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Economic Assessment of Acid Deposition and Ozone Damage on the San Joaquin Valley Agriculture

CALIFORNIA ENVIRONMENTAL PROTECTION

AIR RESOURCES
Research

ECONOMIC ASSESSMENT OF ACID DEPOSITION AND OZONE DAMAGE ON THE SAN JOAQUIN VALLEY AGRICULTURE

Final Report
Contract No. A132-151

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INTRODUCTION

This report is in response to the Health and Safety Code, Section 39912 which requires an assessment of the economic impacts on the San Joaquin valley agricultural industry of ozone and acid deposition damage. Measuring the linkage between farmer profits and consumer prices and ozone in a formal manner requires several different types of research that are linked in a consistent manner. In this study, the dose response work was performed by Randall Mutters and Michael Guzy at the Statewide Air Pollution Research Center at the University of California, Riverside. The economic analysis which builds on the yield response analysis was performed by Richard Howitt at the Department of Agricultural Economics, University of California, Davis and is the main topic of this report.

The analysis of ozone impacts on agricultural profits has to account for the shifts and adjustments in prices and production practices that accompany changes in the effective yield and profitability of certain crops in different areas. Currently, ozone response relationships have been established for thirteen of the forty crops specified in the California Agriculture and Resources Model (C A R M). In addition, for some regions, a reduction of ozone to 0.04 ppm or even 0.025 ppm would not greatly increase the yield. Given the profit incentive for farmers, it follows that ozone reduction would cause some changes in the crop proportions and optimal locations for growing crops. When faced with changes in the relative profitability of crops, farmers will also change their levels of productive inputs used to grow the crops. The resulting changes in quantities of crops offered for sale will change the price that consumers have to pay. The demand functions which model this response determine what proportion of the benefits from ozone reduction get passed on to the consumer.

YIELD RESPONSE

Before any changes in economic impact can be calculated, the changes in yield caused by the new ozone levels must be calculated by crop and region for a particular growing season. The effects of acid deposition have not been explicitly modeled in this study because currently there are no response relationships that show a direct yield reduction from acid deposition in the San Joaquin valley. Appendix A contains a summary of the current level of knowledge on acid deposition effects by Dr. Mutters. The conclusions are part of a more detailed study under progress.

The impact of two levels of ozone standards on crop yields was calculated on a county basis using 1990 as a base year. Nineteen-ninety was also used as the base year to calibrate the economic model. Ambient ozone levels for seven-hour periods in the 1990 growing season was calculated using a more comprehensive set of air monitoring stations than in the past. The two ozone standards specified for the study were 0.04 ppm and 0.025 ppm seven hour means. The differences between the actual 1990 mean values and the standards were then used in a dose response function to calculate the yield increases at particular locations. To obtain a dose response result that was representative of the current level of knowledge, several different models were used for most crops and the mean value for these models was incorporated in the economic model. The number of dose response models used for a crop ranged from one to eight. The county level yield losses were then aggregated to nine agronomic production regions used in the CARM model, and converted to a percentage yield increase basis to measure the economic effect of meeting the standard. This percentage yield change enables the regional crop production function calibrated by the economic model to be shifted up under the ozone reduction scenario. The county level yields for 1990, and the 0.04 ppm and 0.025 ppm ozone standards are shown in appendix C. The increases in yield by crop and production region under a reduction of ozone to 0.04 ppm and 0.025 ppm is shown in Table 1. The yield reductions in 1990 compared with a base standard of 0.025 ppm are much greater in the heavily affected areas than shown in previous studies while the losses for the 0.04 ppm standard are lower than some previous studies. For example, Winer, Olszyka, and Howitt (1990) show that compared with a 0.09 ppm hourly standard, the valleywide loss for cotton yield is 15.7 percent in 1986 and wine grapes 22.5 percent. The losses calculated for this study are concentrated in more precise regions. This higher level of loss at 0.025 ppm is explained mostly by the more stringent "clean air" standard of 0.025 ppm and also the more precise regions used in this study which pick up the pockets of high ozone exposure. Economic impacts can be expected to be correspondingly higher. The yield increase caused by the reduction in ozone levels is expressed as a percentage change in the 1990 regional yields. This increase in productivity is fed into the economic model by increasing the regional production function for 1990 by the appropriate percentage.

