desired or the thickness of soil to be moved. They come in various sizes, 18 to 80 ft long.

Lighting - See Heaters.

List - To make furrows and beds for row crops with a lister, an implement that attaches to a tractor. The lister has sweeps or plow-like shovels on it that make these furrows and beds.

Mulching - The loosening of the soil on the side of the beds, usually with a rolling cultivator. Any type of material is worked into the soil to keep it loose (straw, etc.).

Picking machine - Various kinds or types of machines used to mechanically harvest crops, usually self-propelled (cotton pickers, corn pickers, etc.).

Plant - See (grain) Drill and Broadcast.

Plastic mulch - Plastic put over beds to protect young plants such as strawberries by helping the plants to retain moisture, killing weeds, and protecting young plants from the cold.

Plow - An implement pulled behind a tractor which will turn the soil completely over to a depth of 6 to 36 in. deep. There are many different types of plows; one of the most popular is the moldboard.

Prune - The removal of dead or diseased wood from the tree or shrub; also used to shape the plant; may be done by hand or by machine.

Rake - An implement pulled behind a tractor to rake hay, grain, stubble, or grasses into windrows. There are many different types, such as side delivery, bunch, swathing machine (both cuts and rakes).

Ridger - See Border disc and List.

Ripping - Refers to breaking up the soil from 20 in. to 6 ft deep. The subsoiler machine is pulled by a heavy tractor, and has from one to three shanks which break up hardpan or compacted soil--usually done every 2 to 3 years in row crops.

Rogueing - Thinning out or getting rid of undesirable plants.

Roller - Implement pulled behind a tractor to break up clods and to firm up and level the soil; several kinds, such as ring rollers, solid rollers, etc. (can be used to firm beds after planting).

Rototiller - An implement pulled behind a tractor for pulverizing the soil surface to a depth of about 6 in. Used for weed control.

Scalping - Cutting the tops off of sugar beets with a machine before they are dug.

Scraper - An implement for moving soil pulled by or attached to a tractor. Can be used to level or can be adjusted on an angle to cut ditches. (Also a blade to remove soil from revolving discs or wheels on field implements.)

Shape beds - An implement (bed shaper) for shaping beds which flattens off the tops and smooths the sides.

Shredder - An implement pulled behind a tractor to shred stalks such as cotton, milo, or any other type of light stalks; looks like a rotary lawn mower. Shredding makes it easier to disc the residue under.

Sled - (See Shape beds) - Could also be an implement for pulling products out of the field. Also a machine used for shaping bed.

Springtooth - See Harrow.

Stakes - Used for securing new plantings such as orchard trees, also used for beans, tomatoes, and many other types of plants.

Stocks column (or Column stocks) - Variety of cut flowers grown in Orange County. *Matthiala incana*, many strains available; these plants are unbranched and grow 2 to 3 ft tall. Can be planted 6 to 8 in. apart in rows and are ideal for cutting.

Stubble - The base portion of the stems of plants left standing after cutting (for example, barley, oats, alfalfa, etc.).

Subsoiler - See Ripping.

Summer Pinch - The pinching back of buds and fruit to increase the quality of both.

Swede harrow - See Harrow.

Sweep - A double-bladed V-shaped knife on a cultivating shank. Also a sweeper for sweeping almonds; used to sweep almonds into rows.

Threshing - The process of separating the seeds from the stems on small grains. Done by mechanical means. A threshing machine separates the grain and puts the chaff into a stack.

Wind falls - Refers to fruit that falls from the trees because of strong wind.

Windrow - See Rake.

ABBREVIATIONS

CARB - California Air Resource Board.
The sponsor of this project.

CI - Cascade Impactor.
The Sierra slotted high volume cascade impactor was used in this report to size particles.

EPA - Refers to the United States Environmental Protection Agency.

FP - Fine Particulate.
Particles smaller than 2.5 μm in aerodynamic diameter.

FR - Flow Ratio
Ratio of a profiler head intake speed to the wind speed.

I - Isokinetic Sampling.
The sampling of a moving air stream in a rectilinear fashion using a probe.

IP - Inhalable Particulate.
Particles smaller than 15 μm in aerodynamic diameter.

MRI - Midwest Research Institute.
The prime contractor for this project.

N - Nonisokinetic Sampling.
The sampling of a moving air stream in a nonrectilinear fashion using a probe.

SCFT - Spinning Cup Fog Thrower.
A device used to control particulate emissions by generating electrically charged water droplets which attract the dust.

SSI - Size-selective Inlet.
A device placed atop a high volume sampler which captures 15 μm aerodynamic diameter particles with a 50% collection efficiency.

TP - Total Particulate.
Particles of all sizes.

TSP - Total Suspended Particulate.
Particles captured by a high volume sampler.

USDA - United States Department of Agriculture.

APPENDIX A

SURVEY OF AGRICULTURAL OPERATIONS

KVB initiated a survey of 1978 agricultural operations in the San Joaquin, Sacramento, and Imperial Valleys by contacting the farm advisors in each county and requesting the county Crop Reports obtained from 18 county agricultural commissioner offices, and the crop Cost to Produce sheets.

The harvested acreage in 1978 was tabulated for each county's vegetable, field, seed, and fruit and nut crops. These data were available in the 1978 Agricultural Crop Reports. The Crop Reports list seed crop acreage separately, but also include that acreage in the total harvested acres. This was also true for crops used as forage and silage. To avoid double counting, the field crop tables list the acres of a seed crop in parentheses next to the total harvested crop acreage.

The presentation of harvested acreage was simplified by listing only crops that had more than 500 harvested acres in any county. This number was arbitrarily chosen, but the rationale was to avoid describing the typical farming operations for a minor crop. We also omitted in the totals harvested acreage listed as "other" or "miscellaneous." This acreage was a small percentage of a valley's total crop acreage and was not conducive to determining what typical farming operations were involved in producing the various crops.

The county crop reports often listed the acreage of each major variety of a particular crop. The acreage of the varieties of a crop were summed in the tables since the typical farming operations were considered the same for each variety. If the planting or harvesting dates of each variety differed, these were so indicated in the planting and harvesting calendar presented in the tables.

Tables A-1 through A-79 for the San Joaquin, Sacramento, and Imperial Valleys are generally presented in a similar fashion. The typical land preparation, cultivation, and harvest operations as indicated by the crop specialists are presented on the left-hand side of the table. The number of times each operation is performed is shown by an "X." A gross, qualitative estimate of the soil moisture contents is made, and an arrow indicates that the estimate is identical for each operation.

A planting and harvesting calendar indicates the span of months in which these operations take place. In many cases, numerous crop varieties, as well as long planting and harvesting periods, make these periods merge or reduce the cultivation, growth, and lay-by period.

When planting or harvesting times come together, it is usually <u>not</u> due to a short or nonexistent cultivation or growing period, but rather that an early planted crop will be harvested early and this harvest may occur shortly after the planting of a late harvested crop.

Notes are used in the tables to explain or clarify unusual situations.

TYPICAL FARMING OPERATIONS

The Cost to Produce publications contained the preharvest, cultural, and harvest costs listed by operation for a particular crop in a county or in a valley. Each Cost to Produce sheet reflected a county farm advisor's opinion as to the optimum production methodology to achieve a maximum harvest. KVB felt that it would be cumbersome as well as inexact to simply list the operations included in the Cost to Produce sheets, so Dr. J. B. Siebert, Assistant Vice President of the Cooperative Extension, University of California, was contacted. Dr. Siebert authorized KVB to contact the agricultural specialists at the U.C. campuses to obtain a valley-by-valley picture of crop operations.

San Joaquin Valley and Sacramento Valley

On November 19, 26, and 30, 1979, KVB personnel interviewed specialists on vegetable, field and seed, and fruit and nut crops at the Davis Campus. Each group of specialists identified a county whose Cost to Produce sheets were typical for that valley or listed the typical farming operations in that valley. The typical crop operations for the San Joaquin Valley are presented in Tables A-1 through A-38 and for the Sacramento Valley in Tables A-39 through A-75.

Imperial Valley

On November 16, 1979, KVB personnel visited Dr. William Isom and Mr. Hunter Johnson at the Riverside Campus regarding farming operations in the Imperial Valley. Isom and Johnson pointed out that the difficulties in defining farming operations for a valley were attributable to differences in soils, location in the valley, weather conditions, and personal preferences and the needs of the particular farmer. But they offered the following guidelines which were incorporated into Tables A-76 through A-79:

1. Farming operations in the Imperial Valley are generally similar for all vegetable, field and seed, and fruit crops.

2. The only fruit and nut crops over 500 acres were citrus crops, and these crop operations were typical of Coachella Valley operations for which Cost to Produce sheets were available.

3. Estimates of soil moisture were most difficult. Normally only the top 2 to 4 in. of a soil is tilled, and this layer is generally dry. A soil's capacity to hold water ranges from 8 to 20%. Land preparation is normally done at a time when the soil is at the lower end of the moisture capacity curve, about 8 to 13%. Estimates of soil moisture for each crop type are presented with the tables.

4. The planting and harvesting calendar for vegetable and field crops is found in Circular 104, "Guidelines to Production Costs and Practices," Imperial County, 1979.

5. The typical land preparation, cultivation, and harvest operations are shown in the tables. The number of times each operation is performed is indicated by a number times "X."

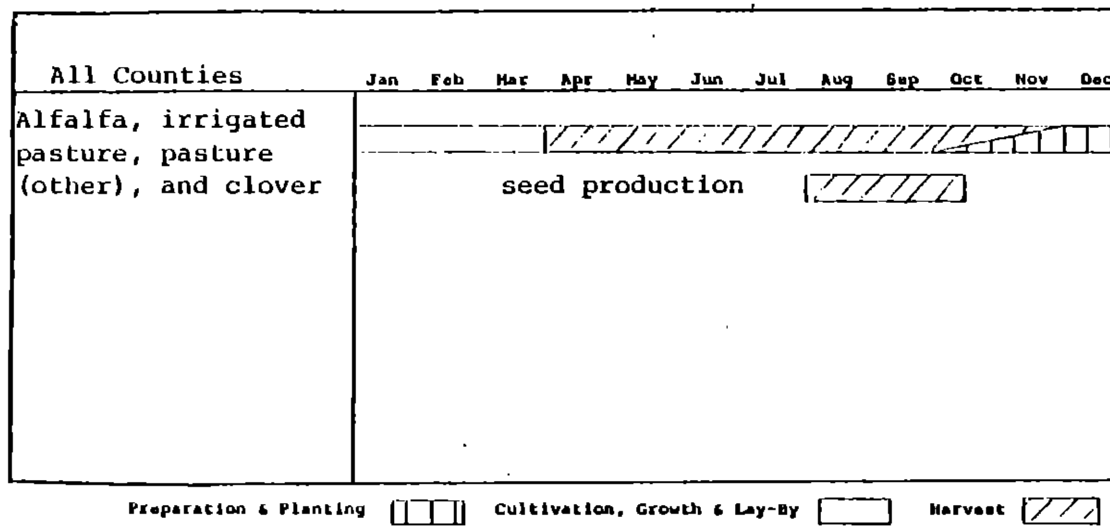
6. Land preparation operations are typically more dusty than cultivation or harvest operations because of the dryer soils. Normally land preparation begins with the soil moist or firm, and it gradually gets dusty with each successive operation.

7. Land planing is normally the dustiest operation.

TABLE A-1. SAN JOAQUIN VALLEY
1978 FIELD AND SEED CROPS
ALFALFA, IRRIGATED PASTURE, PASTURE (OTHER), AND CLOVER

TYPICAL OPERATIONS*

	All counties	Soil Moisture
LAND PREPARATION†		
Chisel	2x	Dry
Disc	2x	↓
Land plane	2x	↓
Fertilize	1x	↓
Border	1x	↓
CULTIVATION		
Plant	1x	Dry
Irrigate	14x	Moist
Weed control		
HARVEST (other than pasture for forage)		
Swath	5-7x	Moist§
Rake	5-7x	↓
Bale	5-7x	↓



Seed crops follow seasonal harvest

1000 Harvested Acres ‖

County	Alfalfa‡	(seed)	Irrig. Pasture	Pasture (other)	Clover
Fresno	82.5	(45.5)	40.0	<0.5	<0.5
Kern	<0.5		12.5	↓	↓
Kings	43.5	(23.4)	10.0	↓	↓
Madera	45.0		41.0	↓	↓
Merced	46.7		100.0	↓	↓
San Joaquin	50.4		60.4	↓	↓
Stanislaus	25.9		78.1	↓	↓
Tulare	75.0		17.0	↓	↓

*Glenn county operations typical of all alfalfa, irrigated pasture, and clover operations in the San Joaquin or Sacramento Valley.

†Land preparation of alfalfa for hay, grain, or seed identical. These field crops are on the land from 5-7 years. Estimate 20% of all harvested acreage requires land preparation.

§Soil moisture is "dry" during seed crop harvest.

‖County crop reports include seed crop acreage in harvested field crop acreage.

‡Alfalfa acreage includes alfalfa for hay, grain, stubble, grass, and seed.

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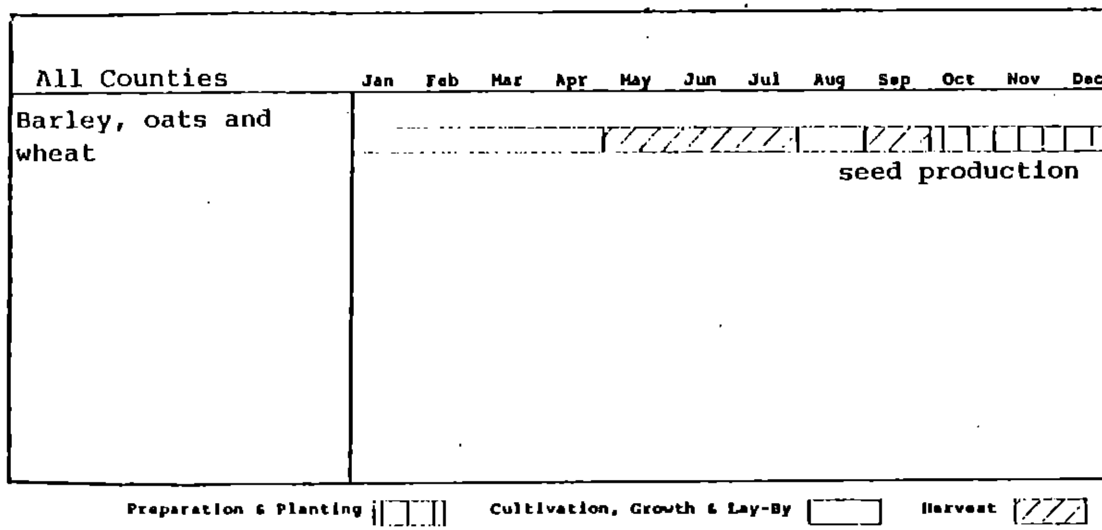
TABLE A-2. SAN JOAQUIN VALLEY
1978 FIELD AND SEED CROPS
BARLEY, OATS and WHEAT

TYPICAL OPERATIONS*

	All counties	Soil Moisture
LAND PREPARATION		
Disc	2x	Dry†
Harrow	1x	
Ditch	1x	
Border	1x	
Land plane	1x	
Fertilize	1x	
CULTIVATION		
Plant	1x	Moist
Irrigate	2x	
HARVEST		
Custom combine	1x	Dry
Haul	1x	
POST HARVEST‡		
Stubble disc	2x	



Seed crops follow seasonal harvest.

1000 Harvested Acres‖

County	Barley (seed)§	Oats (seed)§	Wheat (seed)§
Fresno	209.0 (4.9)	<0.5	8.5
Kern	<0.5	"	35.0
Kings	135.5 (6.9)	"	14.7 (4.6)
Madera	27.0	4.1	22.0
Merced	1.9	4.7	<0.5
San Joaquin	32.3	4.7	25.6
Stanislaus	30.0	2.8	3.9
Tulare	54.0 (0.5)	0.8	23.0 (0.5)

*Fresno county operations typical of BARLEY, OATS & WHEAT operations in the San JoaquinValley for producing a single crop.

†Land preparation normally done prior to first rain.

§County crop reports include seed crop acreage in harvested field crop acreage.

‖Silage and forage acreage included in harvested crop acreage.

‡Wheat and barley that is double-cropped will have 25 percent of harvested acreage in the late fall burned, disked-2x, stubbled and land planed-2x.

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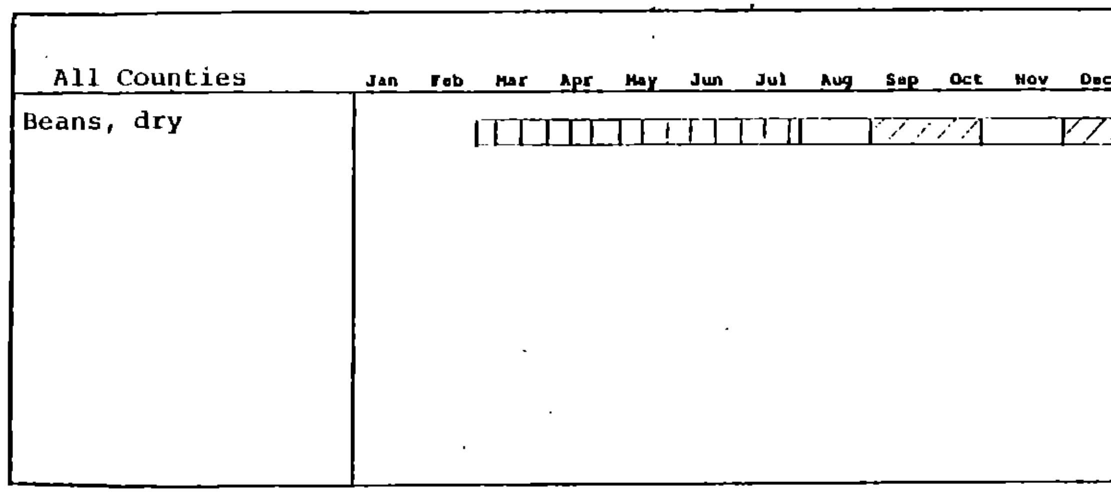
TABLE A-3. SAN JOAQUIN VALLEY
1978 FIELD AND SEED CROPS
BEANS, DRY

TYPICAL OPERATIONS*

	All counties	Soil Moisture
LAND PREPARATION		
Plow or chisel	1x	Moist
Disc	1x	
Triplane	2x	
Land plane(4th yr.)	3x	
Fertilize & herbicide	1x	
Disc	2x	
CULTIVATION		
Irrigate	6x	Moist
Plant	1x	
Cultivate	2x	
Pest control	2x	
HARVEST†		
Machine cut	1x	Dry
Windrow	1x	
Haul	1x	



Preparation & Planting Cultivation, Growth & Lay-By Harvest

seed crops follow seasonal harvest

1000 Harvested Acres

County	Harvested acres	(seed)§
Fresno	8.4	
Kern	<0.5	
Kings	<0.5	
Madera	4.7	
Merced	7.6	(2.2)
San Joaquin	29.2	(8.5)
Stanislaus	36.9	
Tulare	8.8	

*Stanislaus county operations typical of dry bean farming operations in the San Joaquin Valley.
†Machine harvest relatively "dusty" operation.
§County crop reports include seed crop acreage in harvested field crop acreage.

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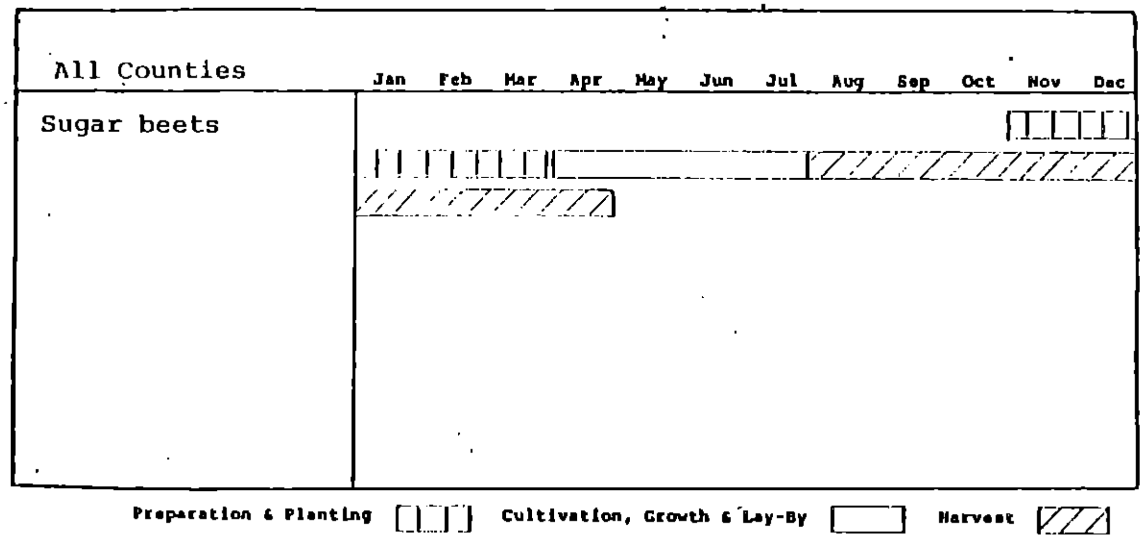
TABLE A-4. SAN JOAQUIN VALLEY
1978 FIELD CROPS - BEETS, SUGAR

TYPICAL OPERATIONS*

	All counties	Soil moisture
LAND PREPARATION		
Fall		
Plow or subsoil	1x	Moist
Land plane	2x	↓
Chisel	1x	↓
Spring		
Disc	2x	Dry
Springtooth & roll	2x	↓
Harrow & roll	1x	↓
List & fertilize	1x	↓
CULTIVATION		
Plant	1x	Moist
Herbicide	1x	↓
Cultivate	3x	↓
Irrigate	8x	↓
Thin and weed	1x	↓
HARVEST		
Top & dig	1x	Moist
Haul	1x	



County	1000 Harvested Acres
Fresno	16.0
Kern	12.0
Kings	1.4
Madera	6.0
Merced	14.9
San Joaquin	22.2
Stanislaus	1.7
Tulare	3.5

* San Joaquin county operations typical of sugar beet operations in the San Joaquin Valley.

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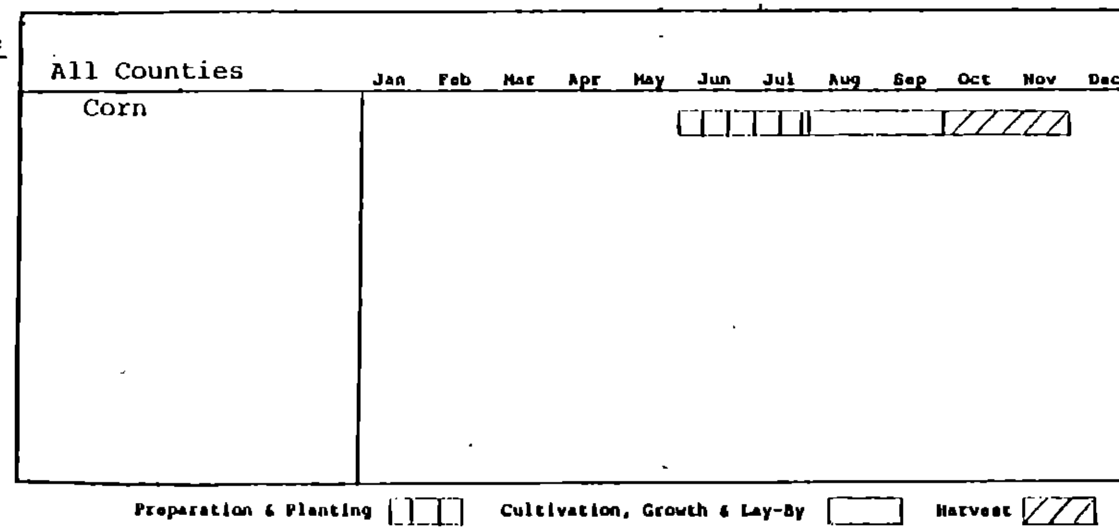
TABLE A-5. SAN JOAQUIN VALLEY

1978 FIELD CROPS - CORN

TYPICAL OPERATIONS*	All counties	Soil Moisture
LAND PREPARATION		
Stubble disc	1x	Moist
Land plane	1x	↓
Disc	2x	↓
Springtooth	1x	↓
List & fertilize & herbicide	1x	↓
CULTIVATION		
Plant	1x	Moist
Irrigate	8x	↓
Cultivate	3x	↓
HARVEST†		
Combine	1x	Dry
Haul	1x	



County	1000 Harvested Acres§
Fresno	30.2
Kern	<0.5
Kings	8.5
Madera	17.8
Merced	30.6
San Joaquin	79.0
Stanislaus	8.1
Tulare	3.1

*Kings or Fresno county operations typical of field corn operations in the San Joaquin Valley.

†Harvest creates little dust because there is minimal disturbance of the soil; only dust is from the handling of the plants.

§Silage and forage acreage included in harvested crop acreage.

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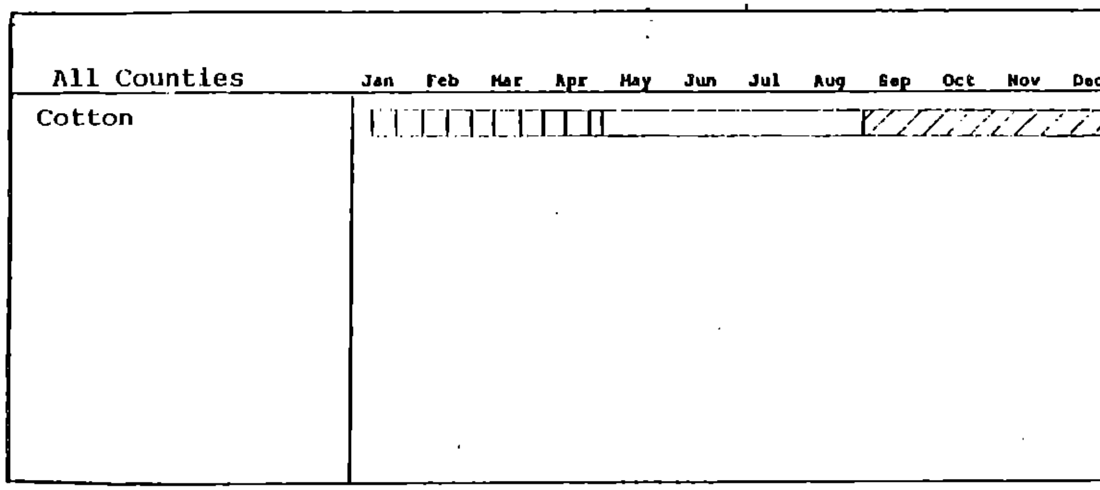
TABLE A-6. SAN JOAQUIN VALLEY
1978 FIELD CROPS - COTTON

TYPICAL OPERATIONS*

	All counties	Soil Moisture
LAND PREPARATION		
Plow	1x	Moist
Disc	2x	↓
Land plane	2x	↓
List & fertilize	1x	↓
CULTIVATION		
Planting	1x	Moist
Irrigate	6x	↓
Hand weed	1x	↓
Cultivate	4x	↓
Fertilize	1x	↓
Pest control	3x	↓
Defoliate	1x	↓
HARVEST		
Machine pick & haul	1x	Dry



Preparation & Planting Cultivation, Growth & Lay-By Harvest

seed crops follow seasonal harvest

County	1000 Harvested Acres Harvested	Acres (seed)†
Fresno	390.0	(13.2)
Kern	380.0	
Kings	284.8	
Madera	63.2	
Merced	69.6	
San Joaquin	<0.5	
Stanislaus	<0.5	
Tulare	214.1	(4.4)

*Fresno County operations typical of cotton operations in the San Joaquin Valley. Cotton is not grown in the Sacramento Valley

†County crop reports include seed crop acreage in the harvested field crop acreage.

