Energy and Resource Consultants, Inc.

EXECUTIVE SUMMARY

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Effects of Air Pollution on
Agricultural Crops in the
San Joaquin Valley

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ECONOMIC ASSESSMENT OF THE EFFECTS OF AIR POLLUTION ON AGRICULTURAL CROPS IN THE SAN JOAQUIN VALLEY

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EXECUTIVE SUMMARY

OBJECTIVES

The objectives of this study were to:

1. Estimate economic measures of the value of air pollution induced agricultural losses in the San Joaquin Valley (SJV) of California. The analysis focuses upon ozone (O_3) and sulfur dioxide (SO_2) as these are the only pollutants that occur at sufficiently high levels in the SJV to potentially cause detectable yield losses. Economic losses are estimated separately by subregion within the SJV, separately for producers and consumers and separately for selected major crops. The relative importance of O_3 and SO_2 is assessed.

2. Develop, apply and evaluate statistical methods for estimating physical yield losses from air pollution, and refine methods for estimating economic measures of these yield losses. The development of these methods may lead to improved accuracy and efficiency of this and future assessments. This effort includes testing the usefulness of the field data regression approach as a method to estimate the relationship between air pollutants and actual yields experienced in the field. The study also refines and applies the California Agricultural Resources (CAR) model to estimate economic damages resulting from physical reductions in yield.

AIR QUALITY SCENARIOS

The impacts of air pollution on agricultural yields in the SJV were estimated by comparing estimated yields under three alternative scenarios to the yields under conditions that existed in 1978. (That year was chosen because air pollution in the San Joaquin Valley was exceptionally high, and the California Agricultural Resources computer model, which was used extensively in the economic analysis, is calibrated to that year.) The alternative scenarios focus mainly on ozone rather than sulfur dioxide, because ozone accounts for over 98 percent of the crop damage in the San Joaquin Valley due to air pollution. The scenarios were assumed to affect air pollution in the San Joaquin Valley only, and air pollution levels throughout the rest of the state were assumed to remain at 1978 levels. The 1978 conditions and the three alternative scenarios are described below.

- **Baseline** - 1978 ambient ozone and sulfur dioxide air pollution conditions in the San Joaquin Valley. Ozone levels exceeded the California ambient air quality standard of 10 pphm (parts per hundred million) ozone in over 700 hours during the growing season, roughly meeting a standard of 13-16 pphm, depending on location. Sulfur dioxide levels rarely exceeded 5 pphm, the state one hour standard, except in Kern County where levels as high as 34 pphm were recorded in the winter.

- **Scenario 1** - A 50 percent reduction in the number of hours when ozone levels are greater than or equal to 10 pphm. This approximates typical ambient ozone concentrations in the San Joaquin Valley from 1970 to 1981, and is roughly consistent with a standard of 12 pphm. Sulfur dioxide levels must not exceed current levels or 3 pphm, whichever is lower.

- **Scenario 2** - Meeting California's current hourly ozone standard of 10 pphm. Sulfur dioxide levels must not exceed current levels or 2 pphm, whichever is lower.

- **Scenario 3** - Meeting an hourly ozone standard of 8 pphm. Limited ozone damage to crops is expected at levels below 8 pphm, so comparing this scenario to the baseline roughly estimates maximum crop damage for the San Joaquin Valley. Sulfur dioxide levels must not exceed current levels or 2 pphm, whichever is lower.

SUMMARY OF APPROACH

Yield Loss Estimates

Crop yield losses were estimated using the field data regression approach, which regresses crop yields against air pollution levels and other explanatory variables and using results from previously conducted chamber studies. The field data regression approach was selected for detailed examination because if it can be used successfully, it may, in future analyses, be considerably faster and less expensive than conducting chamber studies to estimate crop yield losses from air pollution. Previous studies have estimated yield loss functions using the field data regression approach with mixed success. This effort expands on these studies by examining in more detail when the field data regression approach works best, and by considering alternative specifications of the yield function and pollution variables, which influence each other.

Thirty-three crops grown in the San Joaquin Valley are considered in this report, but 10 primary study crops, which comprise over 75 percent of the total economic value of production, were selected for detailed field data regression analysis. These crops were alfalfa, almonds, cotton, dry beans, grapes, lettuce, oranges, peaches, potatoes, and tomatoes. Yield losses for those crops where the field data regression approach appeared not to work, or was not applied, were determined from the best available chamber studies. In almost all cases, these chamber studies were done by the U.S. Environmental Protection Agency sponsored National Crop Loss Assessment Network (NCLAN). For several crops, the evidence was either inconclusive or insufficient to suggest potential yield differences under the alternative scenarios. These crops were assigned zero yield loss from air pollution when considered in the economic analysis.