CALIFORNIA AGRICULTURAL RESOURCES MODEL

The California Agricultural Resources Model (CARM) provides a convenient method of analyzing crop production technology, commodity demand and resource supply changes. CARM was developed to analyze the effects of crop price changes, and state resource and environmental policies on shifts in the location of crop production, commodity prices, and related resource use. As California production increases due to lower ozone levels, crop prices can be expected to fall. But the responsiveness (or flexibility) of California prices to these changes in production varies widely by crop. Prices of those specialty crops grown mostly or entirely in California are very responsive to changes in California production. However, feed and fodder crops are quite insensitive in price, because California production is only a small proportion of national output.

Unless potential adjustments by farmers and consumers to the lower yields and higher costs are accounted for, economic impacts would be overestimated. Economic theory and, more importantly, common sense tell us that farmers and consumers will change their respective production and consumption patterns to make themselves as well off as they can under new conditions. Thus, the CARM model adjusts the economic impact of ozone changes by allowing for the adjustments that producers and consumers would make as costs and prices change. Another avenue of adjustment in this version of CARM is that farmers can also shift the input proportions used in a region to offset the effects of crop yield change.

Changes in crop yields per acre will shift the marginal value product (MVP) for each crop due to *both* productivity and price effects.[1] While a decrease in ozone increases both the average and marginal *physical* products of a crop (given the CES production function which underlies the model), the increase in total product decreases the price which tends to decrease MVP. If the crop is not price responsive, i.e., has a relatively low price elasticity , say 0.154 for cotton, the negative price effect will reduce

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[1] MVP is the value (using market prices) of the increase in output from an additional unit of input.

the positive productivity effect and, in the absence of crop acreage expansion, the MVP will decrease. In this situation, a yield increase over all the major producing regions could theoretically decrease producers' returns to land and management, but decrease prices to consumers. In this way, the effects of ozone increases on growers could be, at least partially, offset.

In addition to price effects, growers will substitute increased acreage of more profitable crops to offset ozone-induced yield decreases for all crops. This substitution response could lead to a reduction in the acreage of lower valued crops. Thus, the reduction in total production of low-value crops may be proportionately greater than their yield reductions would suggest.

On a more technical level the CARM model can be described as a calibrated nonlinear optimization model with 40 crops in 9 regions which are aggregations of counties (Figure 1). Crops in the model account for about 95 percent of the State's total crop acreage and value. CARM is a static model representing a one year production period. The effect of crop changes on Statewide demand prices is modeled by estimating demand functions from past price quantity relationships for California crops. The demands are estimated from data over the past thirty years, and take into account shifts in population and income. The proportional change in quantity demanded due to price changes is summarized in the price elasticity parameter. The price elasticities used in this study are shown in Table 2. Five of the ozone affected crops, alfalfa, cotton, sugar beets, tomatoes, and wheat have very low estimated elasticities of demand below 0.3. These inelastic demands mean that as the quantity of Californian production changes, the price is only slightly reduced. Some recent estimates suggest that the Californian demand elasticities may be substantially higher for these crops. Higher elasticities would reduce the dollar impact of yield increases for these crops. The estimated elasticities are then used to calibrate the base year demand function parameters, assuming that markets for California crops cleared in the base year. By substituting the demand function instead of a fixed product price, the price response of changing production quantities is built into the model objective function.

One of the characteristics of California crop production is that the quality and transport cost of produce varies substantially by region. This means that there is considerable regional price variation despite a common market for produce. The regional variation is modeled by calculating a weighted statewide price and then representing the regional deviation as a constant regional marketing cost per unit produced. Thus the model retains the regional advantages but can also reflect statewide shifts in the demand for crops.

Regional production cost data were derived from county level budgets available through the University of California Cooperative Extension Service (1980-85), primary survey data collected from a California Department of Water Resources survey performed in 1988, and indexed to 1990 price levels. Past versions of the model have been used to project the effects of developing additional water supplies, declining energy supplies, on the amount and location of agricultural production. Regional acreage and yields are collected from the County Agricultural Commissioner's reports of crop acreage and yields.

The CARM model has been under development for the past six years. It is driven by the assumption that farmers attempt to maximize their profits, subject to the resource constraints of land, water, capital, other resources such as labor, contracts and government programs. The reaction of the growers is modeled by incorporating the costs of production and water for a region, along with the yields that a farmer can expect from past data.

Crop production is largely driven by profit maximizing decisions by farmers. To model how farmers will react to changing ozone levels, we have to model the ability of the agricultural industry to adapt to the new regional yields and comparative advantage.