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TABLE A-7. SAN JOAQUIN VALLEY

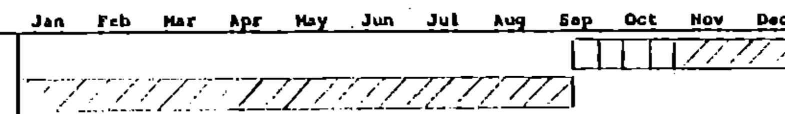
1978 FIELD CROPS - PASTURE, DRY LAND

TYPICAL OPERATIONS

	All counties	Soil Moisture
LAND PREPARATION*		
Disc	2x	Dry
PLANTING		
Plant	1x	Dry
No Cultivation		
HARVEST		
None- animal grazing		

All Counties

Pasture, dry land



Preparation & Planting Growth & Animal grazing

County	1000 Harvested acres
Fresno	1,090
Kern	2,285
Kings	225
Madera	475
Merced	585
San Joaquin	250
Stanislaus	371
Tulare	900

*Land preparation and planting may be done every 10 years, estimate 10% of all dry land pasture acreage requires land preparation.

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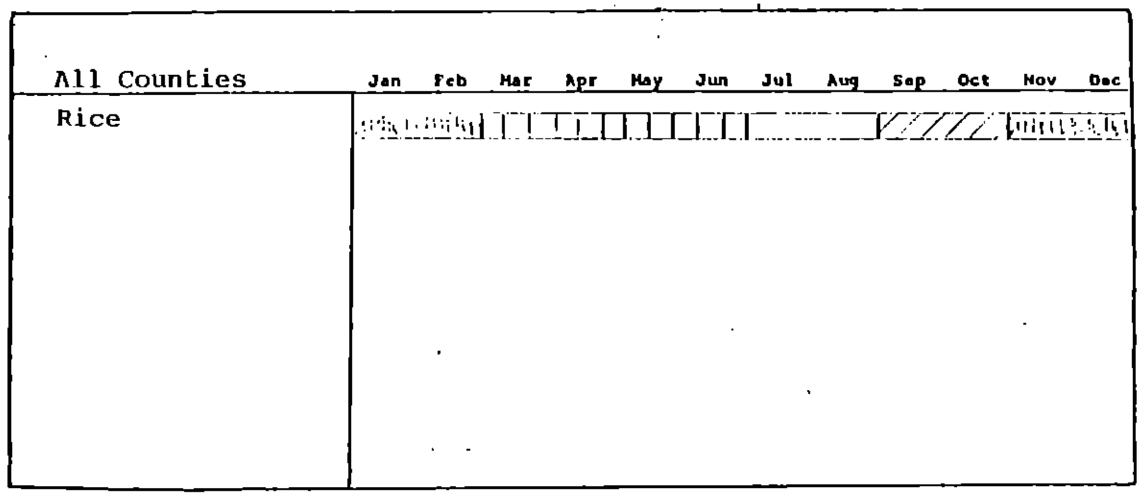
TABLE A-8. SAN JOAQUIN VALLEY

1978 FIELD AND SEED CROPS - RICE

TYPICAL OPERATIONS*

	All counties	Soil Moisture
LAND PREPARATION		
Plow	1x	Moist
Disc	2x	↓
Float	2x	↓
Fertilize	1x	↓
Close & Maintain levees	1x	↓
Flood & irrigate	1x	Wet
PLANTING	1x	Wet
No cultivation		↓
Weed control	1x	↓
Insect control	1x	↓
HARVEST		
Drain levees	1x	Moist
Combine & haul	1x	
LAND PREPARATION		
Burn	2x	Dry
Doze levees	1x	↓
Disc	2x	↓
Stubble	1x	↓
Land plane	2x	↓



Preparation & Planting Cultivation, Growth & Lay-By Harvest

seed crops follow seasonal harvest. Burn

County	1000 Harvested Acres
Fresno	13.0
Kern	2.7
Kings	0.8
Madera	<0.5
Merced	9.5
San Joaquin	7.1
Stanislaus	3.0
Tulare	3.6

* Fresno county operations typical of rice operations in the San Joaquin Valley.

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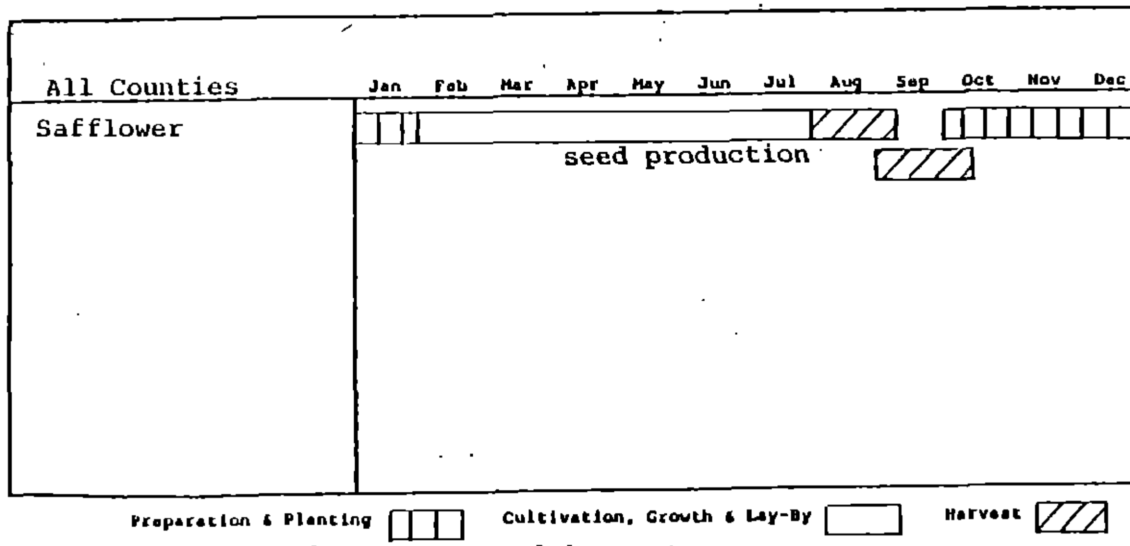
TABLE A-9. SAN JOAQUIN VALLEY

1978 FIELD AND SEED CROPS - SAFFLOWER

TYPICAL OPERATIONS*	All counties	Soil Moisture
LAND PREPARATION		
Chisel	2x	Moist
Disc	2x	↓
Fertilize	1x	↓
Harrow	2x	↓
PLANTING		
Plant	1x	Moist
No Cultivation		↓
Irrigation	3x	↓
HARVEST†		
Combine & haul	1x	Dry



seed crops follow seasonal harvest

County	1000 Harvested acres (seed)§	
Fresno	13.0	
Kern	<0.5	
Kings	39.2	(2.6)
Madera	<0.5	
Merced	2.5	
San Joaquin	13.7	
Stanislaus	<0.5	
Tulare	<0.5	

* Fresno or Kings county operations typical of safflower operations in the San Joaquin Valley.

† Harvest creates little dust because there is minimal disturbance of the soil; only dust is from the handling of the plants.

§County crop reports include seed crop acreage in the harvested field crop acreage.

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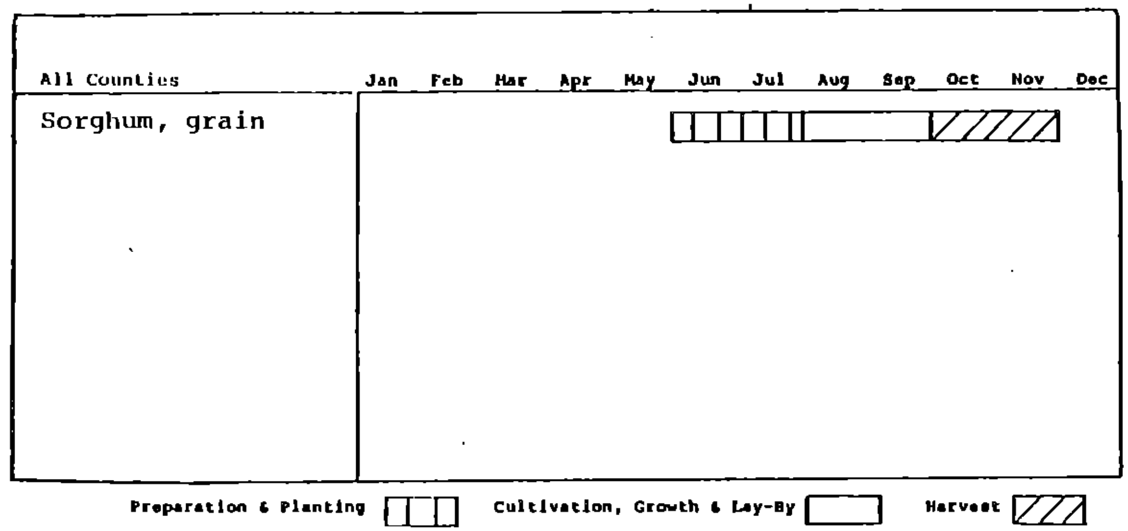
TABLE A-10. SAN JOAQUIN VALLEY

1978 FIELD CROPS - SORGHUM, GRAIN

TYPICAL OPERATIONS*

	All counties	Soil Moisture
LAND PREPARATION		
Stubble disc	1x	Moist
Land plane	1x	↓
Disc	2x	↓
Springtooth	1x	↓
List & fertilize & herbicide	1x	↓
CULTIVATION		
Plant	1x	Moist
Irrigate	8x	↓
Cultivate	3x	↓
HARVEST†		
Combine	1x	Dry
Haul	1x	



County	1000 Harvested acres§
Fresno	9.1
Kern	20.5
Kings	10.8
Madera	3.5
Merced	2.4
San Joaquin	2.2
Stanislaus	0.9
Tulare	14.0

*Kern county operations typical of sorghum operations in the San Joaquin Valley.
†Harvest creates little dust because there is minimal disturbance of the soil; only dust is from the handling of the plants.
§Silage and forage acreage included in harvested crop acreage.

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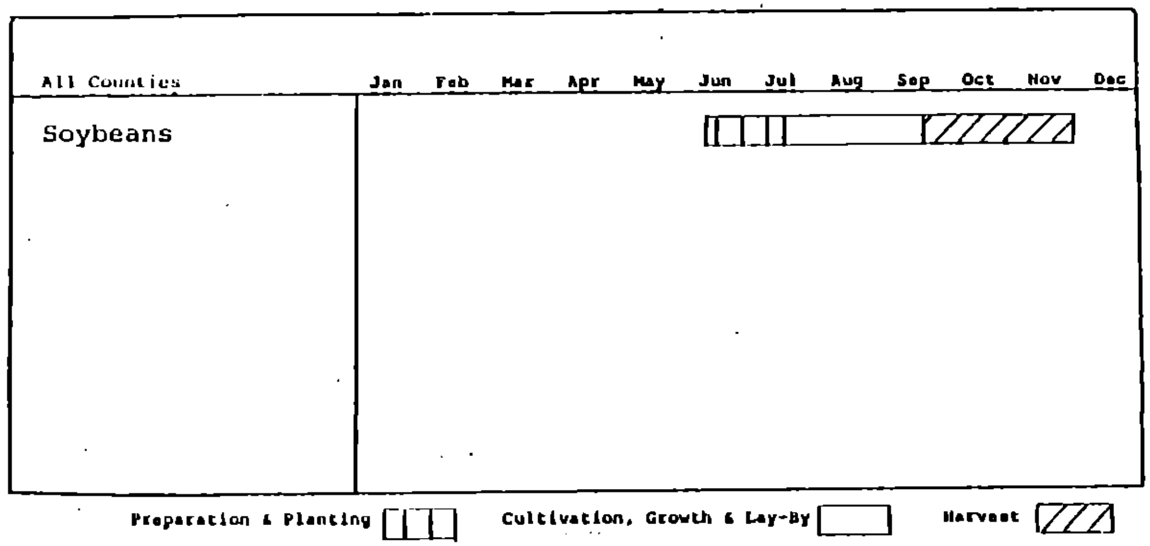
TABLE A-11. SAN JOAQUIN VALLEY

1978 FIELD CROPS - SOYBEANS

TYPICAL OPERATIONS*

	All counties	Soil Moisture
LAND PREPARATION		
Plow or chisel	1x	Moist†
Disc	2x	↓
Land plane	2x	↓
Fertilize	1x	Dry
CULTIVATION		
Plant	1x	Moist
Herbicide	1x	↓
Irrigate	4-5x	↓
Insect control	1x	↓
Cultivation	2x	↓
HARVEST		
Combine and Haul	1x	Dry



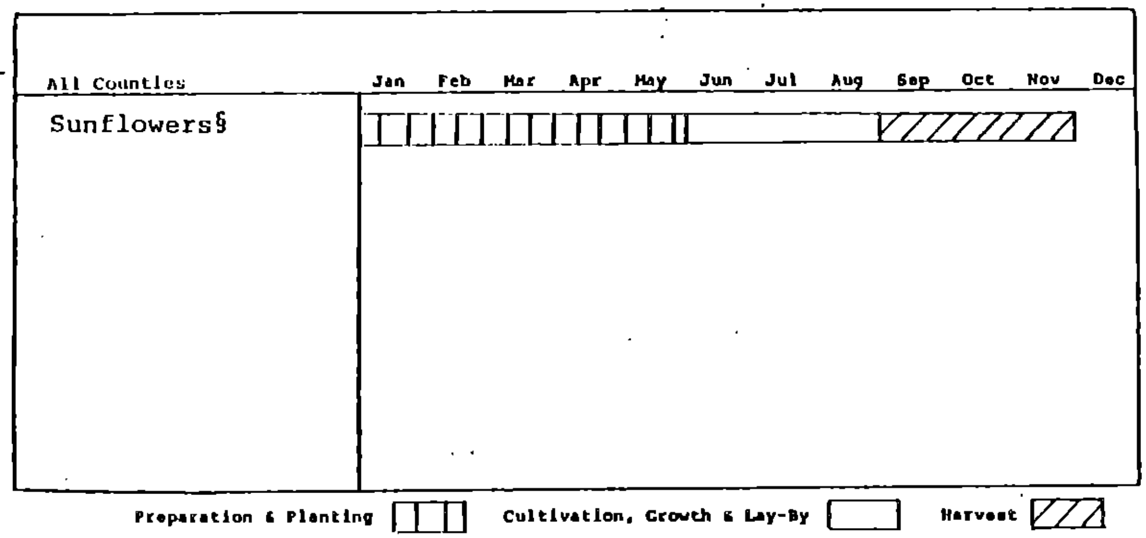
County	1000 Harvested acres
Fresno	<0.5
Kern	0.5
Kings	0.9
Madera	1.1
Merced	1.1
San Joaquin	<0.5
Stanislaus	<0.5
Tulare	6.5

* Tulare county operations typical of soybean operations in the San Joaquin Valley.
†Soil moisture decreases with each successive land preparation operation.

TABLE A-12. SAN JOAQUIN VALLEY

1978 FIELD AND SEED CROPS - SUNFLOWERS

TYPICAL OPERATIONS*	All counties	Soil Moisture
LAND PREPARATION		
Stubble disc	1x	Moist†
Disc	3x	↓
Float	1x	↓
Disc & spike	1x	↓
Land plane(every other year)	2x	↓
Fertilize & herbicide	1x	Dry
CULTIVATION		
Plant	1x	Dry
Cultivate	2x	↓
Moth control	1x	↓
HARVEST		
Combine & haul	1x	Dry



County	1000 Harvested acres
San Joaquin	5.0
All other counties	<0.5

* San Joaquin county operations typical of sunflower operations in the San Joaquin Valley.
†Soil moisture decreases with each successive operation.
§Sunflowers grown in the San Joaquin Valley for confectionary crops.

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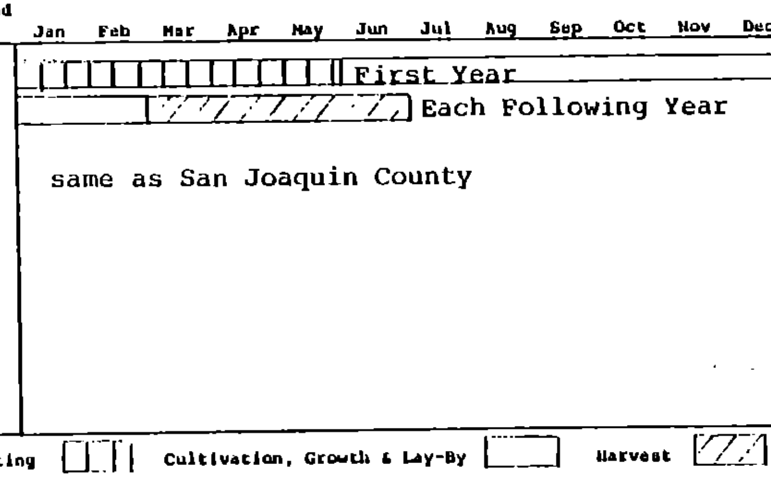
TABLE A-13. SAN JOAQUIN VALLEY

1978 VEGETABLE CROP - ASPARAGUS

TYPICAL OPERATIONS	First Year		Each Following Yr.	
LAND PREPARATION*	San Joaquin County	All Other Counties	All Counties	Soil Moisture
Disc	2X	2X		
Levees	1X	1X		
Flood	1X		1X	
Drain	1X		2X	
Plow	1X	1X	2X	
Disc	1X	1X		Moist†
Rip	2X	2X		↓
Land Plane	2X	2X		Dry
CULTIVATION				
Plant			1X	Dry
Irrigate			3X	
Cultivate			2X	Dry
Hoe			1X	
Weed Control			1X	
HARVEST				
Hand Cut			1X	Dry
Haul			1X	

County	1000 Harvested Acres	Jan–Dec
San Joaquin	17.0	First Year Each Following Year
Each Remaining County	< 0.5	same as San Joaquin County



*Land preparation after the first year is normally done during the fall.

†Soil moisture decreases after each successive operation; land plane is normally the "dusty" operation. Sacramento Valley has "mineral" soil which ranges in moisture content from 5-40 percent. San Joaquin County has "peat" soil that requires additional land preparation. All other counties have "mineral" soil with land preparation operations as shown.

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TABLE A-14. SAN JOAQUIN VALLEY

1978 VEGETABLE CROP - BEANS, SNAP

TYPICAL OPERATIONS	All Counties	Soil Moisture
LAND PREPARATION		
Plow	1X	Wet§
Disc	2X	↓
Shape Beds	1X	↓
Rip*	1X	↓
Land Plane	2X	Dry
CULTIVATION		
Irrigate	6 - 11X	
Plant	1X	
Herbicide	1X	
Cultivate	2X	
HARVEST†		
Combine	1X	High Moisture
Haul	1X	

County	1000 Harvested Acres	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Fresno	1.3												
San Joaquin	1.9										Fall Planting		
Stanis-laus	1.8	same as San Joaquin County											
Tulare	1.9	same as Fresno County											
Each Re-maining County	<0.5	same as Fresno County											

Preparation & Planting — Cultivation, Growth & Lay-By — Harvest

* Ripping included in land preparation if necessitated by previous crop; usually done every other year.
† Harvesting produces little dust.
§ Soil moisture decreases with each successive land preparation operation.

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TABLE A-15. SAN JOAQUIN VALLEY

1978 VEGETABLE CROP - BEANS, LIMA

TYPICAL OPERATIONS	All Counties	Soil Moisture
LAND PREPARATION		
Disc	2X	Moist*
Subsoil	2X	↓
Land Plane	1X	↓
Springtooth	2X	↓
List & Herbicide	1X	↓
Shape Beds	1X	Dry
CULTIVATION		
Plant	1X	Moist
Cultivate	3X	↓
Irrigate	4X	↓
Insect Control	3X	↓
HARVEST		
Machine Harvest	1X	Moist
Haul	1X	

County	1000 Harvested Acres	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Merced	3.9												
San Joaquin	1.2	same as Merced County											
Stanis- laus	9.8	same as Merced County											
Each Remain- ing County	<0.5	same as Merced County											

Preparation & Planting | Cultivation, Growth & Lay-By | Harvest

*Soil moisture decreases with each successive land preparation operation.

KVB 33100-1218

TABLE A-16. SAN JOAQUIN VALLEY

1978 VEGETABLE CROP - BROCCOLI

TYPICAL OPERATIONS	All Counties	Soil Moisture*
LAND PREPARATION		
Disc	3X	Moist
Chisel	2X	↓
Land Plane	2X	Dry
List & Preplant	1X	
Fertilize	1X	
Shape Beds	1X	
CULTIVATION		
Plant (Direct Seed)	1X	Moist
Irrigate	8X	↓
Fertilize	2X	
Cultivate	5X	
Pest Control	2X	
Hoe & Weed	1X	
HARVEST†		
Hand Harvest	1X	Moist
Haul	1X	↓

County	1000 Harvested Acres	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Each County	<0.5												

Preparation & Planting | Cultivation, Growth & Lay-By | Harvest

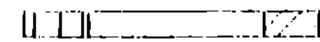
*Soil moisture decreases with each successive operation.
†Harvesting produces little dust.

KVB 33100-1218

TABLE A-17. SAN JOAQUIN VALLEY

1978 VEGETABLE CROP - CANTALOUPES

TYPICAL OPERATION	ALL COUNTIES	SOIL MOISTURE
LAND PREPARATION*		
Plow	1x	moist†
Subsoil	1x	↓
Disc	2x	↓
Land plane	2x	↓
Shape beds	1x	dry
CULTIVATION		
Plant (dry seed)	1x	moist
Irrigate	5x	↓
Cultivate	2x	↓
Pest control	3x	↓
Thin	1x	↓
Turn vines	3x	↓
Hand hoe	2x	↓
HARVEST		
Hand pick	1x	moist
Haul	1x	↓

County §	1000 Harvested Acres	Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Fresno	25.1	
Kern	2.6	
Kings	1.4	same as Fresno County
Merced	7.4	same as Fresno County
Stanislaus	0.9	same as Fresno County
Each remaining county	<0.5	same as Fresno County

Preparation & Planting | Cultivation, Growth & Lay-By | Harvest

*Land preparation for cantaloupes, mixed melons, & watermelons identical.

†Soil moisture decreases with each successive operation.

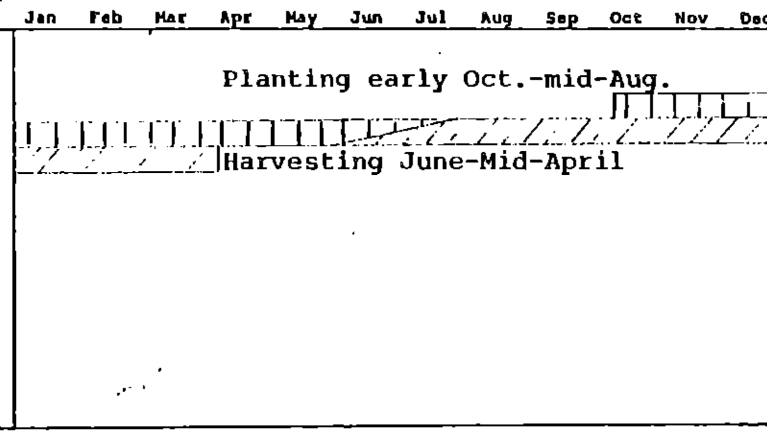
§Planting & harvesting period for each county assumed to be the same as Fresno County; except for Kern County.

KVB 33100-1218

TABLE A-18. SAN JOAQUIN VALLEY
1978 VEGETABLE CROP - CARROTS

TYPICAL OPERATIONS	ALL COUNTIES	SOIL MOISTURE
LAND PREPARATION		
Plow or subsoil	1x	moist*
Disc	2x	↓
Shape beds	1x	↓
Fumigate & fertilize	1x	dry
CULTIVATION		
Irrigate	7x	moist
Plant	1x	↓
Weed control	2x	↓
Cultivate	2x	↓
Fertilize		↓
Pest control	4x	↓
HARVEST		
Mechanical lifting	1x	moist
Haul	1x	↓

County	1000 Harvested Acres
Kern†	11.5
Each remaining county	<0.5



Preparation & Planting | Cultivation, Growth & Lay-By | Harvest

*Soil moisture decreases with each successive operation.
†Multiple planting-cultivation & growth simultaneous with late planting crop or early harvest crop.

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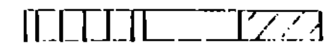
TABLE A-19. SAN JOAQUIN VALLEY

1978 VEGETABLE CROP - CAULIFLOWER

TYPICAL OPERATION	ALL COUNTIES	SOIL MOISTURE
LAND PREPARATION		
Disc	3x	moist†
Chisel	2x	↓
Land plane	2x	dry
List & preplant	1x	
Fertilize	1x	
Shape beds	1x	
CULTIVATION		
Plant (direct seed)	1x	moist
Irrigate	8x	↓
Fertilize	2x	
Cultivate	5x	
Pest control	2x	
Hoe & weed	1x	↓
HARVEST*		
Hand harvest	1x	moist
Haul	1x	↓

County	1000 Harvested Acres	Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Tulare	2.6	
Each remaining county	<0.5	same as Tulare County

Preparation & Planting ▯ Cultivation, Growth & Lay-By ▭ Harvest ▨

*Harvesting produces little dust.

†Soil moisture decrease with each successive operation.

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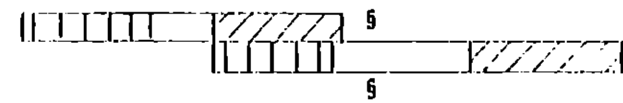
TABLE A-20. SAN JOAQUIN VALLEY
1978 VEGETABLE CROP - CORN, SWEET

TYPICAL OPERATION	All Counties	Soil Moisture
LAND PREPARATION		
Subsoil	1x	Moist†
Disc	2x	↓
Land plane	1x	↓
List & fertilize	1x	Dry
CULTIVATION		
Plant	1x	Moist
Irrigate	8x	↓
Cultivate	2x	↓
Thin & weed	1x	↓
Insect control	4x	↓
HARVEST*		
Machine or hand harvest	2x	Dry
Haul	2x	↓

County	1000 Harvested Acres	Jan–Dec
San Joaquin	0.6	
Each remaining county	<0.5	same as San Joaquin County

Preparation & Planting | Cultivation, Growth & Lay-By | Harvest

*Very little dust during harvesting; no disturbance of the soil.
†Soil Moisture decrease with each successive land preparation operation.
§Multiple crop.