Economic Loss Estimates

After yield-loss data were obtained from the field data regressions and chamber study results, the California Agricultural Resources (CAR) model was used to estimate the economic effects of changes in air pollution on per-acre crop yields. The model considers how changes in farmers' output affect quantities and prices of individual crops sold in the market. The model also considers how farmers change the amount and the mix of acreage of each crop planted in response to changes in yield and price conditions under each scenario. From this information, changes in the well being of consumers and producers were determined. (The CAR model is a Giannini Foundation model maintained at the University of California at Davis and Berkeley.)

SUMMARY OF FINDINGS

Yield Analysis Results

The field data regressions show significant reductions in crop yields due to ozone pollution in the San Joaquin Valley, especially for dry beans, cotton, potatoes, and grapes. The sensitivity of grapes to increased ozone was a finding which only one previous study had quantitatively observed. The results for other crops, however, suggest that the field data regression approach reveals defensible ozone-induced loss estimates only for those crops that are highly sensitive to damage, or when ozone levels are high. Measurement errors inherent in the approach overwhelm the ability to measure ozone impacts for crops with ozone sensitivity classified as intermediate or tolerant. It is important to note that when statistically significant results were reported with field data regressions, the results were generally consistent with chamber study evidence. This indicates it is not inappropriate to use chamber study yield-loss estimates to estimate crop losses in the field. Furthermore, given their respective limitations, it appears likely that the chamber study approach provides more reliable estimates than the field data regression approach.

Substantial yield improvements are observed for Scenarios 1 and 2 compared to the baseline. Minimal yield gains were seen moving from Scenario 2 to Scenario 3. This implies that most crops are able to withstand the Scenario 3 pollution levels with minimal adverse effects.

The estimated yield losses for the alternative scenarios are shown in Table ES-1.

Economic Analysis Results

The results of the CAR model highlight the importance of using an economic model that accounts for changes in farmers' behavior and agricultural markets. To determine effects due to changes in per-acre yields, previous studies have used a simple damage-

Table ES-1

Improvements in Yields Per Acre Under Alternative Air Quality Conditions In the San Joaquin Valley, 1978

Crop	Percent Improvement in Yields*		
	Scenario 1 (12 pphm O_3)	Scenario 2 (10 pphm O_3)	Scenario 3 (8 pphm O_3)
I. Non-Zero Changes**			
Alfalfa	4.0 - 5.3	8.0 - 11.1	8.0 - 11.1
Barley***	3.6 - 4.0	7.4 - 8.4	8.7 - 10.6
Carrots	1.8 - 3.9	4.0 - 4.7	4.9 - 6.7
Corn	1.5 - 2.8	4.3 - 6.0	4.9 - 7.6
Cotton	4.8 - 5.5	17.0 - 20.1	19.3 - 22.9
Dry Beans	7.3 - 8.5	14.8 - 17.0	17.5 - 21.4
Grain Hay	3.6 - 4.0	7.4 - 8.4	8.7 - 10.6
Grain Sorghum	.8 - .9	1.7 - 2.2	2.1 - 2.9
Grapes	4.4 - 6.4	8.4 - 12.5	8.7 - 12.7
Lettuce	4.8 - 5.3	7.2 - 9.7	10.9 - 13.3
Irrigated Pasture	3.6 - 4.0	7.4 - 8.4	8.7 - 10.6
Potatoes	6.0 - 12.2	11.1 - 24.5	11.1 - 32.4
Sunflower	1.8 - 3.9	4.0 - 5.4	4.9 - 6.7
Silage	1.5 - 2.8	4.3 - 6.0	4.9 - 7.6
Tomatoes	1.8 - 3.9	4.0 - 5.4	4.9 - 6.7
Wheat	3.6 - 4.0	7.4 - 8.4	8.7 - 10.6

II. Crops with zero yield improvements under all scenarios:

Almonds, Lemons, Nectarines, Peaches, Rice, Sugar Beets

III. Crops with zero yield improvements under all scenarios and with acreage held constant:

Apples, Asparagus, Avocados, Cantaloupe, Cauliflower, Dry Onions, Oranges, Pears, Plums, Prunes, Walnuts

* Improvements in yields comparing scenarios to actual 1978 ozone levels. The scenarios are defined as approximate hourly standards.