Long run adjustments to changes in ozone by farmers are modeled by considering four types of adjustment. Changes in crop price. Changes in the proportion of water to other inputs for a particular region and crop. Changes in the capital investment per unit of water. Changes in the regional cropping pattern. Modeling agricultural production as an economic process involves specifying costs, revenues, the production processes and resource constraints. Two general methods are used. For the more aggregate models the normal approach is to use econometric estimation of the production and behavioral relations based on observations of past responses to changed conditions. A practical problem in using this approach to the model for this study is that there simply is not enough regional data on the costs and yields of California crops to estimate a reliable production system. The second approach used for modeling agricultural production is to construct mathematical programming models of the production that optimize a specified profit function within a set of constraints that represent the feasible set of production alternatives and resource limits. These models have an advantage for the current situation in that they contain a largely normative description of the production process and thus require much less data than an econometric approach. However a major problem with the usual type of programming specification is that linear constraints are used to define the set of possible production alternatives, which usually prevents input substitution from occurring in a systematic way.

The modeling approach used in this study is a recently developed variant of the programming approach. It differs in four ways, first continuous production functions are explicitly specified in the model. Second, the production functions are flexible in multiple inputs and outputs. Third behavioral parameters in the form of elasticities of substitution are obtained from prior econometric studies and are used to calibrate the production functions. Fourth, the remaining production function coefficients are calibrated on a regional and crop basis from observed behavior. The calibration approach has close parallels with the methods used to construct Computable General Equilibrium (CGE) models. However, the CGE models are unable to calibrate inputs which are subject to inequality constraints, and rarely incorporate multiple production processes from the same restricted input.

The production process used in the model is a "nested" Constant Elasticity of Substitution (CES) production function. The production function is constructed with two levels of nests. The first level being between the allocatable input group comprised of land, ground water, and surface water, while the second nest of purchased inputs has capital costs and other variable expenditures. Figure 2 shows the arrangements of the nests and the elasticities of substitution between them.

The two input CES production function is specified as follows.

$$y = A\left[b_1 x_1^{-\eta} + b_2 x_2^{-\eta}\right]^{-1\backslash\eta}$$

where $\eta = \frac{s-1}{s}$ and s = elasticity of substitution.

For the nested case the two upper level input groups are specified as a CES production function with an elasticity of substitution of 0.5 between the allocatable and variable input groups. Within the subgroups, the elasticity of substitution between water and land, given fixed capital and other inputs, is distinctly low at 0.2. This inelasticity is consistent with several studies of irrigated crop production that have tested the price responsiveness of water use. In some cases the best fits are achieved by fixed proportions, however, given the long term nature of this study we have not set the elasticity at zero. The rate of substitution between capital and other inputs is much higher, and is set at 0.7 based on findings by aggregate models from researchers at USDA Economic Research Service. The full nested model is shown in the equation below, where the subset i refers to the two lower nests and X(1) and X(2) refer to the subsets of land and water, and capital and other inputs respectively. The subscript j refers to the higher nest shown in Figure 2.

$$y = C\left\{\sum_{i=1}^{2} \beta_i (A_i [b_{1i} x_{1i}^{-\eta i} + b_{2i} x_{2i}^{-\eta i}]^{-1\backslash\eta i})\ {-\eta j}\right\}^{-1\backslash\eta j}$$

The CES parameters are calibrated in two stages. The calibration method differs from the usual CGE approach in that the first order conditions for the fixed but allocatable inputs have to be satisfied, and the marginal conditions for the multiple crop outputs have to be satisfied for several common inputs such as land and water. If the total quantity of allocatable input is constrained, then the opportunity cost of the water will exceed its average cost. This occurs in many regions with water, due to the subsidies that are often incorporated in the development costs and the average cost pricing method used by most water districts. The first order conditions will only be satisfied if both the cash cost and opportunity cost of water (or land) are included in the "share " equations.

The production of multiple crops with widely differing marginal value products from the same farm poses a problem for the first order conditions that require that the marginal net value product is equal across all products. If land is a homogeneous input then the marginal product of the higher valued crops must decrease very rapidly with expanded acreage to satisfy the average yield and equal VMP conditions. A more reasonable explanation, and one that is backed by physical reality, is that the productivity of land in a given region is very heterogeneous with the more productive land being used for the higher valued crops. The problem of estimating the different shadow values of the land classes remains. The calibration approach used here takes a hedonic view and uses the crop land shadow values as an estimate of the different opportunity costs of land.