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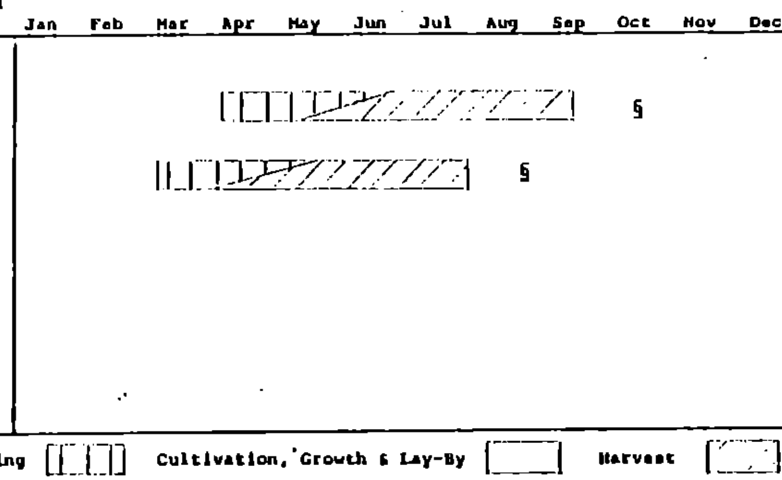
TABLE A-21. SAN JOAQUIN VALLEY

1978 VEGETABLE CROPS - CUCUMBERS

TYPICAL OPERATIONS	All counties	Soil moisture
LAND PREPARATION*		
Subsoil or plow	2x	Moist†
Disc	2x	↓
Land plane	2x	↓
Disc	2x	↓
Furrow & fertilize	1x	Dry
PLANT		
Plant	1x	Moist
Irrigate	12x	↓
Cultivate	1x	↓
Thin & hoe	1x	↓
Cultivate	3x	↓
Furrow & fertilize	1x	↓
Weed & hoe	1x	↓
HARVEST		
Hand harvest	1x	Moist
Haul	1x	↓

County	1000 Harvested Acres
San Joaquin	1.7
Each remaining county	<0.5



*Land preparation for cucumbers and squash the same.

†Soil Moisture decreases with each successive operation.

§Multiple planting-cultivation & growth simultaneous with late planting crop of early harvest crop. Planting and harvesting begin earlier in Southern San Joaquin Counties.

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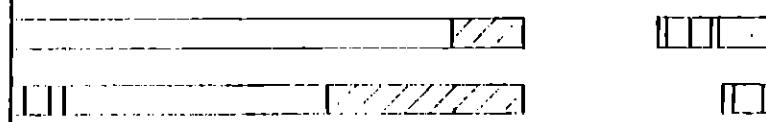
TABLE A-22. SAN JOAQUIN VALLEY
1978 VEGETABLE CROP - GARLIC

TYPICAL OPERATIONS

	All counties	Soil Moisture
LAND PREPARATION		
Plow	1x	Moist*
Disc	2x	↓
Fertilize	1x	↓
Shape beds	1x	Dry
CULTIVATION		
Plant	1x	Moist
Irrigate	4x	↓
Cultivate	5x	↓
HARVEST		
Machine-undercut	1x	Dry†
Top		↓
Pick		↓

County	1000 Harvested Acres	Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Fresno	2.7	
Kern	2.5	
Each remaining county	<0.5	same as Kern County



Preparation & Planting [|[ ]|] Cultivation, Growth & Lay-By [ ] Harvest [///]

*Soil moisture decreases with each successive operation.
†Harvesting typically "dusty".

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TABLE A-23. SAN JOAQUIN VALLEY
1978 VEGETABLE CROP - LETTUCE

TYPICAL OPERATIONS	All counties	Soil Moisture
LAND PREPARATION		
Plow or Disc	2x	Moist*
Chisel	2x	↓
Float or Land plane	2x	↓
Shape beds & herbicide	1x	Dry
CULTIVATION		
Plant (direct seed)	1x	Dry
Irrigate	6x	Moist
Thin	1x	↓
Cultivate	5x	↓
Hand weed	1x	↓
Pest control	1x	↓
HARVEST		
Hand pick	1x	Moist
Haul	1x	↓

County	1000 Harvested Acres	Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Fresno	3.6	Spring
	5.3	Fall
Kern	5.9	same as Fresno County
Kings	2.0	same as Fresno County
Each remaining county	<0.5	No. San Joaquin Valley
		So. San Joaquin Valley-same as Fresno

Preparation & Planting — Cultivation, Growth & Lay-By — Harvest

*Soil moisture decreases with each successive operation.

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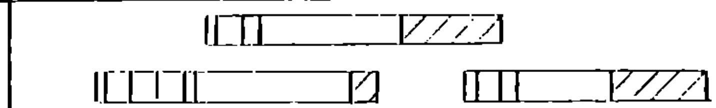
TABLE A-24. SAN JOAQUIN VALLEY

1978 VEGETABLE CROP - MIXED MELONS

TYPICAL OPERATION	All Counties	Soil Moisture
LAND PREPARATION*		
Plow	1x	Moist†
Subsoil	1x	↓
Disc	2x	↓
Land plane	2x	↓
Shape beds	1x	Dry
CULTIVATION		
Plant (dry seed)	1x	Moist
Irrigate	5x	↓
Cultivate	2x	↓
Pest control	3x	↓
Thin	1x	↓
Turn vines	3x	↓
Hand hoe	2x	↓
HARVEST		
Hand pick	1x	Moist
Haul	1x	↓

County§	1000 Harvested Acres	Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Fresno	1.8	
Kern	1.8	
Merced	0.5	same as Fresno County
Stanislaus	3.7	same as Fresno County
Tulare	0.8	same as Fresno County
Each remaining county	<0.5	same as Fresno County



Preparation & Planting | Cultivation, Growth & Lay-By | Harvest

*Land preparation for cantaloupes, mixed melons, & watermelons identical.

†Soil moisture decreases with each successive operation.

§Planting & harvesting period for each county assumed to the same as Fresno County; except for Kern County.

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TABLE A-25. SAN JOAQUIN VALLEY

1978 VEGETABLE CROP - ONIONS, ALL*

TYPICAL OPERATION	All counties	Soil Moisture
LAND PREPARATION		
Plow or disc	2x	Dry†
Land plane	2x	↓
Fertilize & fumigate	1x	Moist
CULTIVATION		
Plant (direct seed)	1x	Dry
Irrigate	5x	Moist
Cultivate	1x	↓
Herbicide	1x	↓
Fungicide	1x	↓
HARVEST		
Dehydrated onions§-undercut		Dry
top		↓
windrow		↓
haul		↓
Fresh onions-hand harvest		↓
haul		↓

County	1000 Harvested Acres	Jan–Dec
Fresno	3.3	
Kern	11.0	same as Fresno County
Kings	1.1	same as Fresno County
San Joaquin	1.9	Fall planting; Spring planting
Each remaining county	<0.5	So. San Joaquin Valley-same as Fresno No. San Joaquin Valley-same as San Joaquin

Preparation & Planting | Cultivation, Growth & Lay-By | Harvest

*Onion production includes: fresh, green & dehydrated.
†Soil moisture decreases with each successive operation.
§Dehydrated onion harvest similar to garlic harvest.

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TABLE A-26. SAN JOAQUIN VALLEY
1978 VEGETABLE CROP - PEAS

TYPICAL OPERATION	All counties	Soil moisture
LAND PREPARATION		
Stubble disc* or plow	1x	Moist†
Disc	2x	↓
Land plane	2x	↓
Spring tooth	2x	↓
List & fertilize	1x	Dry
CULTIVATION		
Plant	1x	Moist
Irrigate	6x	↓
Pest control	1x	↓
Weed control	1x	↓
HARVEST		
Machine cut & windrow	1x	Dry
Haul	1x	

County	1000 Harvested Acres	Jan–Dec
Merced	1.4	
Stanislaus	5.2	same as Merced County
Each remaining county	<0.5	same as Merced County

Preparation & Planting [| |] Cultivation, Growth & Lay-By [ ] Harvest [///]

*Stubble disking often occurs during the fall prior to the following Spring's planting.
†Soil moisture decreases with each successive operation.

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TABLE A-27. SAN JOAQUIN VALLEY
1978 VEGETABLE CROP - PEPPERS ALL

TYPICAL OPERATION	All counties	Soil moisture
LAND PREPARATION		
Disc	2x	Wet§
Land plane	2x	↓
Chisel	1x	↓
Disc	1x	↓
Shape beds	1x	Dry
CULTIVATION		
Plant*	1x	Moist
Irrigate	10x	↓
Cultivate	3x	↓
Pest control	4x	↓
HARVEST†		
Hand pick	1x	Moist
Haul	1x	↓

County	1000 Harvested Acres	Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Fresno	0.6	
Merced	0.7	same as Fresno County
San Joaquin	1.7	
Tulare	0.7	same as Fresno County
Each remaining county	<0.5	No. San Joaquin Valley-same as San Joaquin County. Central San Joaquin Valley-same as Fresno.

Preparation & Planting | Cultivation, Growth & Lay-By | Harvest

*Approximately 40% of peppers are transplanted.
†Harvest is considered "dust free" because plants are kept moist for a sustained harvest.
§Soil moisture decreases with each successive operation.

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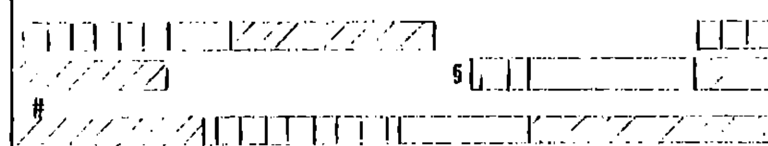
TABLE A-28. SAN JOAQUIN VALLEY

1978 VEGETABLE CROP - POTATOES

TYPICAL OPERATION	All counties	Soil moisture*
LAND PREPARATION		
Disc	2x	Moist†
Dhisel	2x	↓
Land plane	2x	↓
List & fertilize	1x	Dry
CULTIVATION		
Plant	1x	Dry
Irrigate	7x	↓
Cultivate	4x	↓
Hoe & weed	1x	↓
HARVEST		
Mechanical harvest		Dry
Lift	1x	↓
Haul	1x	↓

County	1000 Harvested Acres	Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Kern	23.5	§
San Joaquin	2.1	#
Each remaining county	<0.5	same as San Joaquin County



Preparation & Planting | Cultivation, Growth & Lay-By | Harvest

*Potatoes planted in "sandy" soils that when dry do not result in the production of much dust.
†Soil moisture decreases with each successive land preparation operation.
§Multiple crop
#Planting & harvesting based on operations performed in the central coast counties.

KVB 33100-1218

TABLE A-29. SAN JOAQUIN VALLEY
1978 VEGETABLE CROP - POTATOES, SWEET

TYPICAL OPERATION	All counties	Soil moisture
LAND PREPARATION		
Bed preparation*		Moist
Disc	2x	↓
Fumigate	1x	↓
Plant roots	1x	↓
Field preparation		Dry†
Plow or disc	2x	↓
Fertilize	1x	↓
Shape beds	1x	↓
Transplant into beds	1x	↓
CULTIVATION		
Plant	1x	Dry
Irrigate	8x	↓
Cultivate	2x	↓
Hoe	2x	↓
HARVEST		
Mechanical lift	1x	Dry
Haul	1x	↓

County	1000 Harvested Acres	Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Fresno	1.0	
Merced	6.4	same as Fresno County
Stanislaus	0.5	same as Fresno County
Each remaining county	<0.5	same as Fresno County

Preparation & Planting Cultivation, Growth & Lay-By Harvest

*Bed preparation done in the early spring
†Sweet potatoes planted in a dry, sandy soil that produces little dust during crop operation. Soil moisture decreases with each successive operation.

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TABLE A-30. SAN JOAQUIN VALLEY
1978 VEGETABLE CROP - SPINACH

TYPICAL OPERATION	All counties	Soil Moisture
LAND PREPARATION		
Plow	1x	Moist*
Disc	3x	↓
Land plane	2x	↓
Shape beds	1x	↓
List & fertilize	1x	Dry
CULTIVATION		
Plant	1x	Moist
Herbicide	1x	↓
Irrigate	3x	↓
Cultivate	1x	↓
Weed control	1x	↓
Pest control	1x	↓
Hoe	1x	↓
HARVEST		
Machine harvest	1x	Moist
Haul	1x	↓

County	1000 Harvested Acres	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Stanislaus	2.5						†						
Each remaining county	0.5	same as Stanislaus County†											

Preparation & Planting | Cultivation, Growth & Lay-By | Harvest

*Soil moisture decreases with each successive operation.
†Multiple planting-cultivation, growth & lay-by simultaneous with late planting crop or early harvested crop.

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TABLE A-31. SAN JOAQUIN VALLEY
1978 VEGETABLE CROPS - SQUASH

TYPICAL OPERATION	All counties	Soil moisture
LAND PREPARATION*		
Subsoil or plow	2x	Moist†
Disc	2x	↓
Land plane	2x	↓
Disc	2x	↓
Furrow & fertilize	1x	Dry
CULTIVATION		
Plant	1x	Moist
Irrigate	12x	↓
Cultivate	1x	↓
Thin & hoe	1x	↓
Cultivate	3x	↓
Furrow & fertilize	1x	↓
Weed & hoe	1x	↓
HARVEST		
Hand harvest	1x	Moist
Haul	1x	↓

County	1000 Harvested Acres	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Each county <0.5									§				

Preparation & Planting | Cultivation, Growth & Lay-By | Harvest

*Land preparation for cucumbers and squash the same.
†Soil moisture decreases with each successive operation.
§Multiple planting-cultivation & growth simultaneous with late planting crop or early harvest crop.

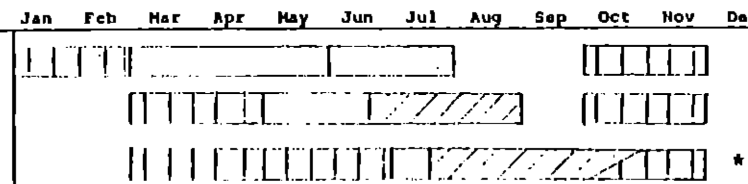
KVB 33100-1210

TABLE A-32. SAN JOAQUIN VALLEY
1978 VEGETABLE CROP - TOMATOES, FRESH MARKET

TYPICAL OPERATION

	All counties	Soil moisture
LAND PREPARATION		
Seedbed preparation		
Fall		
Disc	2x	Dry
Subsoil	2x	↓
Land plane	2x	↓
Spring		
Disc	2x	↓
Springtooth	1x	↓
Harrow & roll	1x	↓
List & fumigate	1x	↓
CULTIVATION		
Plant	1x	Dry
Cultivate	3x	↓
Hoe	1x	↓
Irrigate	10x	↓
Insect control	1x	
HARVEST		
Machine or hand pick	1x	Moist
Haul	1x	↓

County	1000 Harvested Acres	Jan–Dec
Fresno	2.8	
Merced	3.3	
San Joaquin	4.9	*
Stanislaus	1.8	same as San Joaquin County *
Tulare	1.2	same as Fresno County
Each remain-	<0.5	So. San Joaquin Valley-same as Fresno No. San Joaquin Valley-same as San Joaquin County



Preparation & Planting | Cultivation, Growth & Lay-By | Harvest

*Late harvesting crop may be simultaneous with some Fall seedbed preparation.

KVB 33100-121[8]

TABLE A-33. SAN JOAQUIN VALLEY
1978 VEGETABLE CROP - TOMATOES, PROCESSING

TYPICAL OPERATION	All counties	Soil moisture
LAND PREPARATION		
Seedbed preparation		
Fall		
Disc	2x	Dry ↓
Subsoil	2x	
Land plane	2x	
Spring		
Disc	2x	
Springtooth	1x	
Harrow & roll	1x	
List & fumigate	1x	
CULTIVATION		
Plant	1x	Dry ↓
Cultivate	3x	
Hoe	1x	
Irrigate	10x	
Insect control	1x	
HARVEST		
Machine or hand pick	1x	Moist ↓
Haul	1x	

County	1000 Harvested Acres	Jan – Dec
Fresno	36.9	
Kern	5.8	same as Fresno County
Kings	0.5	same as Fresno County
Madera	1.6	same as San Joaquin County
Merced	7.4	same as San Joaquin County
San Joaquin	27.9	*
Stanislaus	6.5	same as San Joaquin County
Tulare	<0.5	same as Fresno County

Preparation & Planting; Cultivation, Growth & Lay-By; Harvest

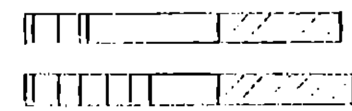
*Late harvesting crop may be simultaneous with some fall seed bed preparation.

KVB 33100-1218

TABLE A-34. SAN JOAQUIN VALLEY
1978 VEGETABLE CROP - WATERMELONS

TYPICAL OPERATIONS	All counties	Soil moisture
LAND PREPARATION*		
Plow	1x	Moist†
Subsoil	1x	↓
Disc	2x	↓
Land plane	2x	↓
Shape beds	1x	Dry
CULTIVATION		
Plant (dry seed)	1x	Moist
Irrigate	5x	↓
Cultivate	2x	↓
Pest control	3x	↓
Thin	1x	↓
Turn vines	3x	↓
Hand hoe	2x	↓
HARVEST		
Hand pick	1x	Moist
Haul	1x	↓

County	1000 Harvested Acres	Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Kern	2.5	
Merced	1.2	
San Joaquin	1.4	same as Merced County
Stanislaus	1.1	same as Merced County
Each remaining county	<0.5	same as Merced County



Preparation & Planting | Cultivation, Growth & Lay-By | Harvest

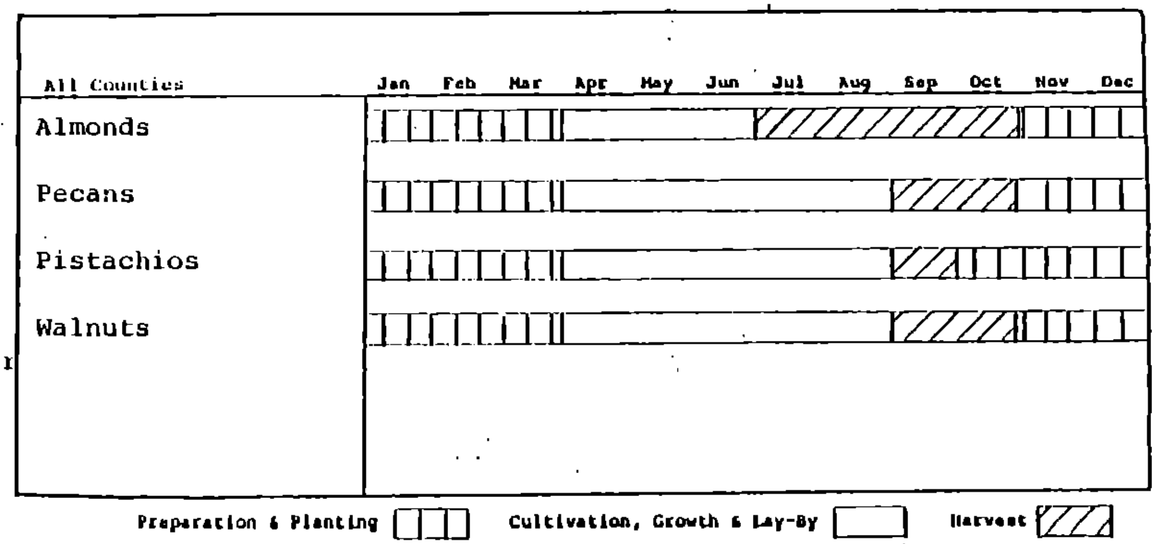
*Land preparation for cantaloupes, mixed melons, & watermelons assumed to be identical.
†Soil moisture decreases with each successive operation.

KVB 33100-1218

TABLE A-35. SAN JOAQUIN VALLEY
1978 FRUIT AND NUT CROPS - BEARING ACRES
NUTS - Almonds, Pecans, Pistachios, and Walnuts

TYPICAL OPERATIONS

	All counties 1st year only	All counties Remaining years	Season
LAND PREPARATION*			
Chisel	1x		
Disc & float	2x	2x	Fall
Fumigation		1x	Fall
CULTIVATION			
Plant	1x	1 tree/acre	Late winter or spring
Prune & brush disposal	1x	1x	Winter
Furrow	3x	6x	
Fertilize	2x	2x	Fall and Winter
Irrigate§	4x	4-8x	Frost protection in Spring
Border	1x	1x	
Disc† or	3x	3-5x	Late spring and summer
weed control	1x	2-3x	
mow	1x	2-3x	
Prune & brush disposal		1x	
HARVEST#			
Knock, sweep, pick-up and haul		1x	



1000 Harvested acres

County	Almonds	Pecans	Pistachios	Walnuts
Fresno	21.2	<0.5	<0.5	3.6
Kern	39.5	↓	0.7	0.6
Kings	4.3	↓	1.7	4.8
Madera	17.4	↓	1.7	1.2
Merced	39.5	↓	<0.5	7.0
San Joaquin	27.6	↓	↓	23.5
Stanislaus	37.4	↓	↓	24.3
Tulare	7.7	↓	↓	26.7

* The percentage of new land preparation dependent on the life of the orchard. Estimate 5-10% new orchard plantings each year. Land preparation operations dependent on soil texture. San Joaquin Valley has light textured soil that requires back-hoe, fumigation, re-filling, and pre-irrigation.

†50% of all nut crops disked or tilled.

§Irrigation may be done by sprinkle, flood, or drip. Soil moisture generally moist.

#Nut crop harvests 95% mechanical.

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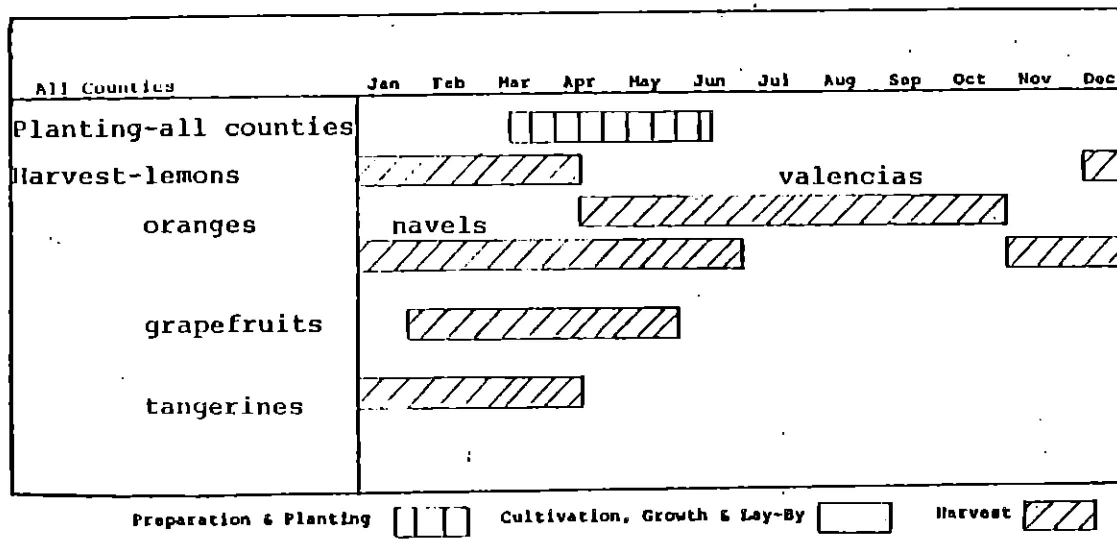
TABLE A-36. SAN JOAQUIN VALLEY

1978 FRUIT AND NUT CROPS - BEARING ACRES

CITRUS - GRAPEFRUIT, LEMONS, ORANGES, AND TANGERINES

TYPICAL OPERATIONS*	All Counties 1st year only	Remaining years
LAND PREPARATION†		
Chisel	1x	
Disc & float	2x	2x
Fumigate		1x
CULTIVATION§		
Plant	1x	
Irrigate	7x	8x
Fertilize	2x	2x
Border	1x	
Pest and disease control	2x	2x
Weed control	2x	2x
Prune & brush disposal#		1x
Furrow	2x	2x
HARVEST		
Hand pick & haul		1x



1000 Harvested acres

County	Grapefruit	Lemons	Oranges	Tangerines
Fresno	<0.5	0.8	19.4	0.5
Kern	0.9	3.6	21.5	1.1
Tulare	<0.5	3.9	81.6	1.7
All remaining counties	<0.5	<0.5	<0.5	<0.5

*Tulare county operations considered typical of all citrus crop operations in the San Joaquin Valley.

†The percentage of new land preparation dependent on the life of the orchard. Estimate 5-10% new orchard plantings each year.

§All orchard cultivations generally similiar.

#Mature lemon groves are pruned annually and oranges are pruned once every 5 years. Pruning and brush disposal done by shredding.

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TABLE A-37. SAN JOAQUIN VALLEY

1978 FRUIT AND NUT CROPS - BEARING ACRES

DECIDUOUS TREE FRUITS - APPLES, APRICOTS, CHERRIES, FIGS, NECTARINES, OLIVES

PEACHES, PEARS, PERSIMMONS, PLUMS, POMEGRANATES, PRUNES

TYPICAL OPERATIONS

	All counties: 1st year only	All counties: Remaining years	Season
LAND PREPARATION*			
Chisel	1x		
Disc & float	2x	2x	Fall
Fumigation		1x	Fall
CULTIVATION			
Plant	1x	1x	Late winter or spring
Prune & brush removal†	1x	1x	Winter
Spray	5x	5x	
Fertilize	2x	2x	Fall & winter
cultivate or non-tillage§	4x	4x	Late spring & summer
Border	1x	1x	
Irrigate#	8x	8x	
HARVEST**			
Pick (mechanized for process fruits)		1x	
Haul		1x	

Crop	Harvest period	Fresno	Kern	Kings	Madera	Merced	San Joaquin	Stanislaus	Tulare
		1000 Harvested Acres							
Apples	Jul-Oct	-	1.4	-	-	-	-	-	-
Apricots	May-June	-	-	-	-	1.6	3.1	9.4	-
Cherries	May-June	-	-	-	-	-	8.2	-	-
Figs	late summer	6.7	-	-	2.6	1.2	-	-	-
Nectarines	May-Aug	7.8	1.2	-	-	-	-	-	4.8
Olives	Sept-Oct	1.6	5.7	1.0	1.4	-	-	-	15.7
Peaches									
Clingstone	Jun-early Sept								
Freestone	May-Sept								
All		8.6	2.1	2.1	1.9	7.1	3.5	15.3	-
Pears	Jul-Aug	-	-	-	-	-	0.9	-	4.3
Persimmons	Fall	-	-	-	-	-	-	-	-
Plums	May-Sept	10.3	2.0	0.8	0.5	-	-	-	10.8
Pomegranates	Fall	0.9	-	-	-	-	-	-	1.3
Prunes	Aug-Sept	-	-	-	-	1.2	-	-	4.1

(- less than 500 acres)

*The percentage of new land preparation dependent on the life of the orchard. Estimate 5% new orchard plantings each year. Land preparation dependent on soil texture. San Joaquin Valley has light textured soil that requires back-hoe, fumigation, re-filling, and pre-irrigation.

†Brush removal is done by shredding and burning, estimate 50% each.

§Cultivation or tillage done by disking. Non-tillage crops require weeds to be mowed and sprayed with herbicide. Estimate that 10% of total acreage have weeds burned.