** Yield losses vary depending upon location in the Valley. All damages are from ozone except for potatoes where the highest figure also includes SO_2 damages in Kern County. For more detail see Section 6.4, Table 6.7.

*** The most recent NCLAN results, released while this report was in final draft, suggest barley sensitivities to air pollution may be much smaller than used in this report, and therefore the economic impacts may be smaller.

function approach, which applies per-acre yield losses to the current number of acres times the current market price of the crop. When the results of the CAR model are compared with those from the simple damage-function approach, one finds that the damage-function approach would have overstated economic damages for some crops by as much as 840 percent.

The CAR model predicts several changes in the agricultural markets under the alternative scenarios. Reductions in air pollution under each scenario increase crop yields per-acre, and this results in lower prices. This price reduction, in turn, benefits all consumers of the crop, not just those in the San Joaquin Valley, because they can now purchase the same amount of the crop for less money, or they can increase the amount they buy.

Farmers in the San Joaquin Valley experience substantial economic benefits because they can produce more crops on less land. Even though market prices fall with increased yields, the percentage yield increase more than offsets the percentage price drop. Farmers outside the San Joaquin Valley, however, are hurt by the changes, as lower prices result in lower receipts not offset by increased yields.

The benefits to the producers and the consumers of 11 crops from reducing air pollution to levels in Scenario 3 are summarized in Table ES-2. The first column lists the benefits to producers in the San Joaquin Valley, and the second column lists the benefits to producers throughout the state, including those in the San Joaquin Valley. The difference in the columns reflects two influences: production-per-acre increases in the San Joaquin Valley, causing production to be shifted into the Valley from other parts of the state; and increased production in the San Joaquin Valley reduces prices throughout the state, even for those producers whose production has not increased. The third column represents the benefits to all consumers of each crop.

Table ES-3 shows the total benefits resulting from the decrease in air pollution from the 1978 baseline condition to conditions under each alternative scenario.

The physical and economic estimates are subject to numerous inaccuracies and biases. However, conservative procedures and assumptions were generally used throughout the analysis so the reported benefit estimates are felt to be understatements of the true benefits of improving air quality.

Table ES-2

Benefits to Producers and Consumers from Air Pollution Improvements in the San Joaquin Valley, 1978 / Selected Crops, Scenario 3

($ millions)

Crop	Producers In the San Joaquin Valley	Producers Statewide (including the SJV)	All Consumers
Cotton	$58.2	$57.8	$ 4.3
Grapes	9.2	8.5	11.0
Alfalfa	6.3	6.1	4.3
Pasture	4.2	2.3	3.2
Tomatoes	2.1	1.3	1.3
Dry Beans	1.7	0.9	1.6
Barley*	3.9	3.8	0.7
Lettuce	1.0	0.1	0.9
Potatoes	1.1	0.8	0.7
Wheat	1.8	1.8	0.1
Corn	3.1	2.4	0.1

* The most recent NCLAN results, released while this report was in final draft, suggest barley sensitivities to air pollution may be much smaller than used in this report, and therefore the economic impacts may be smaller.

Table ES-3

Benefits of Air Pollution Improvements in the San Joaquin Valley 1978 — All Crops

($ millions)

	Scenario 1 (12 pphm O_3)	Scenario 2 (10 pphm O_3)	Scenario 3 (8 pphm O_3)
I. Statewide			
Total Consumers & Producers	$42.6	$105.9	$117.4
To Consumers	13.4	27.7	30.3
To Producers	29.2	78.2	87.1

SUGGESTED DIRECTIONS

This analysis suggests that air pollution has caused substantial economic losses to both producers and consumers of agricultural goods from the San Joaquin Valley. Additional studies could, however, enhance the current study and reveal better estimates of crop damages for more crops. Specifically, undertaking damage-estimate studies for economically important crops such as citrus and almonds, for which limited evidence is currently available, may lead to better understanding of the economic effects of air pollution. The results of this effort suggest use of the chamber study approach for crops with air pollution sensitivity classified as intermediate or tolerant is preferred to the field data regression approach.

The accuracy of the field data regression analysis of air pollution induced yield losses may be increased by obtaining improved estimates of pest losses and by estimating damages across locations with higher pollution levels. Detailed analysis of secondary impacts of air pollution on agriculture in the San Joaquin Valley on industries such as packaging and transportation, which would give a more precise analysis of the total effects of pollution, and an analysis of the statewide effects of reducing air pollution would give a more complete picture to statewide policymakers.