The empirical calibration approach is written in a self contained GAMS MINOS program which is in appendix B. There are two stages. Stage one uses an inequality constrained linear program to derive the shadow values for the allocable inputs. These values are then used in the CES share equations to derive the share coefficients. The total production level is used to calibrate the scale coefficients at each nest level and the resulting CES production function will calibrate the inputs, outputs and resources shadow values under the base year conditions. When faced with changed water inputs in the climate change runs the model adjusts input proportions and the region and crop mix to optimize the regional farm profit given the production function and the regional resource constraints.

The results are presented in the following section.

RESULTS

The results of the economic analysis are presented by the group affected. .The impact on consumers and producers is presented as changes in the levels of consumer and producer surplus. This commonly used measure in economics is an accepted way of calculating net social benefits. Consumer surplus is a measure of the difference between what the consumer would be prepared to pay at a maximum and what they have to pay at the prevailing market price. Clearly increased production and lowered prices would increase consumer surplus.

Producer surplus is a measure of the returns to land and management that farmers receive. The level of producer surplus depends on productivity, costs of production and market prices. Increases in yield due to reduced ozone will increase output and lower the per unit cost of production, however the inverse effect on market prices of the increased production will offset to some degree the gains to the farmer. In some areas where the ozone level in 1990 was not high, the reduction in a severe ozone region such as the Southern San Joaquin valley may actually reduce the producer surplus since statewide prices will go down, but productivity will not rise in the low ozone region.

Table 3 summarizes the net total benefits of reducing ozone to the 0.04 ppm 0.025 ppm standards. Under the 0.04 and 0.025 standards fifty-six and forty-eight percent of the benefits accrue to the crop consumers. respectively while forty-four and fifty-two percent of the benefit remains with the producer. Since at least one-third of the value of California crop production is exported from the state the consumer surplus measure overstates the net state benefits. The striking feature of these summary results is that the results for the 0.04 standard are slightly higher when compared to previous estimates, while the 0.025 benefits are substantially higher. Winer, Olszyk, and Howitt estimated a net benefit from reducing to .09 ppm of $213 million, measured in 1987 dollars. There are three reasons why the 1990 economic impacts of the 0.025 standard is so high. First, the level of reduction of ozone to 0.025 ppm is substantially greater, and with the lower standard a larger area in the central valley will be affected by the ozone reduction. Second, the more detailed calculation of regional ozone levels yields a greater specificity of yield reduction. Third, the earlier study was measured in 1987 dollars and there has been 20 percent inflation of crop prices in the past five years. Even allowing for these adjustments the levels of change in producer and consumer surplus are substantial and sufficient to demonstrate the economic importance of controlling air pollution.

It is ironic that the threat of water shortages stir strong feelings and political pressures among the agricultural community, but the slow erosion of yields by air pollution is not accorded the same importance. In a crude comparison, the cost of the current groundwater overdraft of 1.5 million acre feet has an opportunity cost of $90-$120 million a year. This is less than one quarter the estimated cost of yield losses from ozone levels above 0.025 ppm. Even when discounting for the low base standard, it seems that air pollution in the Southern San Joaquin Valley is already an equal or possibly greater threat to the profitability of the agricultural industry than water shortages.

Table 4 shows how the producer surplus changes greatly in magnitude and sign between regions, and standards. As would be expected from the ozone concentrations and value of agriculture, the Southern and Central San Joaquin Valley regions are the large beneficiaries of ozone reduction. Sacramento and North Coast regions benefit slightly, while Imperial and North East areas are slight losers for the reasons mentioned earlier. For the North Coast and Imperial county, the sign of the consumer benefit changes between the 0.025 and 0.04 standard.

Some of the benefits are caused by increases in the proportion of higher valued crops grown in the benefiting regions. Table 5 summarizes the shift in crop types among regions due to changes in ozone standards. The 40 different crops in the model which are listed in Table 2 are grouped into three classes for convenience. Generally, the fruit and vegetable crop acreage changes are less than the fodder and field crops. In order of profitability per acre the crop types are ordered: first, fruit and vegetables, second field crops, third, fodder crops. The acreage change percentages in Table 5 are calculated with respect to the 1990 base acreages which differ between the crop groups and regions. The dominant trends are strong shifts into field crops in South San Joaquin and Imperial regions while the coastal areas moved out of them. In contrast, the Coastal areas and the Sacramento and Northern San Joaquin regions increased their proportion of fodder crops, showing that some of their current comparative advantage for field crops is due to relatively lower ozone levels. Fruit and vegetable crops showed a dramatic move into the Southern San Joaquin region from all other regions except Imperial, North Coast and the South Coast region. Generally the two ozone standards did not differ in the direction of their effect on crop acreages in the Central Valley regions, although the difference between the 0.04 and 0.025 standard crop shifts was not equal across regions or crop types, thus showing the need for regional disaggregation. Given the slow rate of change that can be expected in the ambient ozone levels from a control program, the adjustment costs of changes such as these will probably be slight.