#Irrigation may be done by sprinkling, flooding after furrows are made, or by drip. Sprinkling in the Spring done to prevent frost. About 10% of acreage use orchard heaters to prevent frost.

**Estimate that 50% of prunes and clingstone peaches are mechanically harvested and the 95% of apples, cherries, nectarines, plums, freestone peaches and ½ clingstone peaches are hand harvested.

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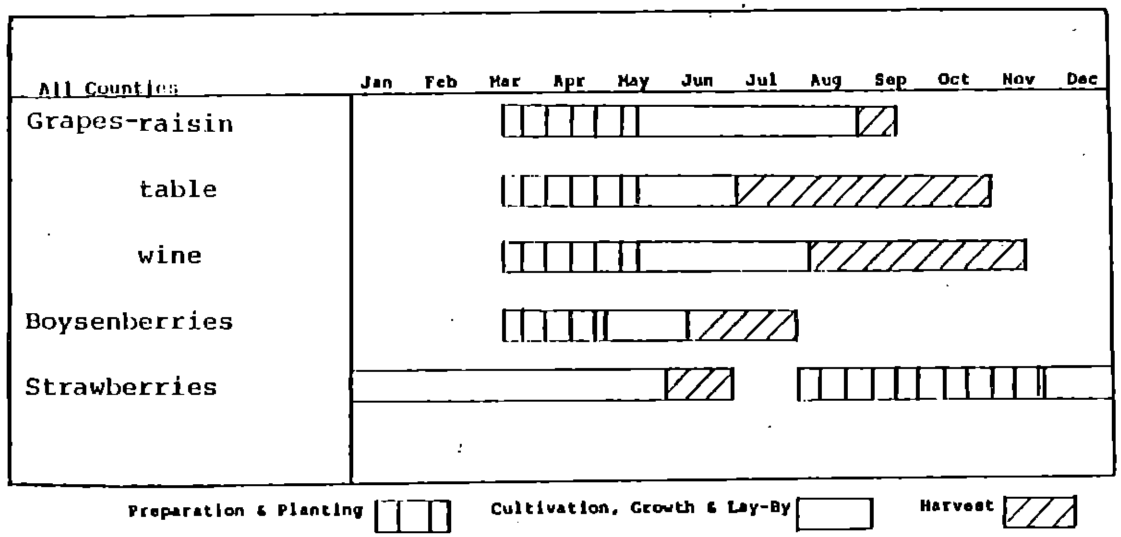
TABLE A-38. SAN JOAQUIN VALLEY

1978 FRUIT AND NUT CROPS - BEARING ACRES

VINE CROPS - Boysenberries, Grapes - raisin, table & wine and Strawberries

TYPICAL OPERATION	All counties	Soil Moisture
LAND PREPARATION*		
Rip	1x	Moist
Disc	2x	
Float	1x	
Level	1x	
Border	1x	
Terrace & roll (raisins only)	1x	
Fumigate	1x	Dry
CULTIVATION		
Plant	1x	Moderately dry
Cultivate	4-6x	
Irrigate	8x	
Weed control	2x	
Pest control	3x	
HARVEST		
Hand pick table grapes	1x 2x	Moderately dry
Machine harvest for wine grapes	1x	
POST-HARVEST†		
Prune & brush disposal	1x	Dry



1000 Harvested Acres

County	Grapes raisins	Grapes table	Grapes wine	Boysenberries	Strawberries
Fresno	145.6	6.3	36.2	<0.5	<0.5
Kern	22.5	9.8	38.2		
Kings	2.6	<0.5	1.2		
Madera	29.0	<0.5	28.8		
Merced	2.9	<0.5	11.5		
San Joaquin	19.7	20.3	31.0		
Stanislaus	4.3	<0.5	20.1		
Tulare	7.8	35.5	30.3		

*The life of a grape orchard is 30 years and the life of a boysenberry crop is 6 years. Estimate 5% new grape orchard plantings and 15% new boysenberry plantings each year. Strawberries are an annual crop.

†Pruning is done in the winter. Brush is disposed of by shredding.

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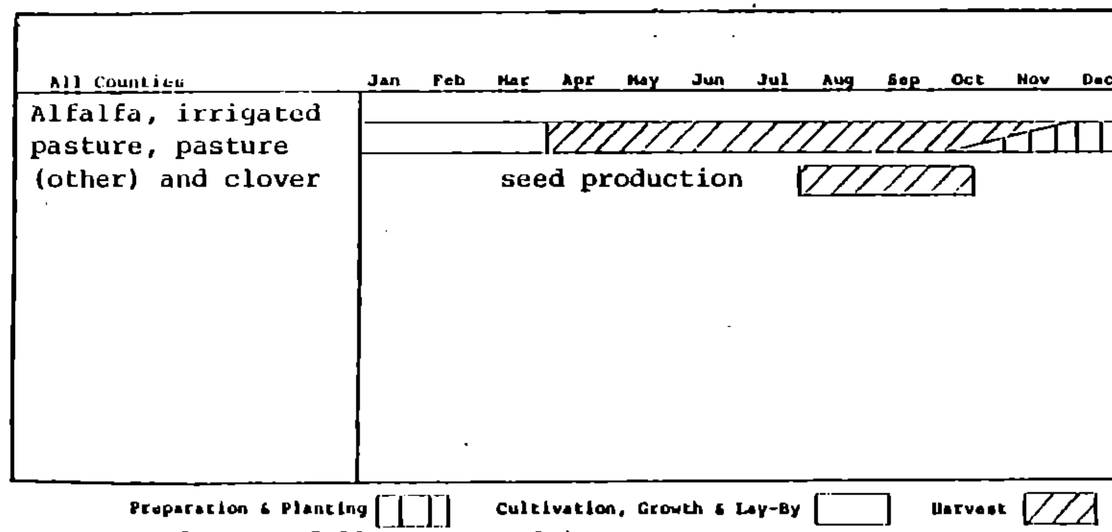
TABLE A-39. SACRAMENTO VALLEY
1978 FIELD AND SEED CROPS
ALFALFA, IRRIGATED PASTURE, PASTURE (OTHER), AND CLOVER

TYPICAL OPERATIONS*

	All counties	Soil Moisture
LAND PREPARATION†		
Chisel	2x	Dry
Disc	2x	
Land plane	2x	
Fertilize	1x	
Border	1x	
CULTIVATION		
Plant	1x	Dry
Irrigate	14x	Moist
Weed control		
HARVEST (other than pasture for forage)		
Swath	5-7x	Moist§
Rake	5-7x	
Bale	5-7x	



Seed crops follow seasonal harvest

1000 Harvested Acres ‡

County	Alfalfa‡	Pasture	Pasture** (other, seed)	Clover
Butte	8.8	19.8		<0.5
Colusa	7.3	4.0		
Glenn	18.5	22.6	0.8	
Sacramento	27.4	48.0	3.6	
Solano	19.3	24.6		
Sutter	25.2	24.0	0.8	
Tehama	13.2	<0.5		
Yuba	3.1	21.0		
Yolo	16.7	16.0		

*Glenn county operations typical of all alfalfa, irrigated pasture, and clover operations in the San Joaquin or Sacramento Valley.

†Land preparation of alfalfa for hay, grain, or seed identical. These field crops are on the land from 5-7 years. Estimate 20% of all harvested acreage requires land preparation.

§Soil moisture is "dry" during seed crop harvest.

‡County crop reports include seed crop acreage in harvested field crop acreage.

‡Alfalfa acreage includes alfalfa for hay, grain, stubble, grass, and seed.

**Sudan grass included in pasture (other).

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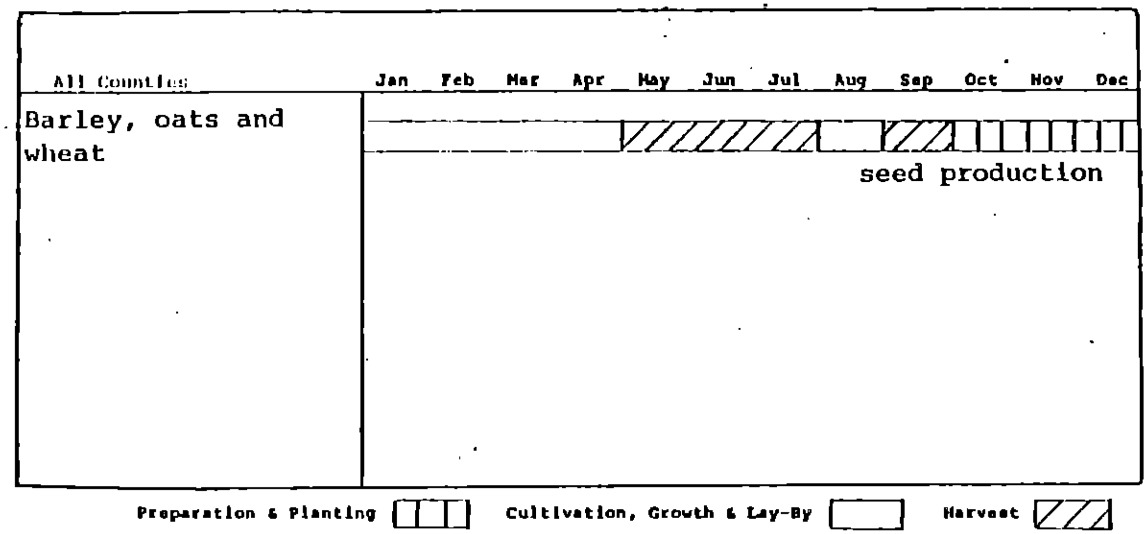
TABLE A-40. SACRAMENTO VALLEY
1978 FIELD AND SEED CROPS
BARLEY , OATS AND WHEAT

TYPICAL OPERATIONS*

	All counties	Soil Moisture
LAND PREPARATION		
Disc	2x	Dry†
Harrow	1x	↓
Ditch	1x	
Border	1x	
Land plane	1x	
Fertilize	1x	
CULTIVATION		
Plant	1x	Moist
Irrigate	2x	
HARVEST		
Custom combine	1x	Dry
Haul	1x	
POST HARVEST‡		
Stubble disc	2x	



Seed crops follow seasonal harvest.

1000 Harvested Acres#

County	Barley	(seed)§	Oats	(seed)§	Wheat	(seed)§
Butte	7.7		7.0	(5.0)	27.0	(3.1)
Colusa	24.0		<0.5		36.0	
Glenn	21.8		<0.5		24.5	
Sacramento	4.9		2.3		18.4	(0.8)
Solano	12.6		4.8		23.3	(0.7)
Sutter	26.5	(3.8)	1.2	(1.7)	23.4	(3.1)
Tehama	9.5		3.0		11.0	
Yuba	1.9		1.7		2.3	
Yolo	47.0		6.0		83.0	

* Sutter county operations typical of BARLEY, OATS & WHEAT operations in the Sacramento Valley for producing a single crop.

†Land preparation normally done prior to first rain.

§County crop reports include seed crop acreage in harvested field crop acreage.

#Silage and forage acreage included in harvested crop acreage.

‡Wheat and barley that is double-cropped will have 25 percent of harvested acreage in the late fall burned, stubble disked-2x, and land planed-2x.

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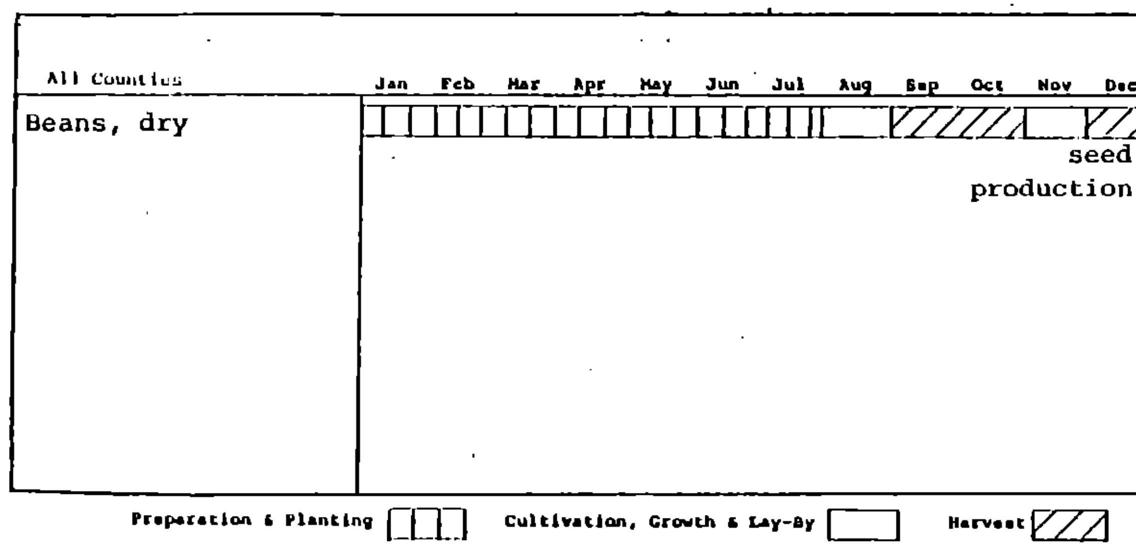
TABLE A-41. SACRAMENTO VALLEY
1978 FIELD AND SEED CROPS
BEANS, DRY

TYPICAL OPERATIONS*

	All counties	Soil Moisture
LAND PREPARATION		
Plow or chisel	1x	Moist
Disc	1x	↓
Triplane	2x	↓
Land plane(4th yr.)	3x	↓
Fertilize & herbicide	1x	↓
Disc	2x	↓
CULTIVATION		
Irrigate	6x	Moist
Plant	1x	↓
Cultivate	2x	↓
Pest control	2x	↓
HARVEST†		
Machine cut	1x	Dry
Windrow	1x	↓
Haul	1x	↓



seed crops follow seasonal harvest

1000 Harvested Acres

County	Harvested acres	(seed)§
Butte	8.0	(1.5)
Colusa	16.1	
Glenn	6.5	
Sacramento	<0.5	
Solano	5.8	(0.5)
Sutter	18.1	(1.0)
Tehama	2.3	(1.0)
Yuba	1.6	
Yolo	3.8	

*Butte county operations typical of dry bean farming operations in the Sacramento valley.
†Machine harvest relatively "dusty" operation.
§County crop reports include seed crop acreage in harvested field crop acreage.

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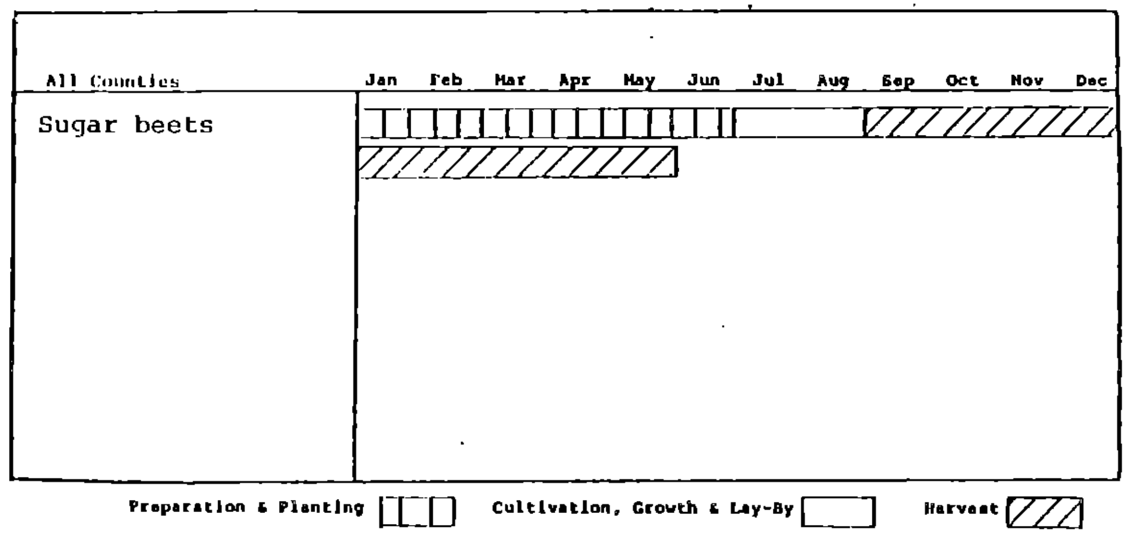
TABLE A-42. SACRAMENTO VALLEY
1978 FIELD CROPS - BEETS, SUGAR

TYPICAL OPERATIONS*

	All counties	Soil moisture
LAND PREPARATION		
Fall		
Plow or subsoil	1x	Moist
Land plane	2x	↓
Chisel	1x	↓
Spring		
Disc	2x	Dry
Springtooth & roll	2x	↓
Harrow & roll	1x	↓
List & fertilize	1x	↓
CULTIVATION		
Plant	1x	Moist
Herbicide	1x	↓
Cultivate	3x	↓
Irrigate	8x	↓
Thin and weed	1x	↓
HARVEST		
Top & dig	1x	Moist
Haul	1x	



County	1000 Harvested Acres
Butte	1.7
Colusa	11.0
Glenn	6.8
Sacramento	3.1
Solano	22.4
Sutter	5.0
Tehama	0.7
Yuba	<0.5
Yolo	17.7

* Yolo county operations typical of sugar beet operations in the Sacramento Valley.

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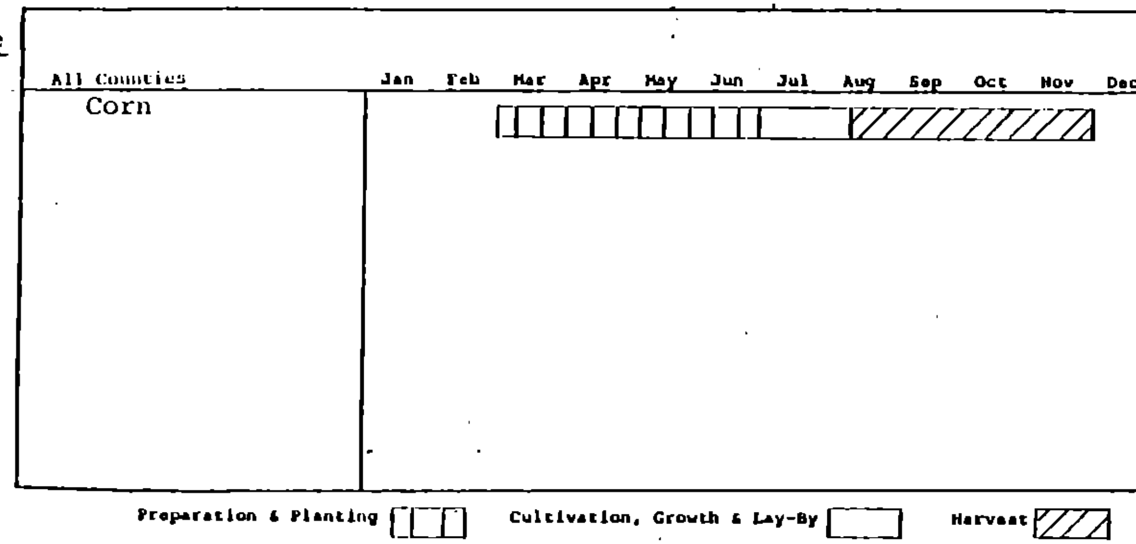
TABLE A-43. SACRAMENTO VALLEY

1978 FIELD CROPS - CORN

TYPICAL OPERATIONS*

	All counties	Soil Moisture
LAND PREPARATION		
Stubble disc	1x	Moist
Land plane	1x	
Disc	2x	
Springtooth	1x	
List & fertilize & herbicide	1x	
CULTIVATION		
Plant	1x	Moist
Irrigate	8x	
Cultivate	3x	
HARVEST†		
Combine	1x	Dry
Haul	1x	



County	1000 Harvested Acres§	(seed)#
Butte	4.4	
Colusa	4.5	
Glenn	6.0	
Sacramento	49.9	
Solano	28.7	
Sutter	8.9	(2.1)
Tehama	2.0	
Yuba	1.1	
Yolo	38.0	

* Yolo county operations typical of field corn operations in the Sacramento Valley.

†Harvest creates little dust because there is minimal disturbance of the soil; only dust is from the handling of the plants.

§Silage and forage acreage included in harvested crop acreage.

#County crop reports include seed crop acreage in harvested field crop acreage.

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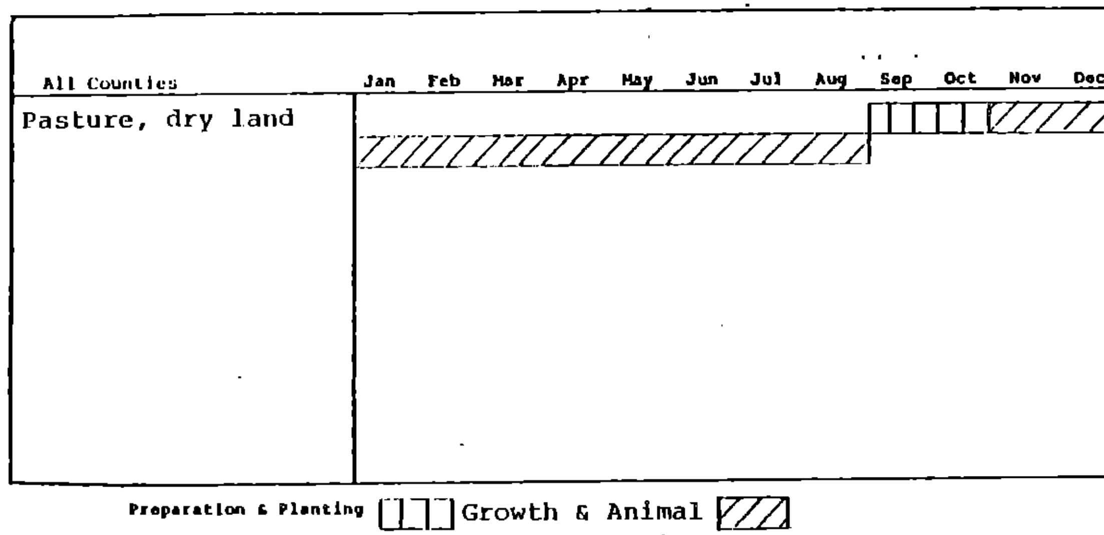
TABLE A-44. SACRAMENTO VALLEY
1978 FIELD CROPS - PASTURE, DRY LAND

TYPICAL OPERATIONS

	All counties	Soil Moisture
LAND PREPARATION*		
Disc	2x	Dry
PLANTING		
Plant	1x	Dry
No Cultivation		
HARVEST		
None- animal grazing		



County	1000 Harvested acres
Butte	295
Colusa	200
Glenn	245
Sacramento	130
Solano	148
Sutter	50
Tehama	not listed
Yuba	200
Yolo	190

*Land preparation and planting may be done every 10 years, estimate 10% of all dry land pasture acreage requires land preparation.

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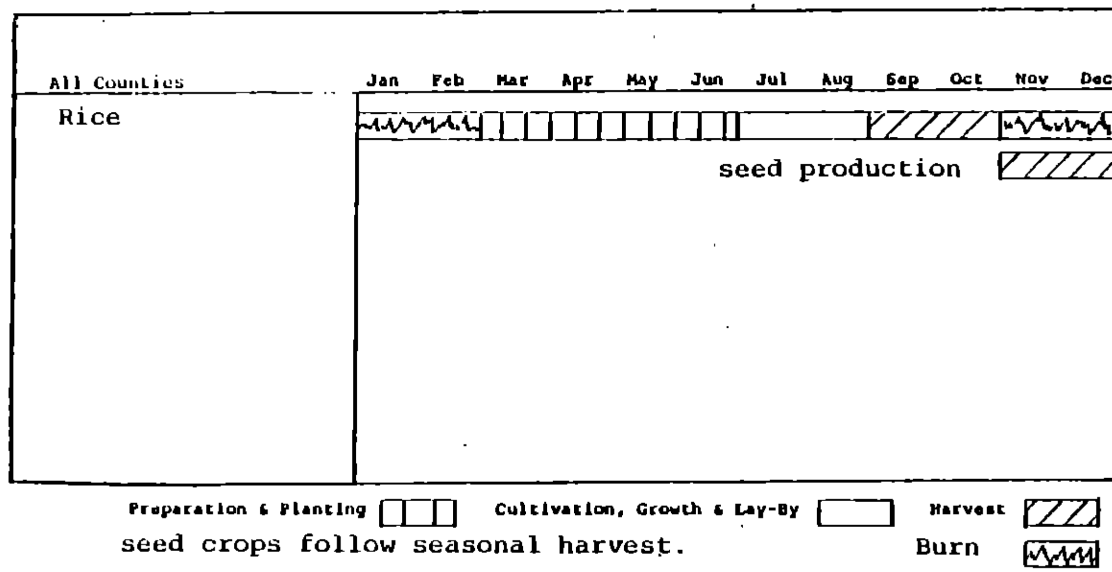
TABLE A-45. SACRAMENTO VALLEY

1978 FIELD AND SEED CROPS - RICE

TYPICAL OPERATIONS*	All counties	Soil Moisture
LAND PREPARATION		
Plow	1x	Moist
Disc	2x	↓
Float	2x	↓
Fertilize	1x	↓
Close & Maintain levees	1x	↓
Flood & irrigate	1x	Wet
PLANTING	1x	Wet
No cultivation		↓
Weed control	1x	↓
Insect control	1x	↓
HARVEST		
Drain levees	1x	Moist
Combine & haul	1x	
LAND PREPARATION		
Burn	2x	Dry
Doze levees	1x	↓
Disc	2x	↓
Stubble	1x	↓
Land plane	2x	↓



County	1000 Harvested Acres	(seed)†
Butte	87.0	(3.0)
Colusa	127.3	
Glenn	67.2	
Sacramento	13.0	(0.8)
Solano	<0.5	
Sutter	85.8	(4.4)
Tehama	<0.5	
Yuba	31.1	
Yolo	33.6	

*Colusa county operations typical of rice operations in the Sacramento Valley.

†County crop reports include seed crop acreage in the harvested field crop acreage.

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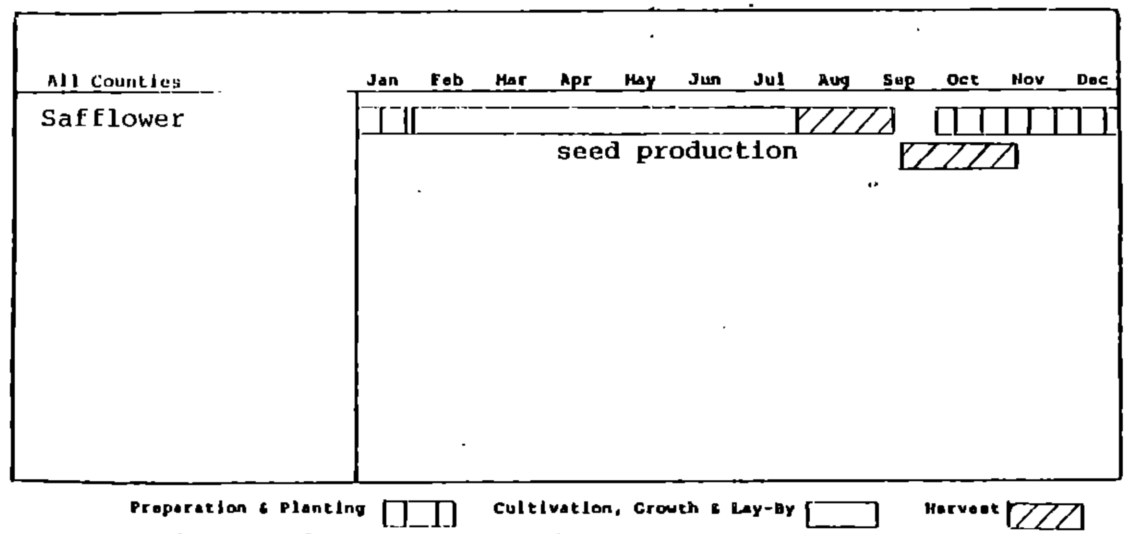
TABLE A-46. SACRAMENTO VALLEY

1978 FIELD AND SEED CROPS - SAFFLOWER

TYPICAL OPERATIONS*

	All counties	Soil Moisture
LAND PREPARATION		
Chisel	2x	Moist
Disc	2x	↓
Fertilize	1x	↓
Harrow	2x	↓
PLANTING		
Plant	1x	Moist
No Cultivation		↓
Irrigation	3x	↓
HARVEST†		
Combine & haul	1x	Dry



seed crops follow seasonal harvest

County	1000 Harvested acres (seed)§	
Butte	<0.5	
Colusa	17.2	
Glenn	4.2	
Sacramento	11.3	
Solano	4.1	
Sutter	4.5	(1.4)
Tehama	<0.5	
Yuba	0.9	
Yolo	35.6	

*Sutter county operations typical of safflower operations in the Sacramento Valley.
†Harvest creates little dust because there is minimal disturbance of the soil; only dust is from the handling of the plants.
§County crop reports include seed crop acreage in the harvested field crop acreage.

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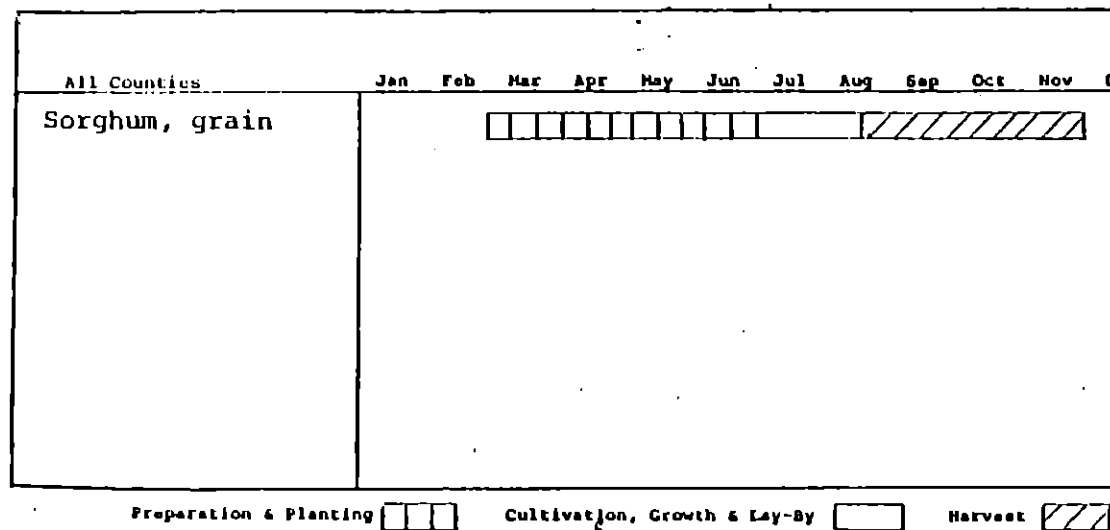
TABLE A-47. SACRAMENTO VALLEY

1978 FIELD CROPS - SORGHUM, GRAIN

TYPICAL OPERATIONS*

LAND PREPARATION	All counties	Soil Moisture
Stubble disc	1x	Moist
Land plane	1x	↓
Disc	2x	
Springtooth	1x	
List & fertilize & herbicide	1x	
CULTIVATION		
Plant	1x	Moist
Irrigate	8x	↓
Cultivate	3x	
HARVEST†		
Combine	1x	Dry
Haul	1x	



County	1000 Harvested acres§ (seed)‖	
Butte	2.9	
Colusa	8.1	
Glenn	5.0	
Sacramento	3.1	
Solano	<0.5	
Sutter	19.4	(3.6)
Tehama	1.5	
Yuba	<0.5	
Yolo	16.6	

*Yolo county operations typical of sorghum operations in the Sacramento valley.

†Harvest creates little dust because there is minimal disturbance of the soil; only dust is from the handling of the plants.

§Silage and forage acreage included in harvested crop acreage.

‖County crop reports include seed crop acreage in harvested field crop acreage.

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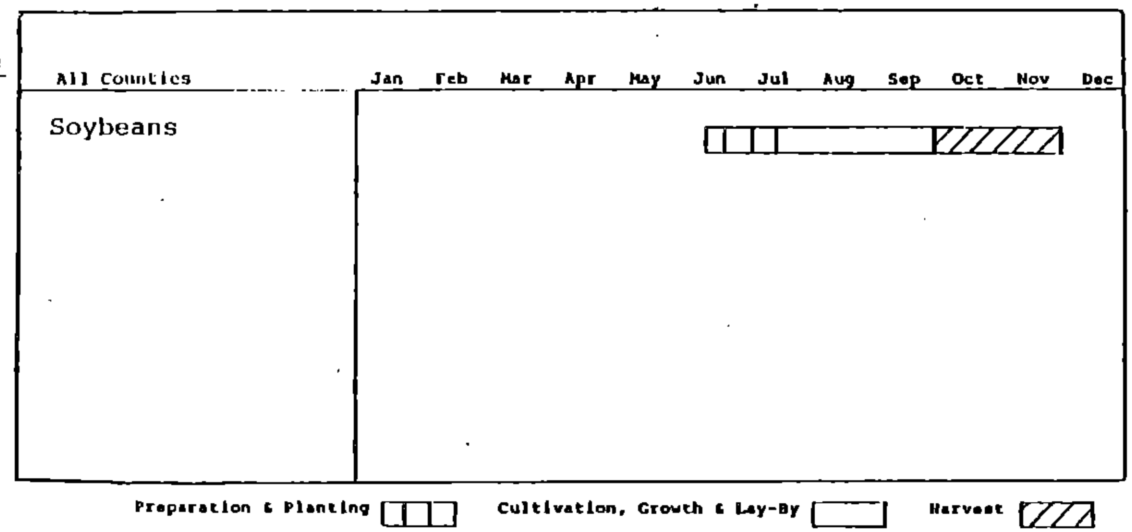
TABLE A-48. SACRAMENTO VALLEY
1978 FIELD CROPS - SOYBEANS

TYPICAL OPERATIONS*

	All counties	Soil Moisture
LAND PREPARATION		
Plow or chisel	1x	Moist†
Disc	2x	↓
Land plane	2x	↓
Fertilize	1x	Dry
CULTIVATION		
Plant	1x	Moist
Herbicide	1x	↓
Irrigate	4-5x	↓
Insect control	1x	↓
Cultivation	2x	↓
HARVEST		
Combine and Haul	1x	Dry



County	1000 Harvested acres
Colusa	3.6
Glenn	4.7
All other counties	<0.5

*Glenn county operations typical of soybean operations in the Sacramento Valley.
†Soil moisture decreases with each successive land preparation operation.

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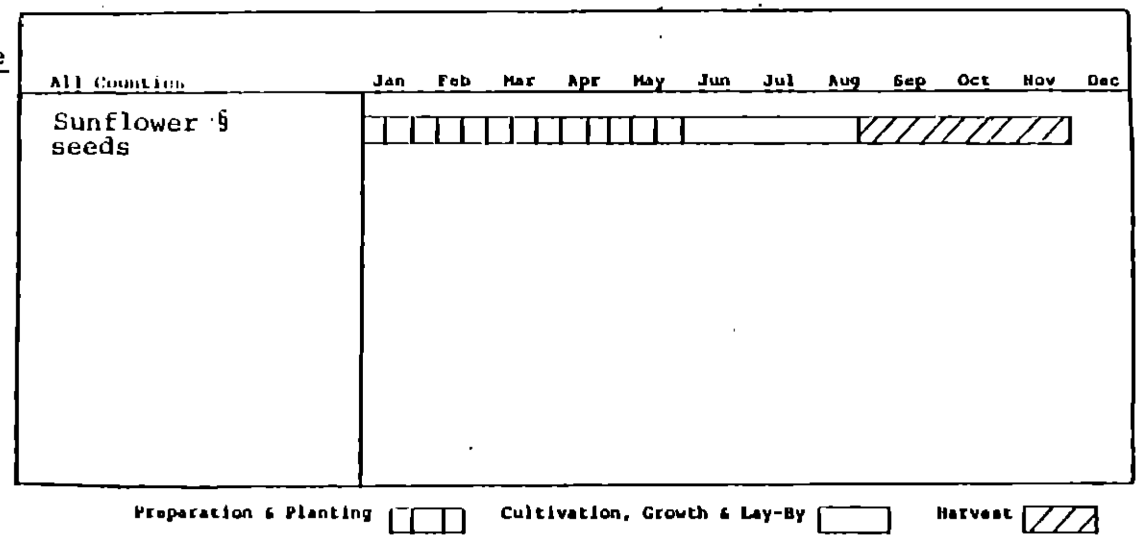
TABLE A-49. SACRAMENTO VALLEY
1978 FIELD AND SEED CROPS - SUNFLOWERS

TYPICAL OPERATIONS*

	All counties	Soil Moisture
LAND PREPARATION		
Stubble disc	1x	Moist†
Disc	3x	↓
Float	1x	
Disc & spike	1x	
Land plane (every other year)	2x	
Fertilize & herbicide	1x	Dry
CULTIVATION		
Plant	1x	Dry
Cultivate	2x	↓
Moth control	1x	
Irrigation	6x	
HARVEST		
Combine & haul	1x	Dry



County	1000 Harvested acres for seeds
Colusa	1.2
Glenn	2.1
Solano	1.1
All other counties	<0.5

* Glenn county operations typical of sunflower operations in the Sacramento valley.
† Soil moisture decreases with each successive operation.
§ Sunflowers grown in the Sacramento Valley for sunflower seed crops.

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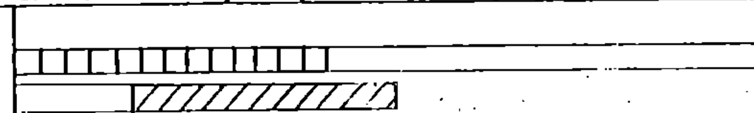
TABLE A-50. SACRAMENTO VALLEY
1978 VEGETABLE CROP - ASPARAGUS

TYPICAL OPERATIONS - ALL COUNTIES

LAND PREPARATION*	1ST YEAR	EACH FOLLOWING YEAR	SOIL MOISTURE
Disc	2x		moist†
Plow	1x		↓
Disc	1x	1x	↓
Rip	2x	2x	↓
Land Plane	2x	2x	dry
CULTIVATION			
Plant		1x	dry
Irrigate		3x	
Cultivate		2x	dry
Hoe		1x	
Weed Control		1x	
HARVEST			
Hand cut		1x	dry
Haul		1x	

County	1000 Harvested Acres	Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Yolo	0.8	
Each remaining	<0.5	Same as Yolo County



Preparation & Planting [| |] Cultivation, Growth & Lay-By [ ] Harvest [///]

*Land Preparation after the first year normally done during the Fall.
†Soil moisture decreases after each successive operation; land plane is normally the "dusty" operation. Sacramento Valley has "mineral" soil which ranges in moisture content from 5-40 percent.

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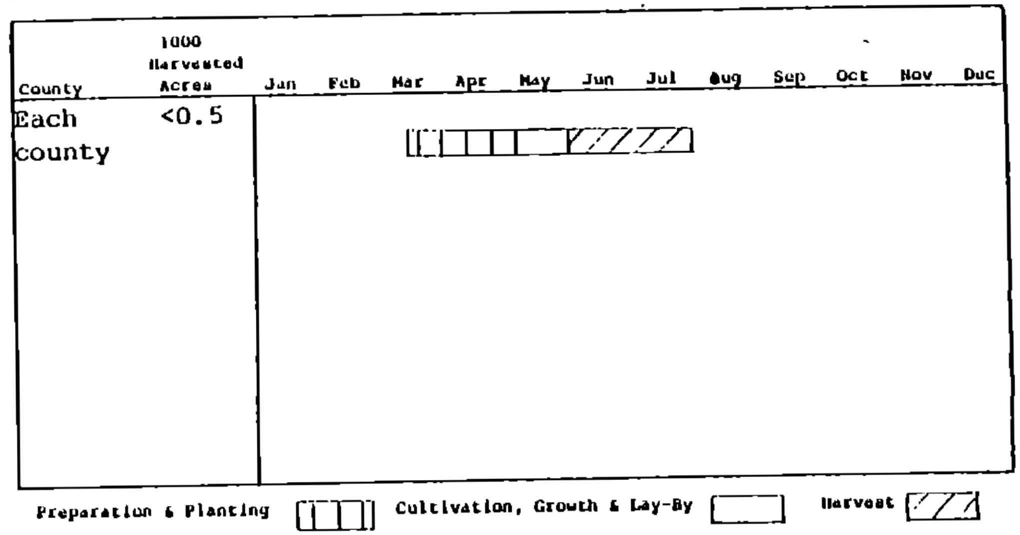
TABLE A-51. SACRAMENTO VALLEY
1978 VEGETABLE CROP - BEANS, SNAP

TYPICAL OPERATIONS	ALL COUNTIES	SOIL MOISTURE
LAND PREPARATION		
Plow	1x	wet§
Disc	2x	↓
Shape beds	1x	↓
Rip*	1x	↓
Land plane	2x	dry
CULTIVATION		
Irrigate	6-11x	
Plant	1x	
Herbicide	1x	
Cultivate	2x	
HARVEST†		
Combine	1x	high moisture
Haul	1x	



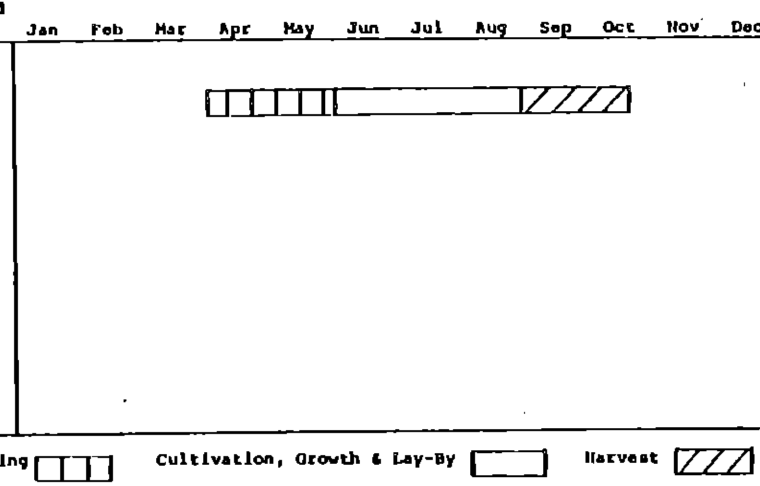
*Ripping included in land preparation if necessitated by previous crop; usually done every other year.
†Harvesting produces little dust.
§Soil moisture decreases with each successive land preparation operation.

KVB 33100-1218

TABLE A-52. SACRAMENTO VALLEY
1978 VEGETABLE CROP - BEANS, LIMA

TYPICAL OPERATIONS	ALL COUNTIES	SOIL MOISTURE
LAND PREPARATION		
Disc	2x	moist*
Subsoil	2x	
Land plane	1x	
Springtooth	2x	
List & Herbicide	1x	
Shape Beds	1x	dry
CULTIVATION		
Plant	1x	moist
Cultivate	3x	
Irrigate	4x	
Insect control	3x	
HARVEST		
Machine harvest	1x	moist
Haul	1x	

County	1000 Harvested Acres
Each county	<0.5



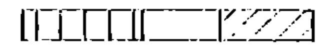
*Soil moisture decreases with each successive land preparation operation.

KVB 33100-1218

TABLE A-53. SACRAMENTO VALLEY
1978 VEGETABLE CROP - BROCCOLI

TYPICAL OPERATION	ALL COUNTIES	SOIL MOISTURE*
LAND PREPARATION		
Disc	3x	moist
Chisel	2x	↓
Land plane	2x	dry
List & Preplant	1x	
Fertilize	1x	
Shape beds	1x	
CULTIVATION		
Plant (direct seed)	1x	moist
Irrigate	8x	↓
Fertilize	2x	↓
Cultivate	5x	↓
Pest control	2x	↓
Hoe & weed	1x	↓
HARVEST†		
Hand harvest	1x	moist
Haul	1x	↓

County	1000 Harvested Acres	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Each county	<0.5												



Preparation & Planting | Cultivation, Growth & Lay-By | Harvest

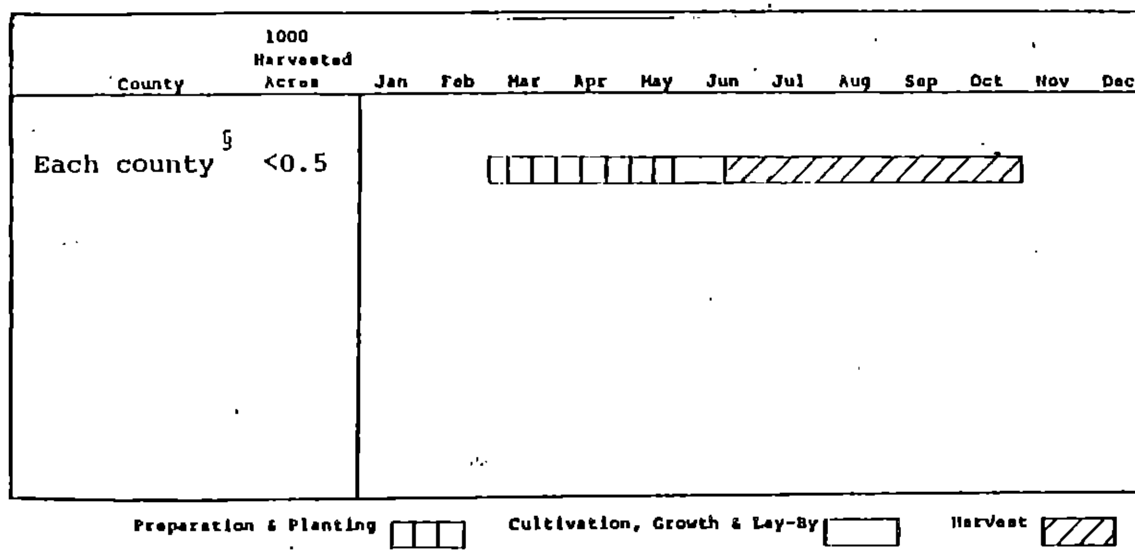
*Soil moisture decrease with each successive operation.
†Harvesting produces little dust.

KVB 33100-1218

TABLE A-54. SACRAMENTO VALLEY

1978 VEGETABLE CROP - CANTALOUPES

TYPICAL OPERATION	ALL COUNTIES	SOIL MOISTURE
LAND PREPARATION*		
Plow	1x	moist†
Subsoil	1x	↓
Disc	2x	↓
Land plane	2x	↓
Shape beds	1x	dry
CULTIVATION		
Plant (dry seed)	1x	moist
Irrigate	5x	↓
Cultivate	2x	↓
Pest control	3x	↓
Thin	1x	↓
Turn vines	3x	↓
Hand hoe	2x	↓
HARVEST		
Hand pick	1x	moist
Haul	1x	



*Land preparation for cantaloupes, mixed melons, & watermelons identical.

†Soil moisture decreases with each successive operation.

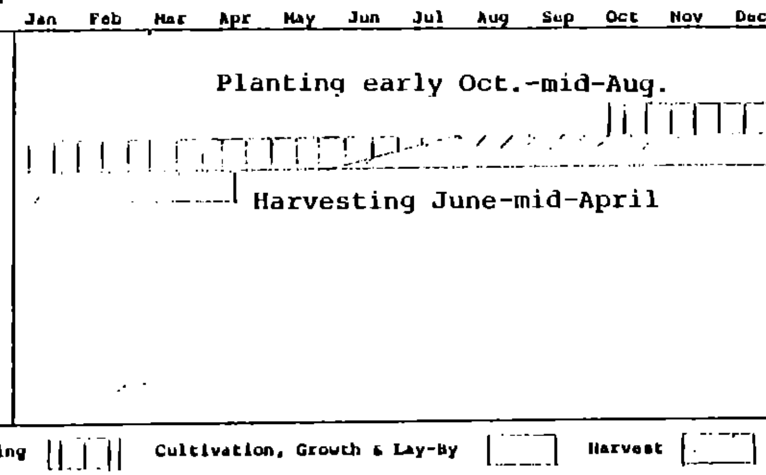
§Planting & harvesting period for each county that grows cantaloupes the same as that for Fresno County.

KVB 33100-1218

TABLE A-55. SACRAMENTO VALLEY
1978 VEGETABLE CROP - CARROTS

TYPICAL OPERATIONS	ALL COUNTIES	SOIL MOISTURE*
LAND PREPARATION		
Plow or subsoil	1x	moist
Disc	2x	↓
Shape beds	1x	↓
Fumigate & fertilize	1x	dry
CULTIVATION		
Irrigate	7x	moist
Plant	1x	↓
Weed control	2x	↓
Cultivate	2x	↓
Fertilize		↓
Pest control	4x	↓
HARVEST		
Mechanical lifting	1x	moist
Haul	1x	↓

County	1000 Harvested Acres
Each county†	<0.5



*Soil moisture decreases with each successive operation.
†Multiple planting-cultivation & growth simultaneous with late planting crop or early harvest crop.

KVB 33100-1218

TABLE A-56. SACRAMENTO VALLEY

1978 VEGETABLE CROP - CAULIFLOWER

TYPICAL OPERATION	ALL COUNTIES	SOIL MOISTURE*
LAND PREPARATION		
Disc	3x	moist
Chisel	2x	↓
Land plane	2x	dry
List & preplant	1x	
Fertilize	1x	
Shape beds	1x	
CULTIVATION		
Plant (direct seed)	1x	moist
Irrigate	8x	↓
Fertilize	2x	
Cultivate	5x	
Pest control	2x	
Hoe & weed	1x	↓
HARVEST†		
Hand harvest	1x	moist
Haul	1x	↓

County	1000 Harvested Acres	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Each county	<0.5												

Preparation & Planting   Cultivation, Growth & Lay-By   Harvest

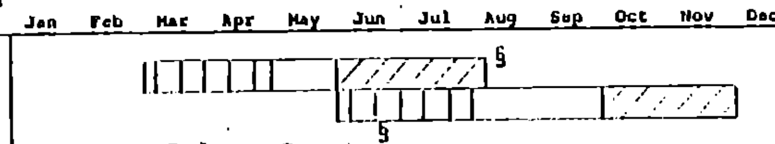
*Soil moisture decrease with each successive operation.

†Harvesting produces little dust.

TABLE A-57. SACRAMENTO VALLEY
1978 VEGETABLE CROP - CORN, SWEET

TYPICAL OPERATION	All Counties	Soil Moisture
LAND PREPARATION		
Subsoil	1x	Moist†
Disc	2x	↓
Land plane	1x	↓
List & fertilize	1x	Dry
CULTIVATION		
Plant	1x	Moist
Irrigate	8x	↓
Cultivate	2x	↓
Thin & weed	1x	↓
Insect control	4x	↓
HARVEST*		
Machine or hand harvest	2x	Dry
Haul	2x	↓

County	1000 Harvested Acres	Jan–Dec
Solano	1.4	(see chart)
Each remaining county	<0.5	same as Solano County



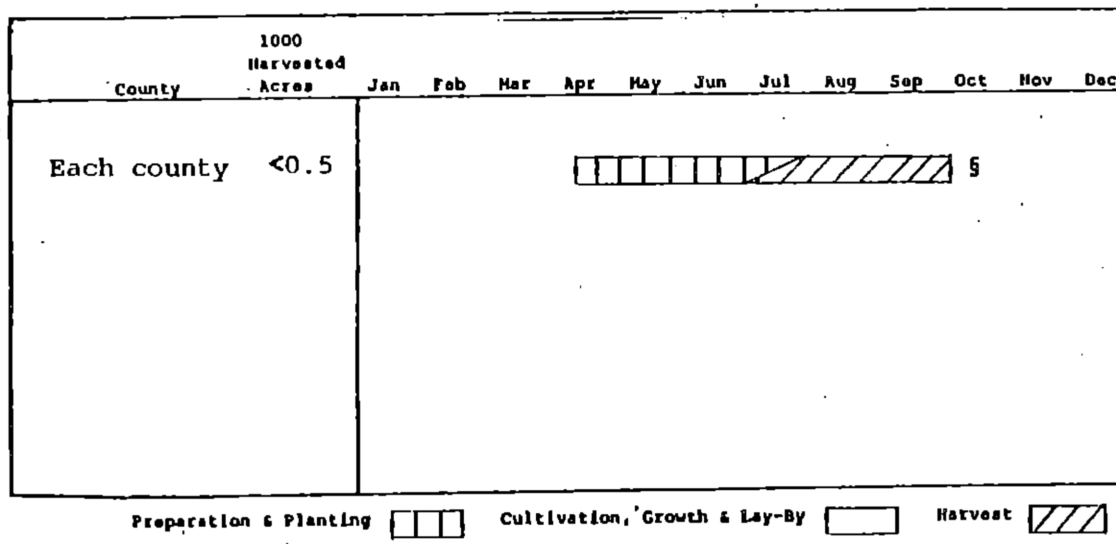
Preparation & Planting | Cultivation, Growth & Lay-By | Harvest

*Very little dust during harvesting; no disturbance of the soil.
†Soil moisture decrease with each successive land preparation operation.
§Multiple crop.