The relative changes in crop prices are shown in Table 6. With an overall increase in statewide production under ozone reduction crop prices can be expected to fall. Of the crops selected in Table 6, the price changes are low in three crops: lettuce, tomatoes, and wheat. Price reductions are slight in hay and rice, but significant in cantaloupes, cotton, and wine grapes. under the 0.04 standard and substantial for changes caused by the 0.025 standard. The magnitude of price reductions are influenced by three factors: the change in productivity, the elasticity of demand, and the ability of the crop to be produced in alternative regions with a similar profitability. In calculating the changes in crop price the effect of competing regions cannot be included in this model. However, the effect of ozone yield reduction son regional competition should not be dismissed, since while California has a comparative advantage in the production of many crops, the margin is not large enough to be invulnerable to losses of productivity such as those in the worst air polluted agricultural regions.

SUMMARY

The study has calculated the economic impact of two levels of ozone reduction in agricultural regions of California. The economic impacts of the 0.04 ppm standard at $489 million is higher than those found in an earlier study which showed $246 million in 1990 dollars. (Winer, Oszyk, and Howitt, 1990). However, this earlier study was based on different ozone monitoring data, and with different hourly standards. Although the reduction to the 0.025 ppm standard is very unlikely, the net returns of such a reduction are correspondingly large. The message of this study is that even allowing for input adjustment, price changes, and crop shifts by farmers, the costs of the current levels of ozone are significant in the Central and Southern San Joaquin Valley and pose an equivalent or more severe threat to the profitability of the agricultural industry as declining groundwater or increasing salinity.

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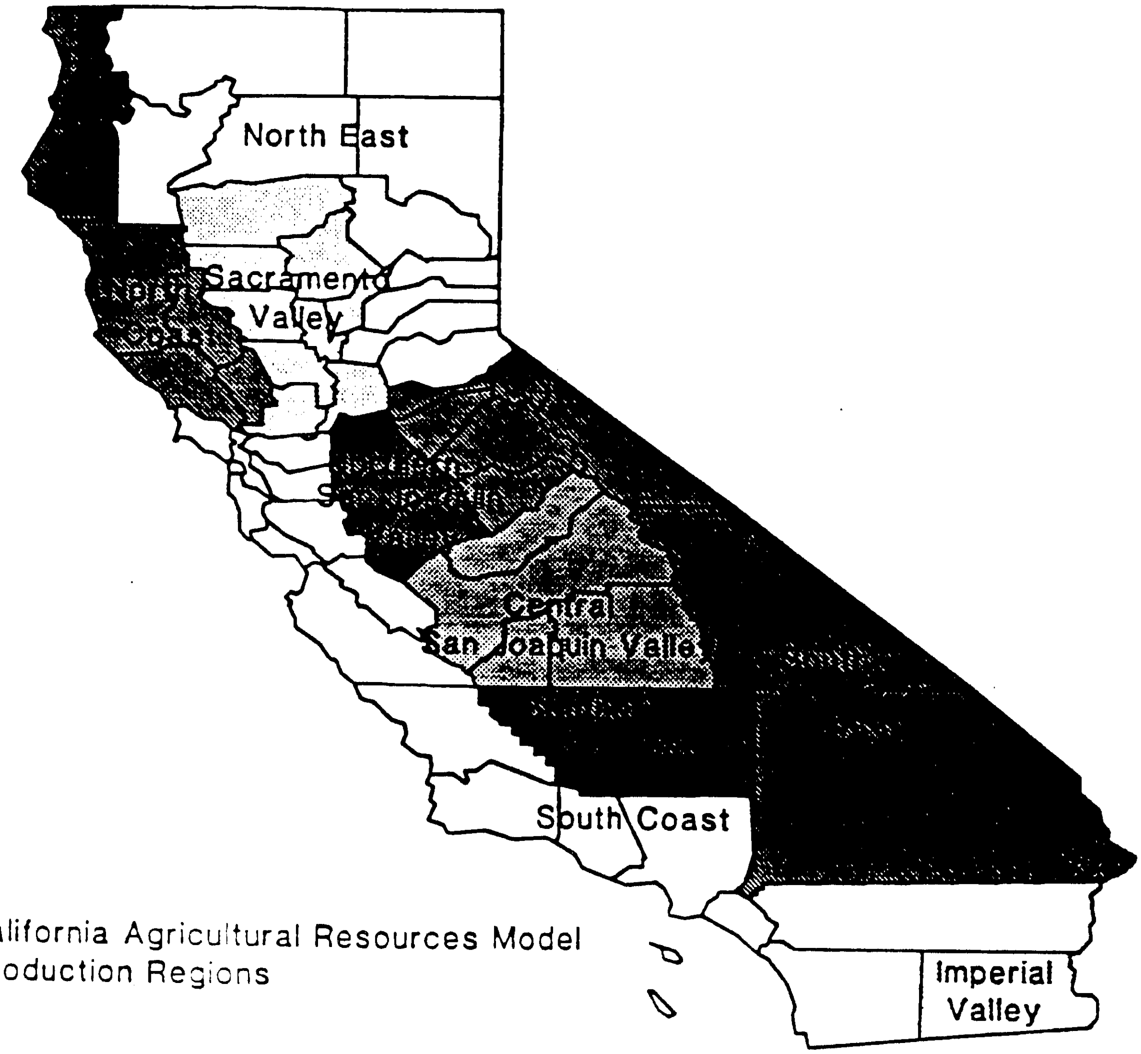