KVB 33100-1218

TABLE A-58. SACRAMENTO VALLEY
1978 VEGETABLE CROPS - CUCUMBERS

TYPICAL OPERATIONS	All counties	Soil moisture
LAND PREPARATION*		
Subsoil or plow	2x	Moist†
Disc	2x	↓
Land plane	2x	↓
Disc	2x	↓
Furrow & fertilize	1x	Dry
PLANT		
Plant	1x	Moist
Irrigate	12x	↓
Cultivate	1x	↓
Thin & hoe	1x	↓
Cultivate	3x	↓
Furrow & fertilize	1x	↓
Weed & hoe	1x	↓
HARVEST		
Hand harvest	1x	Moist
Haul	1x	



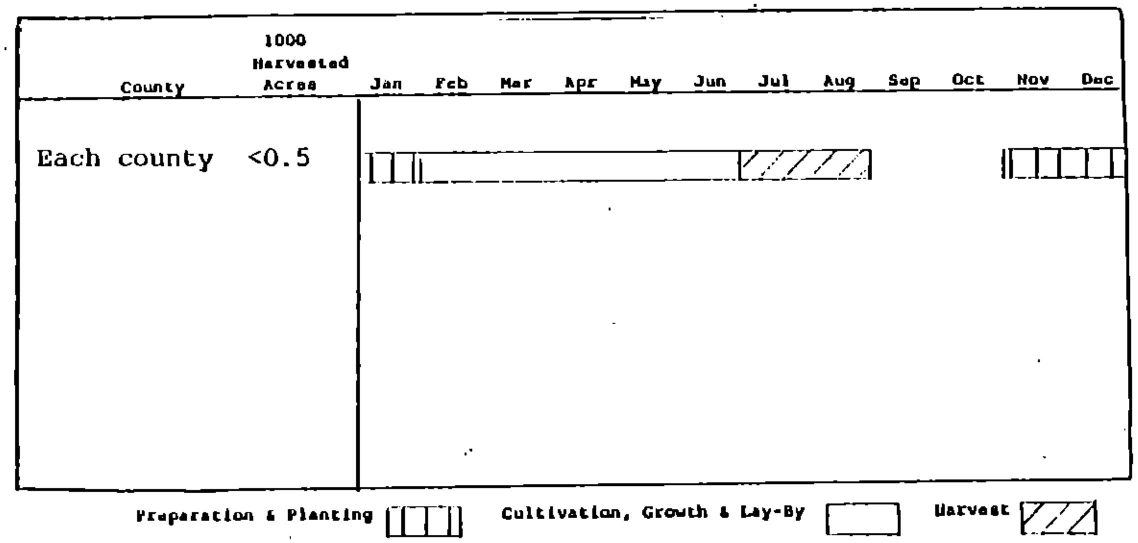
*Land preparation for cucumbers and squash the same.
†Soil Moisture decreases with each successive operation.
§Multiple planting-cultivation & growth simultaneous with late planting crop or early harvest crop.

KVB 33100-1218

TABLE A-59. SACRAMENTO VALLEY

1978 VEGETABLE CROP - GARLIC

TYPICAL OPERATIONS	All counties	Soil Moisture
LAND PREPARATION		
Plow	1x	Moist*
Disc	2x	↓
Fertilize	1x	
Shape beds	1x	Dry
CULTIVATION		
Plant	1x	Moist
Irrigate	4x	↓
Cultivate	5x	
HARVEST		
Machine-undercut	1x	Dry†
Top		↓
Pick		



*Soil moisture decreases with each successive operation.
†Harvesting typically "dusty".

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TABLE A-60. SACRAMENTO VALLEY
1978 VEGETABLE CROP - LETTUCE

TYPICAL OPERATIONS

	All counties	Soil Moisture
LAND PREPARATION		
Plow or Disc	2x	Moist*
Chisel	2x	↓
Float or Land plane	2x	↓
Shape beds & herbicide	1x	Dry
CULTIVATION		
Plant (direct seed)	1x	Dry
Irrigate	6x	Moist
Thin	1x	↓
Cultivate	5x	↓
Hand weed	1x	↓
Pest control	1x	↓
HARVEST		
Hand pick	1x	Moist
Haul	1x	↓

County	1000 Harvested Acres	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Each county	<0.5												

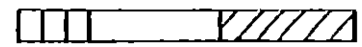
Preparation & Planting Cultivation, Growth & Lay-By Harvest

*Soil moisture decreases with each successive operation.

KVB 33100-1218

TABLE A-61. SACRAMENTO VALLEY
1978 VEGETABLE CROP - MIXED MELONS

TYPICAL OPERATION	All Counties	Soil Moisture
LAND PREPARATION*		
Plow	1x	Moist†
Subsoil	1x	↓
Disc	2x	↓
Land plane	2x	↓
Shape beds	1x	Dry
CULTIVATION		
Plant (dry seed)	1x	Moist
Irrigate	5x	↓
Cultivate	2x	↓
Pest control	3x	↓
Thin	1x	↓
Turn Vines	3x	↓
Hand hoe	2x	↓
HARVEST		
Hand pick	1x	Moist
Haul	1x	

County §	1000 Harvested Acres	Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Sutter	2.8	
Each remaining county	<0.5	Same as Sutter County

Preparation & Planting | Cultivation, Growth & Lay-By | Harvest

*Land preparation for cantaloupes, mixed melons, & watermelons identical.
†Soil moisture decreases with each successive operation.
§Planting & harvesting period for each county that grows melons the same as that for Fresno county.

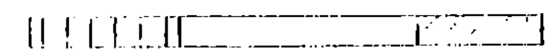
KVB 33100-1218

TABLE A-62. SACRAMENTO VALLEY

1978 VEGETABLE CROP - ONIONS, ALL*

TYPICAL OPERATION	All counties	Soil Moisture
LAND PREPARATION		
Plow or disc	2x	Dry†
Land plane	2x	↓
Fertilize & fumigate	1x	Moist
CULTIVATION		
Plant (direct seed)	1x	Dry
Irrigate	5x	Moist
Cultivate	1x	↓
Herbicide	1x	↓
Fungicide	1x	↓
HARVEST		
Dehydrated onions§-undercut		Dry
top		↓
windrow		↓
haul		↓
Fresh onions-hand harvest		↓
haul		↓

County	1000 Harvested Acres	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Each county	<0.5												



Preparation & Planting   Cultivation, Growth & Lay-By   Harvest

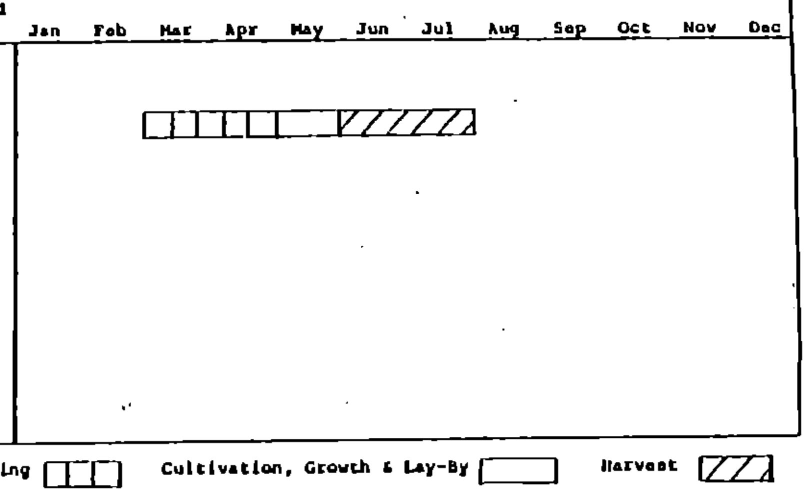
*Onion production includes: fresh, green & dehydrated.
†Soil moisture decreases with each successive operation.
§Dehydrated onion harvest similar to garlic harvest.

KVB 33100-1218

TABLE A-63. SACRAMENTO VALLEY
1978 VEGETABLE CROP - PEAS

TYPICAL OPERATION	All counties	Soil moisture
LAND PREPARATION		
Stubble disc* of plow	1x	Moist†
Disc	2x	↓
Land plane	2x	↓
Spring tooth	2x	↓
List & fertilize	1x	Dry
CULTIVATION		
Plant	1x	Moist
Irrigate	6x	↓
Pest control	1x	↓
Weed control	1x	↓
HARVEST		
Machine cut & windrow	1x	Dry
Haul	1x	

County	1000 Harvested Acres
Each county	<0.5



*Stubble disc often occurs during the fall prior to the following spring's planting.
†Soil moisture decreases with each successive operation.

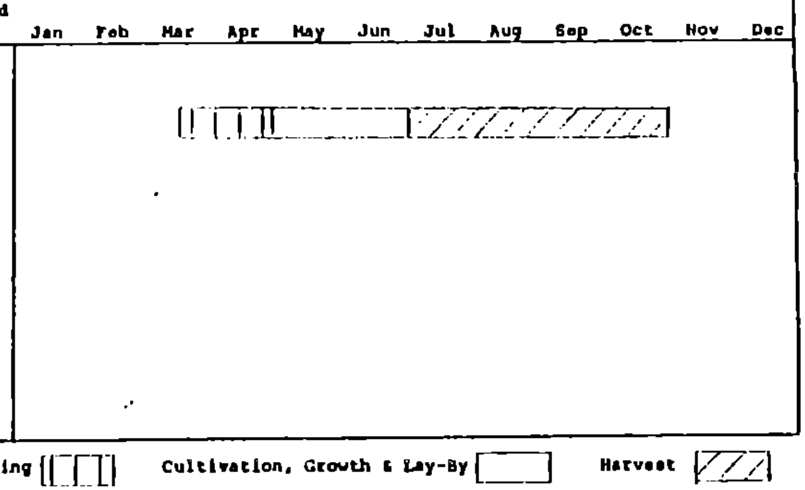
KVB 33100-1218

TABLE A-64. SACRAMENTO VALLEY

1978 VEGETABLE CROP - PEPPERS, ALL

TYPICAL OPERATION	All counties	Soil moisture
LAND PREPARATION		
Disc	2x	Wet§
Land plane	2x	↓
Chisel	1x	↓
Disc	1x	↓
Shape beds	1x	Dry
CULTIVATION		
Plant*	1x	Moist
Irrigate	10x	↓
Cultivate	3x	↓
Pest control	4x	↓
HARVEST†		
Hand pick	1x	Moist
Haul	1x	↓

County	1000 Harvested Acres
Each County#	<0.5

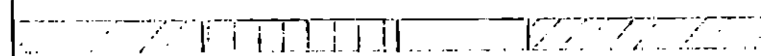


*Approximately 40% of peppers are transplanted.
†Harvest is considered "dust free" because plants are kept moist for a sustained harvest.
§Soil moisture decreases with each successive operation.
#Planting & harvest the same as Northern San Joaquin Valley.

KVB 33100-1218

TABLE A-65. SACRAMENTO VALLEY
1978 VEGETABLE CROP - POTATOES

TYPICAL OPERATION	All counties	Soil moisture*
LAND PREPARATION		
Disc	2x	Moist†
Chisel	2x	↓
Land plane	2x	↓
List & fertilize	1x	Dry
CULTIVATION		
Plant	1x	Dry
Irrigate	7x	↓
Cultivate	4x	↓
Hoe & weed	1x	↓
HARVEST		
Mechanical harvest		Dry
Lift	1x	↓
Haul	1x	↓

County	1000 Harvested Acres	Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Each county§	<0.5	

Preparation & Planting | Cultivation, Growth & Lay-By | Harvest

*Potatoes planted in "sandy" soils that when dry do not result in the production of much dust.
†Soil moisture decreases with each successive land preparation operation.
§Planting & harvesting based on the operations in Central Coast counties.

KVB 33100-1218

TABLE A-66. SACRAMENTO VALLEY
1978 VEGETABLE CROP - POTATOES, SWEET

TYPICAL OPERATION	All counties	Soil moisture
LAND PREPARATION		
Bed preparation*		Moist
Disc	2x	↓
Fumigate	1x	↓
Plant roots	1x	↓
Field preparation		Dry†
Plow or disc	2x	↓
Fertilize	1x	↓
Shape beds	1x	↓
Transplant into beds	1x	↓
CULTIVATION		
Plant	1x	Dry
Irrigate	8x	↓
Cultivate	2x	↓
Hoe	2x	↓
HARVEST		
Mechanical lift	1x	Dry
Haul	1x	↓

County	1000 Harvested Acres	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Each county	<0.5												

Preparation & Planting | Cultivation, Growth & Lay-By | Harvest

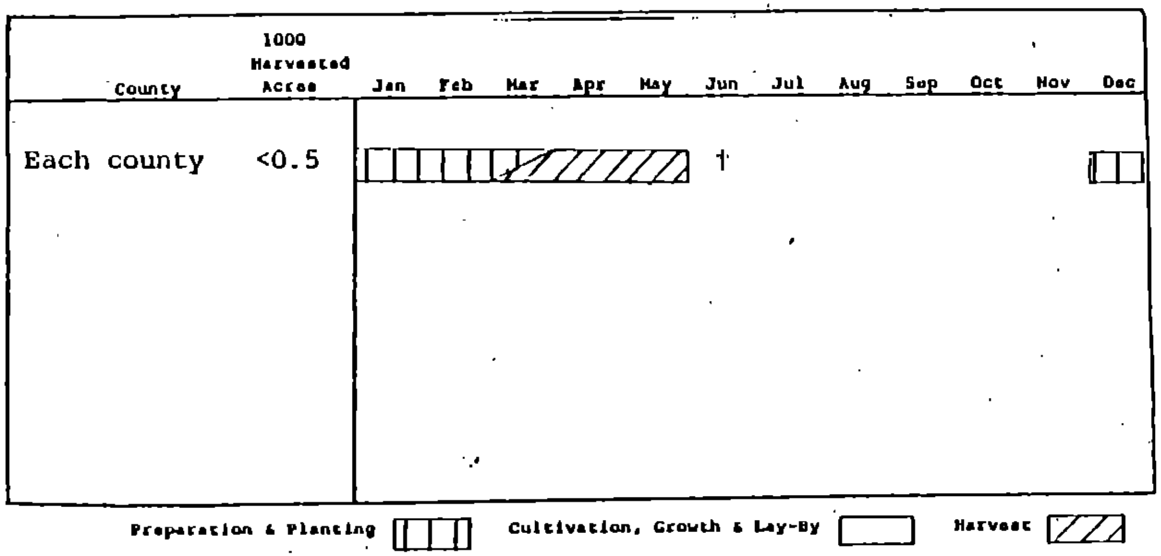
*Bed preparation done in the early spring
†Sweet potatoes planted in a dry, sandy soil that produces little dust during crop operation. Soil moisture decreases with each successive operation.

KVB 33100-1218

TABLE A-67. SACRAMENTO VALLEY
1978 VEGETABLE CROP - SPINACH

TYPICAL OPERATION

LAND PREPARATION	All counties	Soil Moisture
Plow	1x	Moist*
Disc	3x	↓
Land plane	2x	↓
Shape beds	1x	↓
List & fertilize	1x	Dry
CULTIVATION		
Plant	1x	Moist
Herbicide	1x	↓
Irrigate	3x	↓
Cultivate	1x	↓
Weed control	1x	↓
Pest control	1x	↓
Hoe	1x	↓
HARVEST		
Machine harvest	1x	Moist
Haul	1x	↓



*Soil moisture decreases with each successive operation.
†Multiple planting-cultivation, growth & lay-by simultaneous with late planting crop or early harvested crop.

KVB 33100-1218

TABLE A-68. SACRAMENTO VALLEY
1978 VEGETABLE CROPS - SQUASH

TYPICAL OPERATION	All counties	Soil moisture
LAND PREPARATION*		
Subsoil or plow	2x	Moist†
Disc	2x	↓
Land plane	2x	↓
Disc	2x	↓
Furrow & fertilize	1x	Dry
PLANT		
Plant	1x	Moist
Irrigate	12x	↓
Cultivate	1x	↓
Thin & hoe	1x	↓
Cultivate	3x	↓
Furrow & fertilize	1x	↓
Weed & hoe	1x	↓
HARVEST		
Hand harvest	1x	Moist
Haul	1x	↓

County	1000 Harvested Acres	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sutter	1.1										§		
Each county	<0.5	same as Sutter County											

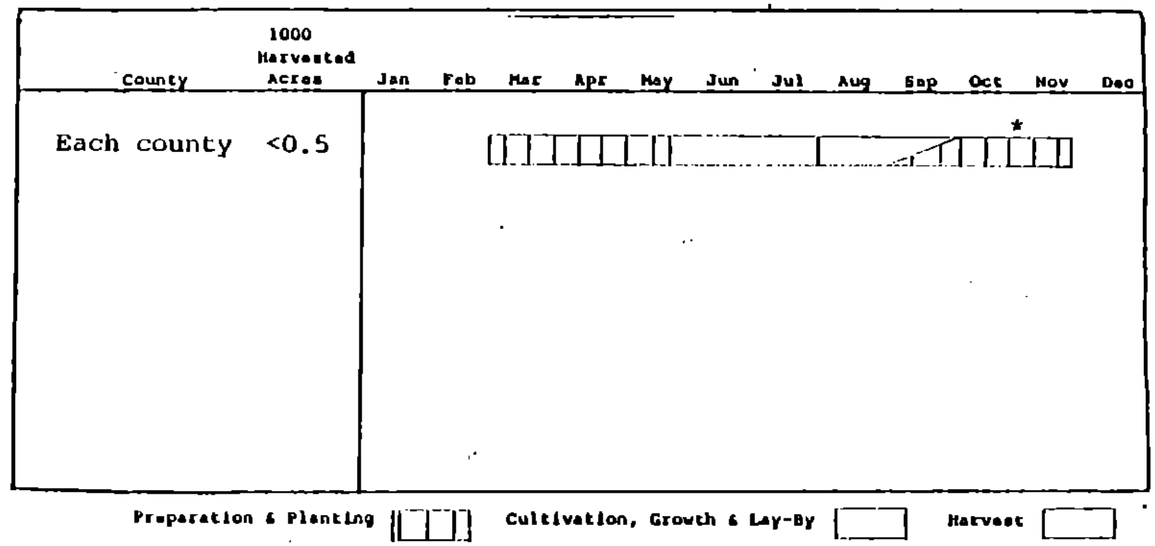
Preparation & Planting   Cultivation, Growth & Lay-By   Harvest

*Land preparation for cucumbers and squash the same.
†Soil moisture decreases with each successive operation.
§Multiple planting-cultivation & growth simultaneous with late planting crop or early harvest crop.

KVB 33100-1218

TABLE A-69. SACRAMENTO VALLEY
1978 VEGETABLE CROP - TOMATOES, FRESH MARKET

TYPICAL OPERATION	All counties	Soil moisture
LAND PREPARATION		
Seedbed preparation		
Fall		
Disc	2x	Dry
Subsoil	2x	↓
Land plane	2x	↓
Spring		
Disc	2x	↓
Springtooth	1x	↓
Harrow & roll	1x	↓
List & fumigate	1x	↓
CULTIVATION		
Plant	1x	Dry
Cultivate	3x	↓
Hoe	1x	↓
Irrigate	10x	↓
Insect control	1x	↓
HARVEST		
Machine or hand pick	1x	Moist
Haul	1x	↓



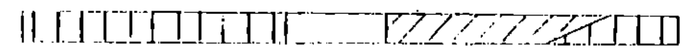
*Late harvesting crop may be simultaneous with some Fall seedbed preparation.

KVB 33100-1218

TABLE A-70. SACRAMENTO VALLEY

1978 VEGETABLE CROP - TOMATOES, PROCESSING

TYPICAL OPERATION	All counties	Soil moisture
LAND PREPARATION		
Seedbed preparation		
Fall		
Disc	2x	Dry
Subsoil	2x	
Land plane	2x	
Spring		
Disc	2x	
Springtooth	1x	
Harrow & roll	1x	
List & fumigate	1x	
CULTIVATION		
Plant	1x	Dry
Cultivate	3x	
Hoe	1x	
Irrigate	10x	
Insect control		
HARVEST		
Machine or hand pick	1x	Moist
Haul	1x	

County	1000 Harvested Acres	Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Colusa	8.3	 *
Sacramento	7.8	same as Colusa County
Solano	15.4	same as Colusa County
Sutter	29.7	same as Colusa County
Yolo	58.0	same as Colusa County
Each remaining county	<0.5	same as Colusa County

Preparation & Planting　　Cultivation, Growth & Lay-By　　Harvest

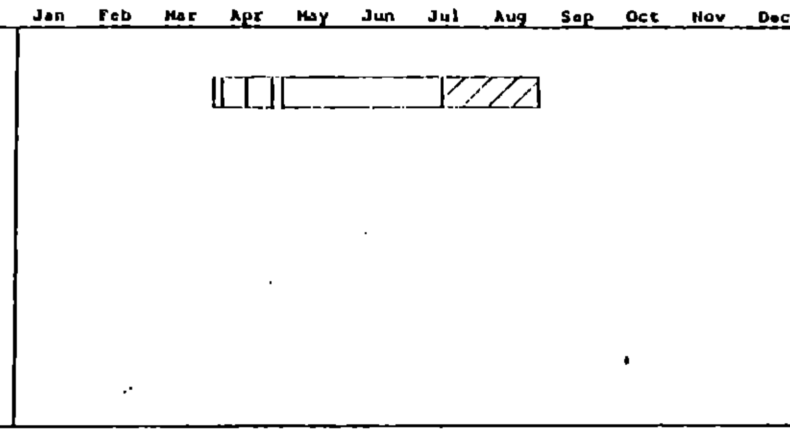
*Late harvesting crop may be simultaneous with some fall seed bed preparation.

KVB 33100-1218

TABLE A-71. SACRAMENTO VALLEY
1978 VEGETABLE CROP - WATERMELONS

TYPICAL OPERATIONS	All counties	Soil moisture
LAND PREPARATION*		
Plow	1x	Moist†
Subsoil	1x	↓
Disc	2x	↓
Land plane	2x	↓
Shape beds	1x	Dry
CULTIVATION		
Plant (dry seed)	1x	Moist
Irrigate	5x	↓
Cultivate	2x	↓
Pest control	3x	↓
Thin	1x	↓
Turn vines	3x	↓
Hand hoe	2x	↓
HARVEST		
Hand pick	1x	Moist
Haul	1x	↓

County	1000 Harvested Acres
Each county	<0.5



Preparation & Planting | Cultivation, Growth & Lay-By | Harvest

*Land preparation for cantaloupes, mixed melons, & watermelons assumed to be identical.
†Soil moisture decreases with each successive operation.

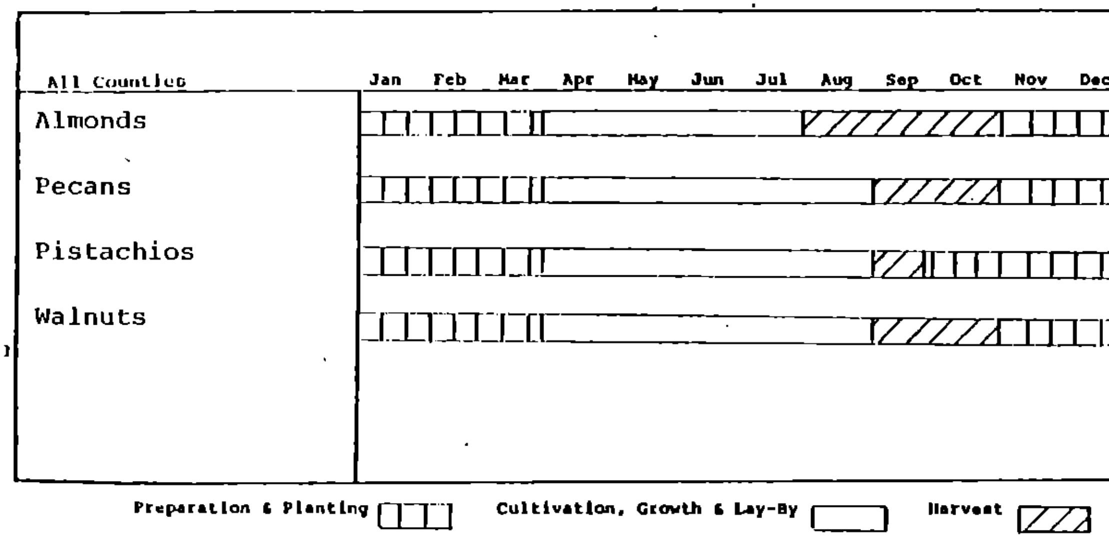
KVB 33100-1218

TABLE A-72. SACRAMENTO VALLEY

1978 FRUIT AND NUT CROPS - BEARING ACRES

NUTS - Almonds, Pecans, Pistachios, and Walnuts

TYPICAL OPERATIONS	All counties 1st year only	All counties Remaining years	Season
LAND PREPARATION*			
Chisel	1x		
Disc & float	2x	2x	Fall
Fumigation		1x	Fall
CULTIVATION			
Plant	1x	1 tree/acre	Late winter or spring
Prune & brush disposal	1x	1x	Winter
Furrow	3x	6x	
Fertilize	2x	2x	Fall and Winter
Irrigate§	4x	4-8x	Frost protection in Spring
Border	1x	1x	
Disc† or	3x	3-5x	Late spring and summer
weed control	1x	2-3x	
mow	1x	2-3x	
Prune & brush disposal		1x	
HARVEST‖			
Knock, sweep, pick-up and haul		1x	



1000 Harvested acres

County	Almonds	Pecans	Pistachios	Walnuts
Butte	30.1	<0.5	<0.5	10.9
Colusa	14.0			5.4
Glenn	7.0			4.6
Sacramento	<0.5			<0.5
Solano	3.4			2.0
Sutter	5.7			13.3
Tehama	5.1			10.7
Yuba	1.9			3.9
Yolo	11.0			5.5

*The percentage of new land preparation dependent on the life of the orchard. Estimate 5-10% new orchard plantings each year. Land preparation operations dependent on soil texture. Sacramento Valley has medium textured soil that requires no back-hoe, fumigation, re-filling, and pre-irrigation.

†50% of all nut crops disked or tilled.

§Irrigation may be done by sprinkle, flood, or drip. Soil moisture generally moist.

‖Nut crop harvests 95% mechanical.

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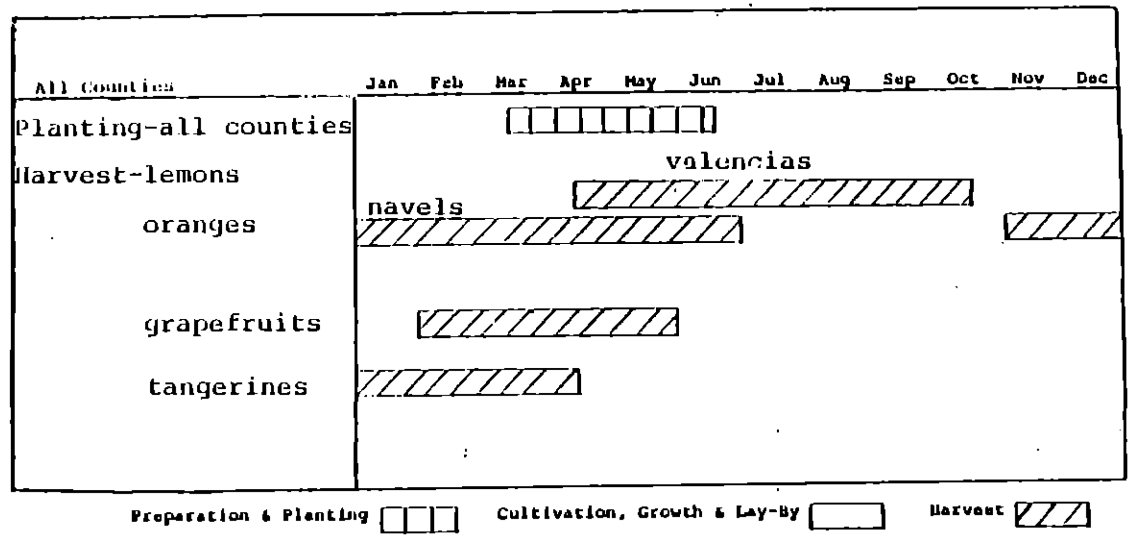
TABLE A-73. SACRAMENTO VALLEY

1978 FRUIT AND NUT CROPS - BEARING ACRES

CITRUS - GRAPEFRUIT, LEMONS, ORANGES, AND TANGERINES

TYPICAL OPERATIONS*

	All Counties	
	1st year only	Remaining years
LAND PREPARATION†		
Chisel	1x	
Disc & float	2x	2x
Fumigate		1x
CULTIVATION§		
Plant	1x	
Irrigate	7x	8x
Fertilize	2x	2x
Border	1x	
Pest and disease control	2x	2x
Weed control	2x	2x
Prune & brush disposal#		1x
Furrow	2x	2x
HARVEST		
Hand pick & haul		1x



1000 Harvested acres

County	Grapefruit	Lemons	Oranges	Tangerines
Glenn	<0.5	<0.5	1.9	<0.5
All remaining counties	<0.5	<0.5	<0.5	<0.5

*Tulare county operations considered typical of all citrus crop operations in the Sacramento Valley.