Figure 1. California Agricultural Resources Model Production Regions

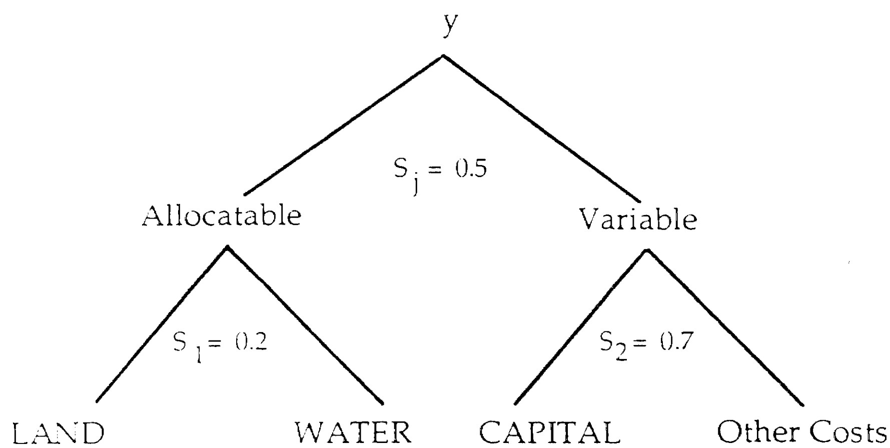

Figure 2. Four Input Nested CES

Estimated Regional Crop Yield Increases Above 1990 Observed Ambient Level

Under 0.04 ppm and 0.025 ppm Seven Hour Mean Standard

Table 1. Percentage Yield Increase Over 1990

	Sacramento		North San Joaquin Valley		Central San Joaquin Valley		South San Joaquin Valley		Imperial	
	0.04	0.025	0.04	0.025	0.04	0.025	0.04	0.025	0.04	0.025
Alfalfa-Hay	4.6	5.6	5.0	5.8	5.1	10.7	5.1	14.8	4.1	4.1
Beans-Dry	11.2	15.7	11.9	17.8	11.9	33.3	11.9	48.8	0	0
Cantaloupe	0	0	14.6	26.6	14.6	47.6	14.6	70.0	12.6	12.6
Citrus	8.6	8.6	0	0	10.4	18.0	10.4	24.2	9.4	9.4
Cotton	0	0	6.7	27.9	6.7	38.1	6.7	50.0	5.8	20.1
Grape-Dry	0	0	10	19.9	10	31.2	10	43.6	0	0
Grape-Table	0	0	10	12.3	10	31.8	10	43.6	0	0
Grape-Wine	10	31.2	10	16.1	10	30.2	10	43.6	0	0
Lettuce	0	0	0	0.3	0	1.0	0	1.7	0	0.01
Onions-Dry	4.3	4.3	3.7	3.7	8.0	11.5	8.0	24.0	5.3	5.3
Rice	2.6	3.7	2.6	4.0	2.6	8.0	2.6	10.0	0	0
Sugarbeets	1.2	3.9	1.8	8.1	1.8	13.6	1.8	9..9	1.3	3.8
Tomato-Pro	2.97	8.7	3.6	3.7	4.2	6.6	4.2	10.1	2.7	2.7
Wheat	1.3	1.3	1.6	1.6	8.8	9.7	9.4	15.0	4.9	4.9