†The percentage of new land preparation dependent on the life of the orchard. Estimate 5-10% new orchard plantings each year.

§All orchard cultivations generally similiar.

#Mature lemon groves are pruned annually and oranges are pruned once every 5 years. Pruning and brush disposal done by shredding.

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TABLE A-74. SACRAMENTO VALLEY

1978 FRUIT AND NUT CROPS - BEARING ACRES

DECIDUOUS TREE FRUITS - APPLES, APRICOTS, CHERRIES, FIGS, NECTARINES, OLIVES PEACHES, PEARS, PERSIMMONS, PLUMS, POMEGRANATES, PRUNES

TYPICAL OPERATIONS

	All counties: 1st year only	All counties: Remaining years	Season
LAND PREPARATION*			
Chisel	1x		
Disc & float	2x	2x	Fall
Fumigation		1x	Fall
CULTIVATION			
Plant	1x	1x	Late winter or spring
Prune & brush removal†	1x	1x	Winter
Spray	5x	5x	
Fertilize	2x	2x	Fall & winter
cultivate or non-tillage§	4x	4x	Late spring & summer
Border	1x	1x	
Irrigate#	8x	8x	
HARVEST**			
Pick (mechanized for process fruits)		1x	
Haul		1x	

Crop	Harvest period	Butte	Colusa	Glenn	Sacramento	Solano	Sutter	Tehama	Yuba	Yolo
		1000 Harvested Acres								
Apples	Jul-Oct	-	-	-	-	-	-	-	-	-
Apricots	May-June	-	-	-	-	1.8	-	-	-	1.5
Cherries	May-June	-	-	-	-	-	-	-	-	-
Figs	late summer	-	-	-	-	-	-	-	-	-
Nectarines	May-Aug	-	-	-	-	-	-	-	-	-
Olives	Sept-Oct	3.8	-	1.7	-	-	-	5.0	-	-
Peaches										
Clingstone	June-Sept early									
All		3.2	-	-	-	0.6	11.2	0.5	4.6	-
Freestone	May-Sept									
Pears	Jul-Aug	0.8	-	0.7	6.9	3.5	1.4	-	1.6	0.8
Persimmons	Fall	-	-	-	-	-	-	-	-	-
Plums	May-Sept	-	-	-	-	-	-	-	-	-
Pomegranates	Fall	-	-	-	-	-	-	-	-	-
Prunes	Aug-Sept	1.5	5.5	4.4	-	3.3	16.1	7.4	8.7	2.0

(- less than 500 acres)

*The Percentage of new land preparation dependent on the life of the orchard. Estimate 5% new orchard plantings each year. Land preparation dependent on soil texture. Sacramento Valley has medium textured spil that requires no back-hoe, fumigation, re-filling, and pre-irrigation.

†Brush removal is done by shredding and burning, estimate 50% each.

§Cultivation or tillage done by disking. Non-tillage crops require weeds to be mowed and sprayed with herbicide. Estimate that 10% of total acreage have weeds burned.

#Irrigation may be done by sprinkling, flooding after furrows are made, or by drip. Sprinkling in the Spring done to prevent frost. About 10% of acreage use orchard heaters to prevent frost.

**Estimate that 50% of prunes and clingstone peaches are mechanically harvested and that 95% of apples, cherries, nectarines, plums, freestone peaches and ½ clingstone peaches are hand harvested.

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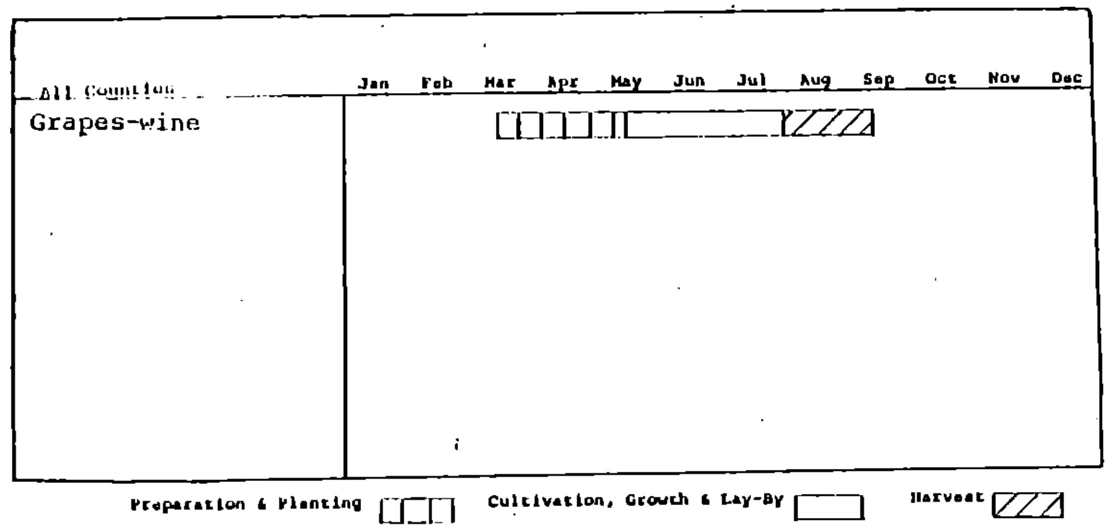
TABLE A-75. SACRAMENTO VALLEY
1978 FRUIT AND NUT CROPS - BEARING ACRES
VINE CROPS - Grapes, wine only

TYPICAL OPERATION	All counties	Soil Moisture
LAND PREPARATION*		
Rip	1x	Moist
Disc	2x	↓
Float	1x	↓
Level	1x	↓
Border	1x	↓
Fumigate	1x	Dry
CULTIVATION		
Plant	1x	Moderately dry
Cultivate	4-6x	↓
Irrigate	8x	↓
Weed control	2x	↓
Pest control	3x	↓
HARVEST		
Hand pick	1x	Moderately dry
Machine harvest for wine grapes	1x	↓
POST-HARVEST†		
Prune & brush disposal	1x	Dry



1000 Harvested Acres

County	Grapes, wine
Butte	1.4
Glenn	0.8
Sacramento	3.3
Solano	1.3
Yolo	0.6
All remaining counties	<0.5

* The life of a grape orchard is 30 years. Estimate 5% new grape orchard plantings.
†Pruning is done in the winter. Brush is disposed of by shredding.

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TABLE A-76. IMPERIAL VALLEY
1978 FIELD CROPS

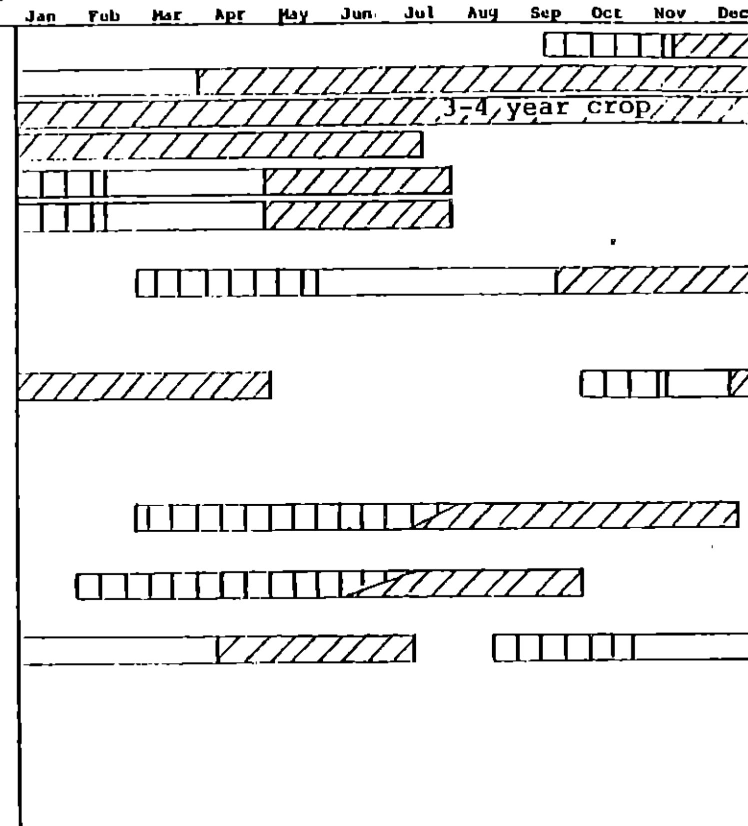
TYPICAL OPERATIONS - IMPERIAL COUNTY

LAND PREPARATION*	Alfalfa & sugar beets	All other field crops	Soil Moisture†
Subsoil	1x		8-13%
Disc	2x	2x	
Fertilize	1x	1x	
Build & break borders	1x	1x	
Flood	1x		
Disc	2x		
Land plane	2x		
Float	1x	2x	

CULTIVATION	Cotton	Sugar beets	All other field crops	Soil Moisture†
Plant	1x	1x	1x	13-18%
Weed control		1x		
Herbicide	1x		1x	
Cultivate	3x	3x		
Fertilize	2x	2x	1x	
Insect control	12x		1x	
Irrigate	10x	12x	8-10x	
Defoliate	2x			
Pest control		8x		

HARVEST	Alfalfa & pasture crops§	Sugar beets#	Cotton	Barley, wheat & sorghum	Soil moisture
Swath & rake, bale	3-7x, 1x				10%-14%
Combine				1x	
Gin			1x		
Dig		1x			
Haul	1x	1x	1x	1x	

	1000 Harvested Acres
Alfalfa-hay	18.1
dehydrated	16.0
pasture	153.0
Barley	8.0
Wheat	140.1
Cotton	67.0
Pasture	
ryegrass	8.3
others	53.5
Sorghum**	
grain	15.0
Sudan grass**	11.8
Sugar beets	34.3



Preparation & Planting Cultivation, Growth & Lay-By Harvest

*Land preparation and harvesting typically the "dusty" operations. Land preparation occurs 30-45 days prior to planting.
†Soil moisture varies with soil type; heavier soils hold more water.
§Alfalfa yield 7 cuttings; other grasses yield 2-3 cuttings.
#Sugar beet harvest typically "dusty"; beets are topped, undercut and lifted; soil moisture content usually higher.
**Multiple planting-cultivation & growth simultaneous with late planting crop or early harvest crop.

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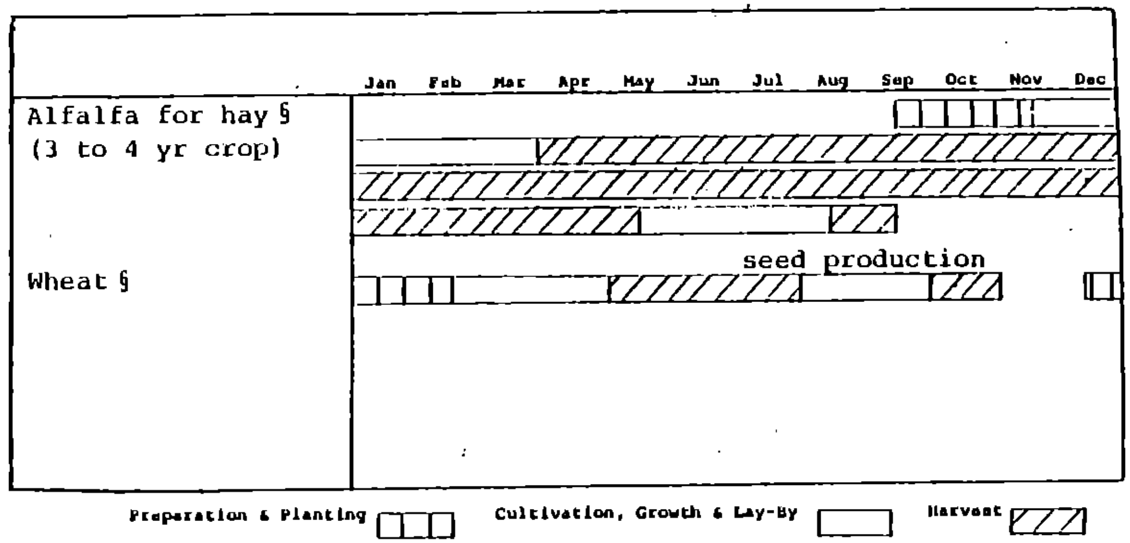
TABLE A-77. IMPERIAL VALLEY
1978 SEED CROPS

TYPICAL OPERATIONS - IMPERIAL COUNTY

	Alfalfa	Wheat	Soil† Moisture
LAND PREPARATION*			
Subsoil	1x		8-13%
Disc	2x	2x	
Fertilize	1x	1x	
Build & break border	1x	1x	
Flood	1x		
Disc	2x		
Land plane	2x		
Float	1x	1x	
CULTIVATION	Alfalfa & Wheat		
Plant	1x		13-18%
Herbicide	1x		
Irrigate	4-7x		
Insect control	1x		
Defoliate	1x		
HARVEST			
Combine	1x		10-14%
Haul	1x		"



seed crops follow seasonal cropping

*Land preparation for seed crops identical to that for field crops; occurs 30-45 days prior to planting.
†Soil moisture varies with soil type; heavier soil should hold more water.
§Seed crop acreage included in harvested crop acreage, see Table 3-2.

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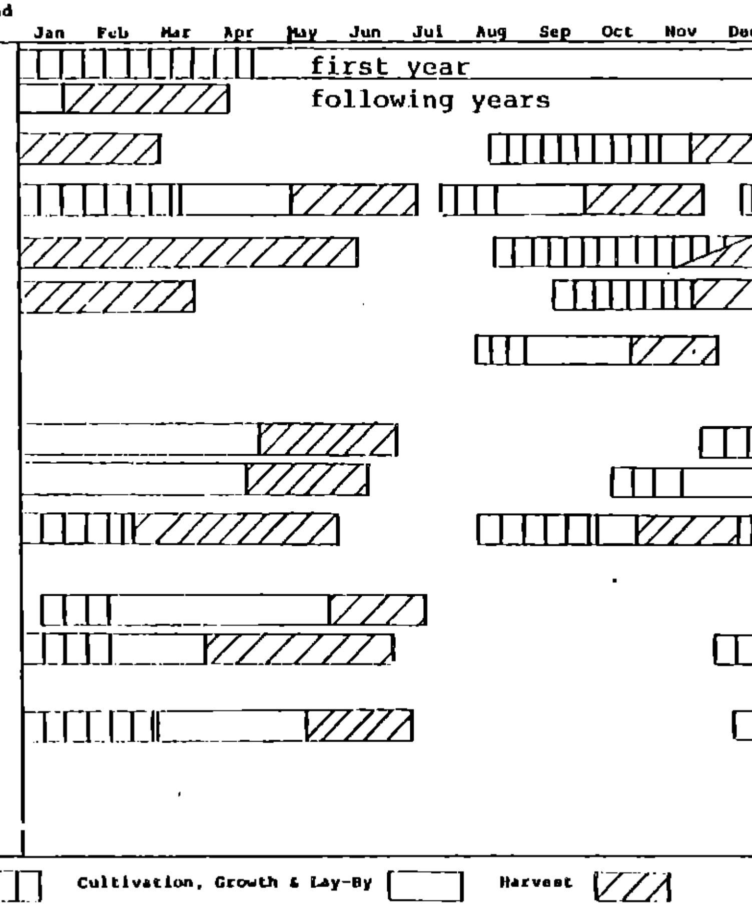
TABLE A-78. IMPERIAL VALLEY
1978 VEGETABLE CROPS

TYPICAL OPERATION - IMPERIAL COUNTY
ALL VEGETABLE CROPS

*	No. of Operations	Soil Moisture†
LAND PREPARATION		
Subsoil		8-13%
Disc	2x	↓
Border, cross check break border	1x	↓
Flood	1x	↓
Fertilize	1x	↓
Disc	2x	↓
Triplane	2x	↓
List	1x	↓
CULTIVATION		
Plant	1x	13-18%
Cultivate	2-5x	↓
Fertilize	2x	↓
Irrigate	3-23x	↓
Pest control	2-8x	↓
Weed control	1-2x	↓
Thin	1x	↓
Herbicide	1x	↓
HARVEST§		
Pick, cut or machine	1x	10-14%
Haul	1x	

Vegetable Crop	1000 Harvested Acres
Asparagus (10 yr crop)	3.2
Broccoli	2.7
Cantaloupes	12.4
Carrots#	6.4
Lettuce	40.9
Melons	2.3
Onions	
dehydrated	2.0
market	2.0
Squash	0.5
Tomatoes	
cannery	1.2
market	1.9
Watermelons	1.8



*Land preparation and harvesting typically the "dusty' operations. Land preparation occurs 30-45 days prior to planting, for asparagus first year only.

†Soil moisture varies with the soil type; heavier soils hold more water.

§Harvest of dehydrated onions "dusty"; harvest operations include: roller and beat, under cut, lifting and grading of the onions.

#Multiple planting-Cultivation & growth simultaneous with late planting crop or early harvest crop.

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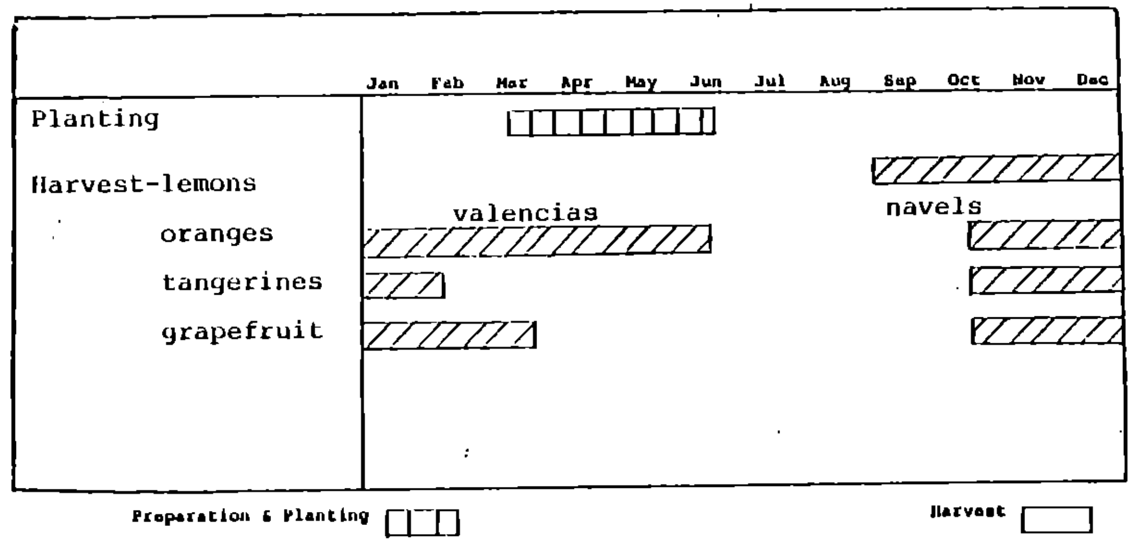
TABLE A-79. IMPERIAL VALLEY
1978 FRUIT AND NUT CROPS - BEARING ACRES
CITRUS - GRAPEFRUIT, LEMONS, ORANGES, AND TANGERINES
All other crops less than 500 harvested acres

TYPICAL OPERATIONS* - IMPERIAL COUNTY
All counties

	1st yr. only	Remaining years
LAND PREPARATION†		
Chisel	1x	
Disc & float	2x	2x
Fumigate		1x
CULTIVATION§		
Plant	1x	
Irrigate	10x	14x
Fertilize	2x	2x
Border	1x	
Pest & disease control	2x	2x
Weed control (cultivation)	2x	2x
Prune & brush disposal#		1x
Furrow	2x	2x
HARVEST		
Hand pick & haul		1x



1000 Harvested Acres

Grapefruit	Lemons	Oranges	Tangerines
0.5	1.8	0.9	<0.5

* Cochella Valley operations considered typical of all citrus crop operations in the Imperial Valley.

†The percentage of new land preparation dependent on the life of the orchard. Estimate 5-10% new orchard plantings each year.

§All orchard cultivations generally similiar.

#Mature lemon groves are pruned annually and oranges are pruned once every 5 years. Pruning and brush disposal done by shredding.

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APPENDIX B

1978 IP EMISSIONS INVENTORY

This appendix contains the detailed calculations of the emissions generated by crop and by agricultural operations in the San Joaquin, Sacramento, and Imperial Valleys. The tables are ordered according to the following hierarchy:

I. Level 1
   A. San Joaquin Valley
   B. Sacramento Valley
   C. Imperial Valley

II. Level 2
   A. Field and Seed Crops
   B. Vegetable Crops
   C. Fruit and Nut Crops

III. Level 3
   A. Soil Preparation Operations
   B. Cultivation Operations
   C. Harvesting Operations

The inventory was performed using the criteria listed in Section 5.3. Since there were no fruit and nut crops of significant acreage (> 40.5 km^2) in the Imperial Valley, there are no tables for operations on these crops.

The method for calculating the IP emission rate by valley was to multiply a representative emission factor times the number of operations, and finally, times the land area harvested. The number of operations and the area harvested were both taken from tables in Appendix A.

TABLE B-1. 1978 EMISSIONS INVENTORY SUMMARY--SOIL PREPARATION
San Joaquin Valley
Field and Seed Crops

Type of produce	Number of typical[a] operations/year	Total land area harvested[b] km²	(acres)	Total annual emissions of inhalable[c] particulate matter-Mg/yr	(tons/yr)
Alfalfa	8	1,500	(369,000)	934	(1,030[d])
Irrigated pasture	8	1,450	(359,000)	916	(1,010[d])
Barley	7	1,980	(489,700)	5,440	(6,000)
Oats	7	75.3	(18,600)	207	(228)
Wheat	7	537	(132,700)	1,480	(1,630)
Dry beans	10	387	(95,600)	1,520	(1,670)
Sugar beets	10	315	(77,700)	1,230	(1,360)
Corn	6	718	(177,300)	1,690	(1,860)
Cotton	6	5,680	(1,401,700)	13,300	(14,700)
Dry land pasture	2	25,000	(6,181,000)	1,960	(2,160[e])
Rice	13[f]	161	(39,700)	819	(903)
Safflower	7	277	(68,400)	760	(838)
Grain sorghum	6	257	(63,400)	604	(666)
Soybeans	6	40.9	(10,100)	96.1	(106)
Total				31,000	(34,200)

a Does not include flooding and draining of fields.
b Crops with < 40.5 km² (10,000 acres) being harvested were not included in the emissions inventory.
c An average emission factor of 393 kg. particulate matter/km² harvested (3.5 lbs/acre) was used to calculate the annual emissions from all soil preparation operations based on results of field tests.
d Emissions based on 20% of land area undergoing preparation on an annual basis.
e Emissions based on 10% of land area undergoing soil preparation on an annual basis.
f Does not include burning.

TABLE B-2. 1978 EMISSIONS INVENTROY SUMMARY--CULTIVATION
San Joaquin Valley
Field and Seed Crops

Type of produce	Number of typical[a] operations/year	Total land area harvested[b] km² (acres)		Total annual emissions of inhalable[c] particulate matter-Mg/yr (tons/yr)	
Alfalfa	1	1500	(369,000)	293	(323)
Irrigated pasture	1	1450	(359,000)	285	(314)
Barley	1	1980	(489,700)	389	(429)
Oats	1	75.3	(18,600)	14.8	(16.3)
Wheat	1	537	(132,700)	105	(116)
Dry beans	3	387	(95,600)	228	(251)
Sugar beets	5	315	(77,700)	308	(340)
Corn	4	718	(177,300)	563	(621)
Cotton	7	5680	(1,401,700)	7790	(8590)
Dry land pasture	1	25,000	(6,181,000)	491	(541[d])
Rice	0	161	(39,700)	0	0
Safflower	1	277	(68,400)	54.3	59.9
Grain sorghum	4	257	(63,400)	201	222
Soybeans	3	40.9	(10,100)	24.0	26.5
Total				10,800	11,900

[a] Does not include irrigation, the application of herbicides and insecticides, hand weeding and cultivation, fumigation, pruning and brush removal where applicable.
[b] Crops with < 40.5 km² (10,000 acres) being harvested were not included in the emissions inventory.
[c] Emission factor assumed = 0.5 (Emission Factor for Land Preparation Operations) = 196 kg/km² (1.75 lbs/acre).
[d] Emissions based on 10% of land area undergoing preparation on an annual basis.

TABLE B-3. 1978 EMISSIONS INVENTORY SUMMARY--HARVESTING
San Joaquin Valley
Field and Seed Crops

Type of produce	Number of typical operations/year[a]	Total land area harvested[b] km²	(acres)	Total annual emissions of inhalable particulate matter-Mg/yr[c]	(tons/yr)
Alfalfa	18	1,500	(369,000)	9,980	(11,000)
Irrigated pasture	18	1,450	(359,000)	9,710	(10,700)
Barley	4	1,490	(367,000[d])	2,270	(2,500[e])
Barley (post harvest)	8[f]	496	(122,000[g])	1,530	(1,690[h])
Oats	4	75.3	(18,600)	115	(127[e])
Wheat	4	403	(99,500[d])	614	(677[e])
Wheat (post harvest)	8[f]	135	(33,200[g])	417	(460[h])
Dry beans	3	387	(95,600)	859	(947)
Sugar beets	2	315	(77,700)	465	(513)
Corn	2	718	(177,000)	531	(585)
Cotton	1	5,680	(1,400,000)	2,100	(2,310)
Dry land pasture	0	25,000	(6,180,000)	0	0
Rice	1	161	(39,700)	59.4	(65.5)
Safflower	1	277	(68,400)	103	(113)
Grain sorghum	2	257	(63,400)	190	(209)
Soybeans	1	40.9	(10,100)	30.2	(33.3)
Total				29,000	32,000

a Does not include hand harvesting, hand picking and knock harvesting as applicable.

b Crops with < 40.5 km² (10,000 acres) being harvested were not included in the emissions inventory.

c Emission factor used for calculations was 740 kg/km² (6.6 lbs/acre) for "digging" operations based on the results of field tests for the harvesting of sugar beets, and 370 kg/km² (3.3 lbs/acre) for all other harvesting activities which assumes a 50% reduction in emissions from that tested.

d Assumes 100% of land area is double cropped.

e Emission factor used = 0.5 (Emission factor for "nondigging" harvesting) + 0.5 (Emission factor for soil preparation).

f Does not include burning.

g 25% of total land area harvested undergoes additional post harvesting soil preparation.

h Emission factor used = 0.25 (Emission factor for "nondigging" harvesting) + 0.75 (Emission factor for soil preparation).