Table 1. Percentage Yield Increase Over 1990 (Continued)

	South Coast		North Coast		North East		South Esat	
	0.04	0.025	0.04	0.025	0.04	0.025	0.04	0.025
Alfalfa-Hay	4.1	5.5	1.9	1.9	4.7	8.3	5.1	9.6
Beans-Dry	11.3	39.1	0	0	0	0	0	0
Cantaloupe	14.5	27.7	0	0	0	0	14.7	46.9
Citrus	9.2	13.4	0	0	0	0	10.4	37.2
Cotton	5.8	20.1	0	0	0	0	0	0
Grape-Dry	0	0	0	0	0	0	12.0	20.0
Grape-Table	9.97	45.2	0	0	0	0	9.97	20.2
Grape-Wine	7.6	10.3	3.0	3.0	9.9	27.9	10.0	20.3
Lettuce	0	0.15	0	0	0	0	0	1.69
Onions-Dry	4.99	10.8	0	0	6.2	6.2	2.7	2.7
Rice	0	0	0	0	2.6	6.6	0	0
Sugarbeets	1.1	3.4	0	0	1.8	10.5	0	0
Tomato-Pro	2.2	2.2	0	0	0	0	0	0
Wheat	6.1	6.3	0	0	7.2	8.8	0	0

Table 2

Price Elasticities of Demand for California Crops

Alfalfa-Hay	–0.189	Grape-Table	–0.15
Alfalfa-Seed	–0.0088	Grape-Wine	–1.647
Almonds	–0.54	Lettuce	–2.6212
Apple and Pea	–0.623	Onions-Dry	–0.457
Apricots	–0.356	Pasture	–0.189
Asparagus	–0.401	Peach/Nectarine	–0.65
Avocados	–1.849	Plums	–1.496
Barley	–0.103	Potatoes	–0.41337
Beans-Dry	–0.787	Prunes	–0.682
Broccoli and Cauliflower	–0.36608	Rice	–0.729
Cantaloupe	–0.39358	Safflower	–1.3
Carrots	–0.52331	Silage	–0.189
Celery	–3.7537	Sugarbeet	–0.003
Citrus	–0.734	Tomato-Pro	–0.277
Corn	–0.078	Walnuts	–0.604
Cotton	–0.154	Wheat	–0.237
Grain-Hay	–0.189	Field Crop	–0.0088
Grain Sorghum	–0.005	Fruits and Vegetables	–0.36608
Grape-Raisin	–0.357	Tree Nuts	–0.57

Table 3

Statewide Economic Impact of Ozone Reduction to 0.025 ppm

	1990 Actual			Net	
		0.04 ppm	0.025 ppm	0.04 ppm	0.025 ppm
Consumer Surplus ($ Mil)	4,532.770	4,807.627	5,245.388	274.857	712.618
Producer Surplus ($ Mil)	7,114.441	7328.955	7,893.305	214.514	778.864
		Net Direct Benefit		$489.371	$1491.482

Table 4

Changes in Regional Producer Surplus

	1990 Actual			Percent Change	
		0.04 ppm	0.025 ppm	0.04 ppm	0.025 ppm
Sacramento	391.889	402.611	426.839	2.74	8.92
North San Joaquin	562.819	561.900	563.583	-0.16	0.14
Central San Joaquin	2,158.462	2,284.936	2,578.349	5.86	19.45
South San Joaquin	653.125	710.501	982.384	8.78	50.41
Imperial	525.430	542.603	513.648	3.27	-2.24
South Coast	2,533.373	2,527.757	2,523.220	– 0.22	-0.40
North Coast	190.898	194.891	186.745	0.02	-2.18
North East	58.588	62.720	69.698	7.05	18.96
South East	39.857	41.036	48.839	2.96	22.54