TABLE B-4. 1978 EMISSIONS INVENTORY SUMMARY--SOIL PREPARATION
San Joaquin Valley
Vegetable Crops

Type of produce	Number of typical[a] operations/year	Total land area harvested[b] km^2	(acres)	Total annual emissions of inhalable[c] particulate matter-Mg/yr	(tons/yr)
Asparagus (existing)	2	62.0	(15,300[d])	48.6	(53.6)
Lima beans	9	60.3	(14,900)	213	(235)
Cantalopes	7	141	(34,800)	386	(426)
Carrots	5	46.6	(11,500)	91.6	(101)
Lettuce	7	68.0	(16,800)	187	(206)
Onions	5	70.1	(17,300)	137	(151)
Potatoes	7	104	(25,600)	285	(314)
Tomatoes (fresh)	11	56.7	(14,000)	245	(270)
Tomatoes (process)	11	351	(86,600)	1,520	(1,670)
Total				3,110	3,430

a Does not include flooding and draining of fields.
b Crops with < 40.5 km^2 (10,000 acres) being harvested were not included in the emissions inventory.
c An average emission factor of 393 kg. particulate matter/km^2 harvested (3.5 lbs/acre) was used to calculate the annual emissions from all land preparation operations based on results of field tests.
d Does not include new fields < 40.5 km^2 (10,000 acres) per footnote b. New fields assumed to be approximately 10% of the total land area harvested.

TABLE B-5. 1978 EMISSIONS INVENTORY SUMMARY--CULTIVATION
San Joaquin Valley
Vegetable Crops

Type of produce	Number of typical[a] operations/year	Total land area harvested[b] km² (acres)		Total annual emissions of inhalable[c] particulate matter-Mg/yr (tons/yr)	
Asparagus	5	68.9	(17,000)	67.5	(74.4)
Lima beans	4	60.3	(14,900)	47.3	(52.2)
Cantalopes	7	141	(34,800)	193	(213)
Carrots	5	46.6	(11,500)	45.6	(50.3)
Lettuce	7	68.0	(16,800)	93.4	(103)
Onions	2	70.1	(17,300)	27.5	(30.3)
Potatoes	6	104	(25,600)	122	(134)
Tomatoes (fresh)	5	56.7	(14,000)	55.6	(61.3)
Tomatoes (process)	5	351	(86,600)	344	(379)
Total				996	1,100

[a] Does not include irrigation, the application of herbicides and insecticides, hand weeding, and cultivation, fumigation, pruning and brush removal where applicable.
[b] Crops with < 40.5 km² (10,000 acres) being harvested were not included in the emissions inventory.
[c] Emission factor assumed = 0.5 (Emission factor for soil preparation operations) = 196 kg/km² (1.75 lbs/acre).

TABLE B-6. 1978 EMISSIONS INVENTORY SUMMARY--HARVESTING
San Joaquin Valley
Vegetable Crops

Type of produce	Number of typical[a] operations/year	Total land area harvested[b] km^2	(acres)	Total annual emissions of inhalable[c] particulate matter-Mg/yr	(tons/yr)
Asparagus	1	68.9	(17,000)	25.5	(28.1)
Lima beans	2	60.3	(14,900)	44.6	(49.2)
Cantalopes	1	141	(34,800)	52.1	(57.4)
Carrots	2	46.6	(11,500)	68.8	(75.9)
Lettuce	1	68.0	(16,800)	50.2	(55.4)
Onions	3	70.1	(17,300)	155	(171)
Potatoes	2	104	(25,600)	153	(169)
Tomatoes (fresh)	2	56.7	(14,000)	41.9	(46.2)
Tomatoes (process)	2	351	(86,600)	259	(286)
Total				850	938

[a] Does not include hand harvesting, hand picking and knock harvesting as applicable.
[b] Crops with < 40.5 km^2 (10,000 acres) being harvested were not included in the emissions inventory.
[c] Emission factor used for calculations was 740 kg/km^2 (6.6 lbs/acre) for "digging" operations based on the results of field tests for the harvesting of sugar beets and 370 kg/km^2 (3.3 lbs/acre) for all other harvesting activities which assumes a 50% reduction in emissions from that tested.

TABLE B-7. 1978 EMISSIONS INVENTORY SUMMARY--SOIL PREPARATION
San Joaquin Valley
Fruit and Nut Crops

Type of produce	Number of typical[a] operations/year	Total land area harvested[b] km^2	(acres)	Total annual emissions of inhalable[c] particulate matter-Mg/yr	(tons/yr)
Almonds (new)	3	59.1	(14,600)	69.6	(76.7)
Almonds (existing)	2	729	(180,000)	571	(630)
Walnuts (existing)	2	343	(84,800[d])	269	(297)
Oranges (new)	3	37.3	(9,200)	43.8	(48.3)
Oranges (existing)	2	459	(113,300)	360	(397)
Deciduous tree fruits	2	581	(143,500[e])	455	(502)
Raisins (new)	7	47.4	(11,700)	130	(143)
Raisins (existing)	7	902	(222,700)	2,480	(2,730)
Table grapes	7	277	(68,300[e])	759	(837)
Wine grapes	7	759	(187,400[e])	2,090	(2,300)
Total				7,230	7,960

a Does not include flooding and draining of field as applicable.

b Crops with < 40.5 km^2 (10,000 acres) being harvested were not included in the emissions inventory.

c An average emission factor of 393 kg. particulate matter/km^2 harvested (3.5 lbs/acre) was used to calculate the annual emissions from all land preparation operations based on results of field tests.

d Does not include new orchards < 40.5 km^2 (10,000 acres) per footnote b. New orchard plantings estimated at 7.5% at the total land area harvested on an annual basis.

e Does not include new orchards < 40.5 km^2 (10,000 acres) per footnote b. New orchard plantings estimated at 5% of the total land area harvested on an annual basis.

TABLE B-8. 1978 EMISSIONS INVENTORY SUMMARY--CULTIVATION
San Joaquin Valley
Fruit and Nut Crops

Type of produce	Number of typical[a] operations/year	Total land area harvested[b] km² (acres)		Total annual emissions of inhalable[c] particulate matter-Mg/yr (tons/yr)	
Almonds (new)	10	59.1	(14,600)	116	(128)
Almonds (existing)	15.5[d]	729	(180,000)	2,210	(2,440)
Walnuts (existing)	15.5[d]	343	(84,800[e])	1,040	(1,150)
Oranges (new)	8	37.3	(9,200)	58.4	(64.4)
Oranges (new)	6	459	(113,300)	540	(595)
Deciduous tree fruits	8	581	(143,500[f])	916	(1,010)
Raisins (new)	8	47.4	(11,700)	74.3	(81.9)
Raisins (existing)	8	902	(222,700)	1,420	(1,560)
Table grapes	8	277	(68,300[f])	434	(478)
Wine grapes	8	759	(187,400)	1,190	(1,310)
Total				8,000	8,820

[a] Does not include irrigation, the application of herbicides and insecticides, hand weeding and cultivation, fumigation, pruning and brush removal where applicable.
[b] Crops with < 40.5 km² (10,000 acres) being harvested were not included in the emissions inventory.
[c] Emission factor assumed = 0.5 (Emission Factor for Soil Preparation Operations) = 197 kg/km² (1.75 lbs/acre).
[d] Assumes 50% of crops disced or tilled.
[e] Does not include new orchards < 40.5 km² (10,000 acres) per footnote b. New orchard planting estimated at 7.5% of the total land area harvested on an annual basis.
[f] Does not include new orchards < 40.5 km² (10,000 acres) per footnote b. New orchard planting estimated at 5% of the total land area harvested on an annual basis.

TABLE B-9. 1978 EMISSIONS INVENTORY SUMMARY--HARVESTING
San Joaquin Valley
Fruit and Nut Crops

Type of produce	Number of typical[a] operations/year	Total land area harvested[b] km²	(acres)	Total annual emissions of inhalable[c] particulate matter-Mg/yr	(tons/yr)
Almonds (new)	0	59.1	(14,600)	0	(0)
Almonds (existing)	0	729	(180,000[d])	0	(0)
Walnuts (existing)	0	343	(84,800)	0	(0)
Oranges (new)	0	37.3	(9,200)	0	(0)
Oranges (existing)	0	459	(113,400)	0	(0)
Deciduous tree fruits	2	581	(143,500[e])	430	(474)
Raisins (new)	1[f]	47.4	(11,700)	17.5	(19.3)
Raisins (existing)	1[f]	902	(222,700)	334	(368)
Table grapes	0	277	(68,300[e])	0	(0)
Wine grapes	1	759	(187,400[e])	280	(309)
Total				1,060	1,170

[a] Does not include hand harvesting, hand picking and knock harvesting as applicable.
[b] Crops with < 40.5 km² (10,000 acres) being harvested were not included in the emissions inventory.
[c] Emission factor used for calculations was 370 kg/km² (3.3 lbs/acre) which assumes a 50% reduction in emissions from those measured during the harvesting of sugar beets.
[d] Does not include new orchards < 40.5 km² (10,000 acres) per footnote b. New orchard plantings estimated at 7.5% of the total land area harvested on an annual basis.
[e] Does not include new orchards < 40.5 km² (10,000 acres) per footnote b. New orchard plantings estimated at 5% of the total land area harvested on an annual basis.
[f] Assumes raisins are machine harvested.

TABLE B-10. 1978 EMISSIONS INVENTORY SUMMARY--SOIL PREPARATION
Sacramento Valley
Field and Seed Crops

Type of produce	Number of typical[a] operations/year	Total land area harvested[b] km²	(acres)	Total annual emissions of inhalable[c] particulate matter-Mg/yr	(tons/yr)
Alfalfa	8	565	(140,000)	355	(391[d])
Irrigated pasture	8	729	(180,000)	457	(504[d])
Barley	7	631	(156,000)	1,730	(1,910)
Oats	7	105	(26,000)	289	(319)
Wheat	7	1,010	(248,900)	2,770	(3,050)
Dry beans	10	252	(62,200)	989	(1,090)
Sugar beets	10	277	(68,400)	1,090	(1,200)
Corn	6	581	(144,000)	1,370	(1,510)
Dry land pasture	2	5,910	(1,460,000)	463	(510)
Rice	13[e]	1,800	(445,000)	9,160	(10,100[f])
Safflower	7	315	(77,800)	864	(953)
Grain sorghum	6	229	(56,600)	539	(594)
Total				20,100	22,100

a Does not include flooding and draining of fields as applicable.
b Crops with < 40.5 km² (10,000 acres) being harvested were not included in the emissions inventory.
c An average emission factor of 393 kg. particulate matter/km² harvested (3.5 lbs/acre) was used to calculate the annual emissions from all soil preparation operations based on results of field tests.
d Emissions based on 20% of land area undergoing preparation on an annual basis.
e Does not include burning.
f Emissions based on 10% of the land area undergoing preparation on an annual basis.

TABLE B-11. 1978 EMISSIONS INVENTORY SUMMARY--CULTIVATION
Sacramento Valley
Field and Seed Crops

Type of produce	Number of typical[a] operations/year	Total land area harvested[b] km^2	(acres)	Total annual emissions of inhalable[c] particulate matter-Mg/yr	(tons/yr)
Alfalfa	1	565	(140,000)	111	(122)
Irrigated pasture	1	729	(180,000)	143	(158)
Barley	1	631	(156,000)	123	(136)
Oats	1	105	(26,000)	20.7	(22.8)
Wheat	1	1,010	(249,000)	198	(218)
Dry beans	3	252	(62,200)	148	(163)
Sugar beets	5	277	(68,400)	271	(299)
Corn	4	581	(144,000)	455	(502)
Dry land pasture	1	5,910	(1,460,000)	1,160	(1,280)
Rice	0	1,800	(445,000)	0	(0)
Safflower	1	315	(77,800)	61.8	(68.1)
Grain sorghum	4	229	(56,600)	180	(198)
Total				2,870	3,170

a Does not include irrigation, the application of herbicides and insecticides, hand weeding and cultivation, fumigation, pruning and brush removal where applicable.
b Crops with < 40.5 km^2 (10,000 acres) being harvested were not included in the emissions inventory.
c Emission factor assumed = 0.5 (Emission Factor for Soil Preparation Operations) = 197 kg/km^2 (1.75 lbs/acre).

TABLE B-12. 1978 EMISSIONS INVENTORY SUMMARY--HARVESTING
Sacramento Valley
Field and Seed Crops

Type of produce	Number of typical[a] operations/year	Total land area harvested[b] km^2 (acres)		Total annual emissions of inhalable[c] particulate matter-Mg/yr (tons/yr)	
Alfalfa	18	565	(140,000)	3,760	(4,140)
Irrigated pasture	18	729	(180,000)	4,850	(5,350)
Barley	4	473	(117,000[d])	721	(795[e])
Barley (post harvest)	6[f]	158	(39,000[g])	367	(405[h])
Oats	4	105	(26,000)	161	(177[e])
Wheat	4	756	(187,000[d])	1,150	(1,270[e])
Wheat (post harvest)	6[e]	252	(62,200[g])	586	(646[h])
Dry beans	3	252	(62,200)	559	(616)
Sugar beets	2	277	(68,400)	409	(451)
Corn	2	581	(144,000)	430	(474)
Dry land pasture	0	5,910	(1,460,000)	0	(0)
Rice	1	1,800	(445,000)	666	(734)
Safflower	1	315	(77,800)	116	(128)
Grain sorghum	2	229	(56,600)	170	(187)
Total				14,000	15,400

a Does not include hand harvesting, hand picking and knock harvesting as applicable.
b Crops with < 40.5 km^2 (10,000 acres) being harvested were not included in the emissions inventory.
c Emission factor used for calculations was 740 kg/km^2 (6.6 lbs/acre) for "digging" operations based on the results of field tests for the harvesting of sugar beets and 370 kg/km^2 (3.3 lbs/acre) for all other harvesting activities which assumes a 50% reduction in emissions from that tested.
d Assumes 100% of land area is double-cropped.
e Emission factor used = 0.5 (Emission factor for "nondigging" harvesting) + 0.5 (Emission factor for soil preparation).
f Does not include burning.
g 25% of total land area harvested which undergoes additional post harvesting soil preparation.
h Emission factor used = 0.25 (Emission factor for "nondigging" harvesting) + 0.75 (Emission factor for soil preparation).

TABLE B-13. 1978 EMISSIONS INVENTORY SUMMARY--SOIL PREPARATION
Sacramento Valley
Vegetable Crops

Type of produce	Number of typical[a] operations/year	Total land area harvested[b] km^2 (acres)	Total annual emissions of inhalable[c] particulate matter-Mg/yr (tons/yr)
Tomatoes (process)	11	483 (119,000)	2,090 (2,300)

a Does not include flooding and draining of fields as applicable.

b Crops with < 40.5 km^2 (10,000 acres) being harvested were not included in the emissions inventory.

c An average emission factor of 393 kg. particulate matter/km^2 harvested (3.5 lbs/acre) was used to calculate the annual emissions from all land preparation operations based on results of field tests.

TABLE B-14. 1978 EMISSIONS INVENTORY SUMMARY--CULTIVATION
Sacramento Valley
Vegetable Crops

Type of produce	Number of typical[a] operations/year	Total land area harvested[b] km^2 (acres)		Total annual emissions of inhalable[c] particulate matter-Mg/yr (tons/yr)	
Tomatoes (process)	5	483	(119,000)	474	(522)

[a] Does not include irrigation, the application of herbicides and insecticides, hand weeding and cultivation, fumigation, pruning and brush removal where applicable.
[b] Crops with < 40.5 km^2 (10,000 acres) being harvested were not included in the emissions inventory.
[c] Emission factor assumed = 0.5 (Emission factor for soil preparation operations) = 197 kg/km^2 (1.75 lbs/acre).

TABLE B-15. 1978 EMISSIONS INVENTORY SUMMARY--HARVESTING
Sacramento Valley
Vegetable Crops

Type of produce	Number of typical[a] operations/year	Total land area harvested[b] km^2 (acres)	Total annual emissions of inhalable[c] particulate matter-Mg/yr (tons/yr)
Tomatoes (process)	2	483 (119,000)	357 (393)

[a] Does not include hand harvesting, hand picking and knock harvesting as applicable.
[b] Crops with < 40.5 km^2 (10,000 acres) being harvested were not included in the emissions inventory.
[c] Emission factor used for calculations was 370 kg/km^2 (3.3 lbs/acre) which assumes a 50% reduction in emissions from those measured during the harvesting of sugar beets.

TABLE B-16. 1978 EMISSIONS INVENTORY SUMMARY--SOIL PREPARATION
Sacramento Valley
Fruit and Nut Crops

Type of produce	Number of typical[a] operations/year	Total land area harvested[b] km^2 (acres)		Total annual emissions of inhalable[c] particulate matter-Mg/yr (tons/yr)	
Almonds (existing)	2	293	(72,300[d])	230	(253)
Walnuts (existing)	2	211	(52,100[d])	165	(182)
Deciduous tree fruits	2	379	(93,600[e])	298	(328)
Total				693	(763)

a Does not include flooding and draining of fields as applicable.
b Crops with < 40.5 km^2 (10,000 acres) being harvested were not included in the emissions inventory.
c An average emission factor of 393 kg. particulate matter/km^2 harvested (3.5 lbs/acre) was used to calculate the annual emissions from all soil preparation operations based on results of field tests.
d Does not include new orchards < 40.5 km^2 (10,000 acres) per footnote b. New orchards estimated to be 7.5% of the total land area harvested.
e Same as footnote d. New orchards estimated to be 5% of the total land area harvested.

TABLE B-17. 1978 EMISSIONS INVENTORY SUMMARY--CULTIVATION
Sacramento Valley
Fruit and Nut Crops

Type of produce	Number of typical[a] operations/year	Total land area harvested[b] km^2	(acres)	Total annual emissions of inhalable[c] particulate matter-Mg/yr	(tons/yr)
Almonds (existing)	15.5[d]	293	(72,300[e])	890	(981)
Walnuts (existing)	15.5[d]	211	(52,100[e])	641	(707)
Deciduous tree fruits	8	379	(93,600[f])	594	(655)
Total				2,130	(2,340)

a Does not include irrigation, the application of herbicides and insecticides, hand weeding and cultivation, fumigation, pruning and brush removal where applicable.
b Crops with < 40.5 km^2 (10,000 acres) being harvested were not included in the emissions inventory.
c Emission factor assumed = 0.5 (Emission factor for soil preparation operations) = 196 kg/km^2 (1.75 lbs/acre).
d Assumes 50% of crops disced or tilled.
e Does not include new orchards < 40.5 km^2 (10,000 acres) per footnote b. New orchards estimated to be 7.5% of the total land area harvested.
f Same as footnote e. New orchards estimated to be 5% of the total land area harvested.

TABLE B-18. 1978 EMISSIONS INVENTORY SUMMARY--HARVESTING
Sacramento Valley
Fruit and Nut Crops

Type of produce	Number of typical[a] operations/year	Total land area harvested[b] km^2	(acres)	Total annual emissions of inhalable[c] particulate matter-Mg/yr	(tons/yr)
Almonds (existing)	0	293	(72,300[d])	0	(0)
Walnuts (existing)	0	211	(52,100[d])	0	(0)
Deciduous tree fruits	2	379	(93,600[e])	280	(309)
Total				280	(309)

a Does not include hand harvesting, hand picking and knock harvesting as applicable.
b Crops with < 40.5 km^2 (10,000 acres) being harvested were not included in the emissions inventory.
c Emission factor used for calculations was 370 kg/km^2 (3.3 lbs/acre) which assumes a 50% reduction in emissions from those measured during the harvesting of sugar beets.
d Does not include new orchards < 40.5 km^2 (10,000 acres) per footnote b. New orchards estimated to be 7.5% of of the total land area harvested.
e Same as footnote d. New orchards estimated to be 5% of the total land area harvested.

TABLE B-19. 1978 EMISSIONS INVENTORY SUMMARY--SOIL PREPARATION
Imperial Valley
Field and Seed Crops

Type of produce	Number of typical[a] operations/year	Total land area harvested[b] km² (acres)		Total annual emissions of inhalable[c] particulate matter-Mg/yr (tons/yr)	
Alfalfa (hay)	10[d]	73.3	(18,100)	288	(317)
Alfalfa (dehydrated)	10[d]	64.8	(16,000)	254	(280)
Alfalfa (pasture)	10[d]	620	(153,000)	2,430	(2,680)
Wheat	6[e]	567	(140,000)	1,330	(1,470)
Cotton	6	271	(67,000)	639	(704)
Pasture (other than rye)	6	217	(53,500)	510	(562)
Grain sorghum	6	60.8	(15,000)	143	(158)
Sudan grass	6	47.8	(11,800)	113	(124)
Sugar beets	10[d]	139	(34,300)	544	(600)
Total				6,250	(6,900)

[a] Does not include flooding and draining of fields as applicable.
[b] Crops with < 40.5 km² (10,000 acres) being harvested were not included in the emissions inventory.
[c] An average emission factor of 393 kg. particulate matter/km² harvested (3.5 lbs/acre) was used to calculate the annual emissions from all land preparation operations based on results of field tests.
[d] Does not include the flooding of fields during land preparation.
[e] Does not include burning.

TABLE B-20. 1978 EMISSIONS INVENTORY SUMMARY--CULTIVATION
Imperial Valley
Field and Seed Crops

Type of produce	Number of typical[a] operations/year	Total land area harvested[b] km^2 (acres)		Total annual emissions of inhalable[c] particulate matter-Mg/yr (tons/yr)	
Alfalfa (hay)	2	73.3	(18,100)	28.8	(31.7)
Alfalfa (dehydrated)	2	64.8	(16,000)	25.4	(28.0)
Alfalfa (pasture)	2	620	(153,000)	243	(268)
Wheat	2	567	(140,000)	222	(245)
Cotton	8	271	(67,000)	425	(469)
Pasture (other than rye)	2	217	(53,500)	84.9	(93.6)
Grain sorghum	2	60.8	(15,000)	23.9	(26.3)
Sudan grass	2	47.8	(11,800)	18.8	(20.7)
Sugar beets	7	139	(34,300)	191	(210)
Total				1,260	(1,390)

[a] Does not include irrigation, the application of herbicides and insecticides, hand weeding and cultivation, fumigation, pruning and brush removal where applicable.
[b] Crops with < 40.5 km^2 (10,000 acres) being harvested were not included in the emissions inventory.
[c] Emission factor assumed = 0.5 (Emission factor for soil preparation operations) = 196 kg/km^2 (1.75 lbs/acre).

TABLE B-21. 1978 EMISSIONS INVENTORY SUMMARY--HARVESTING
Imperial Valley
Field and Seed Crops

Type of produce	Number of typical[a] operations/year	Total land area harvested[b] km² (acres)		Total annual emissions of inhalable[c] particulate matter-Mg/yr (tons/yr)	
Alfalfa (hay)	2	73.3	(18,100)	54.1	(59.7)
Alfalfa (dehydrated)	9	64.8	(16,000)	216	(238)
Alfalfa (pasture)	9	620	(153,000)	2,060	(2,270)
Wheat	2	567	(140,000)	419	(462)
Cotton	2	271	(67,000)	200	(221)
Pasture (other than rye)	5	217	(53,500)	400	(441)
Grain sorghum	2	60.8	(15,000)	44.9	49.5
Sudan grass	5	47.8	(11,800)	88.3	(97.4)
Sugar beets	2	139	(34,300)	205	(266)
Total				3,690	(4,070)

[a] Does not include hand harvesting, hand picking and knock harvesting as applicable.
[b] Crops with < 40.5 km^2 (10,000 acres) being harvested were not included in the emissions inventory.
[c] Emission factor used for calculations was 740 kg/km^2 (6.6 lbs/acre) for "digging" operations based on the results of field tests for the harvesting of sugar beets and 370 kg/km^2 (3.3 lbs/acre) for all other harvesting activities which assumes 50% less emissions than that tested.

TABLE B-22. 1978 EMISSIONS INVENTORY SUMMARY--SOIL PREPARATION
Imperial Valley
Vegetable Crops

Type of produce	Number of typical[a] operations/year	Total land area harvested[b] km^2 (acres)		Total annual emissions of inhalable[c] particulate matter-Mg/yr (tons/yr)	
Cantaloupes	10	50.2	(12,400)	197	(217)
Lettuce	10	166	(40,900)	649	(716)
Total				846	(933)

[a] Does not include flooding and draining of fields as applicable.
[b] Crops with < 40.5 km^2 (10,000 acres) being harvested were not included in the emissions inventory.
[c] An average emission factor of 393 kg. particulate matter/km^2 harvested (3.5 lbs/acre) was used to calculate the annual emissions from all soil preparation operations based on results of field tests.

TABLE B-23. 1978 EMISSIONS INVENTORY SUMMARY--CULTIVATION
Imperial Valley
Vegetable Crops

Type of produce	Number of typical[a] operations/year	Total land area harvested[b] km^2	(acres)	Total annual emissions of inhalable[c] particulate matter-Mg/yr	(tons/yr)
Cantaloupes	10	50.2	(12,400)	98.9	(109)
Lettuce	10	166	(40,900)	325	(358)
Total				424	(467)

[a] Does not include irrigation, the application of herbicides and insecticides, hand weeding and cultivation, fumigation, pruning and brush removal where applicable.
[b] Crops with < 40.5 km^2 (10,000 acres) being harvested were not included in the emissions inventory.
[c] Emission factor assumed = 0.5 (Emission Factor for soil preparation operations) = 196 kg/km^2 (1.75 lbs/acres).

TABLE B-24. 1978 EMISSIONS INVENTORY SUMMARY--HARVESTING
Imperial Valley
Vegetable Crops

Type of produce	Number of typical[a] operations/year	Total land area harvested[b] km²	(acres)	Total annual emissions of inhalable[c] particulate matter-Mg/yr	(tons/yr)
Cantaloupes	2	50.2	(12,400)	37.1	(40.9)
Lettuce	2	166	(40,900)	245	(270)
Total				282	(311)

[a] Does not include hand harvesting, hand picking and knock harvesting as applicable.
[b] Crops with < 40.5 km² (10,000 acres) being harvested were not included in the emissions inventory.
[c] Emission factor used for calculations was 740 kg/km² (6.6 lbs/acre) for digging operations based on the results of field tests for the harvesting of sugar beets and 370 kg/km² (3.3 lbs/acre) for all other harvesting activities which assumes a 50% reduction in emissions from that tested.

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15. Supplementary Notes

16. Abstract

For the San Joaquin Valley, the Sacramento Valley, and the Imperial Valley, Midwest Research Institute quantified the impact of agricultural operations on fugitive dust emissions. Thirteen tests were performed in the spring of 1980 to quantify emission factors from discing, land planning, and vehicles traveling on unpaved farm roads. Six tests were performed in the fall of 1980 to quantify emission factors from sugar beet harvesting.

Since fugitive emissions from a given operation can vary depending on physical properties of the soil or equipment, and depending on climate, predictive emission factors were developed to relate total inhalable and fine particulate emission factors to important independent variables. Significant relationships were determined between the emission factor and the soil silt content.

An inhalable particulate emission inventory performed for the three valleys showed that in 1978, agricultural operations produced 148,000 Mg/year of fugitive dust less than 15 μm in aerodynamic diameter. Field crops yielded the most significant emissions while soil preparation was the most significant category of operations.

Two categories of control techniques were suggested: (a) those that included control equipment to be added to the farm implement and (b) those that included operational modifications. Control efficiences and potential emission reductions were estimated for these control techniques.

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