Table 5

Changes in Regional Cropping Pattern from Ozone Reduction to 0.025 ppm

	Field Crop Acres		Fodder Crop Acres		Fruits & Vegetables	
	percent					
	0.04 ppm	0.025 ppm	0.04 ppm	0.025 ppm	0.04 ppm	0.025 ppm
Sacramento	– 0.17	– 0.25	1.89	1.13	– 1.19	0
North San Joaquin	6.9	9.76	3.99	6.98	0	– 1.73
Central San Joaquin	0.76	4.59	– 0.9	-9.26	– 0.8	– 4.28
South San Joaquin	5.8	32.20	– 5.0	-23.02	4.95	13.96
Imperial	3.7	12.27	40.29	-47.53	1.33	-0.89
South Coast	6.3	– 2.90	-12.6	5.04	0.4	0
North Coast	31.25	0	-4.4	7.35	– 0.99	– 4.95
North East	0.94	-8.0	-0.62	2.89	9.0	27.27
South East	0	0	-0.88	-0.88	0.0	0.1

Table 6

Selected Crop Price Changes ($)

	1990 Actual			Percent Change	
		0.04 ppm	0.025 ppm	0.04 ppm	0.025 ppm
Alfalfa Hay	108.27	106.66	106.24	– 1.5	– 1.9
Cantaloupe	323.86	298.57	258.44	– 7.8	–20.2
Cotton	1,577.88	1,548.48	1,385.48	– 1.9	–12.2
Wine Grapes	463.56	444.19	418.76	– 4.1	– 9.6
Lettuce	256.79	254.07	254.55	– 1.1	– 0.9
Rice	187.27	183.45	182.24	– 2.0	– 2.7
Tomatoes	54.25	53.84	53.25	– 0.8	– 1.8
Wheat	108.63	106.85	107.58	– 1.6	– 1.0

Appendix A

Effects of Acidic Deposition on Crops in the San Joaquin Valley

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Riverside, CA

A. Introduction

Atmospheric deposition of acidic air pollutants is widely recognized as an important environmental process. Depending on meteorological conditions, these pollutants are transported a few to hundreds of kilometers from sources to receptors (Legge, 1990). Primary and secondary pollutants which emanate from natural and anthropogenic sources are deposited on the Earth's surface by precipitation (e.g., rain, fog) or through dry deposition. In the agriculturally rich San Joaquin Valley, dry deposition is an important means by which airborne acidic pollutants enter the agroecosystem during the summer growing season (ARB, 1988a).

Dry deposition is the turbulent transport and sedimentation of gases and particles to the laminar boundary layer close to the leaf or soil surface (Allegrini and de Santis, 1989). The pollutant is then chemically or physically captured on the surfaces by processes of diffusion, convection or inertial impaction (Legge and Krupa, 1986). Dry deposition can modify the chemical microenvironment of the leaf three to thirty times more than that of wet deposition alone (Dolske, 1988). Dry-deposited materials are repeatedly dissolved by dew and light rain.

During the autumn and winter when cool season crops are grown, rain and fog are the primary sources of wet acidic deposition. Wet deposition is the removal of both nitrate (NO_3^-) and sulfate (SO_4^{2-}) from the atmosphere following their reaction with water to form nitric and sulfuric acid, respectively. Once on the leaf surface, the pollutant may be taken up by the plant directly, chemically react with the surface of the leaf or be washed off by subsequent precipitation onto the soil (Marshall and Cadle, 1989).

In some soil environments, acidic deposition may alter essential nutrient levels and influence soil pH. Because of the suspected involvement of acidic deposition in the decline of some natural and agroecosystems, considerable research efforts have focused on the impact of acidic deposition on the productivity of forests and agricultural crops. Results from controlled experiments in relation to data from the California Acid Deposition Monitoring Program (CADMP) are reviewed here to assess the potential impact of acidic deposition on the productivity of agriculture in the San Joaquin Valley.

B. Effects of Dry Deposition on Summer Crops

The bulk of agricultural sales are generated from crop production during summer months. Therefore, the impact of dry deposition on crop productivity is of primary concern because the peak of the growing season occurs when there is very little precipitation. Among the important constituents of dry deposition potentially harmful to plants (see Tables 2, 3 and 4 in the main body of this report), nitric acid is the prominent species of concern in California. Although the input of nitric acid from wet deposition into agroecosystems has been characterized, data describing the magnitude of the input of dry-deposited nitric acid has only recently become available (Dasch, 1989). Because the dry deposition of nitric acid only recently has been recognized as a potential problem and because of experimental difficulties associated with its chemical nature, a limited number of controlled studies have been published that evaluate its impact on plant physiology and growth. No studies were found in the literature that evaluated the response of agricultural crops to nitric acid vapor.

Dry deposition of nitric acid occurs via one of three routes: surface, transcuticular and stomatal deposition (Cadle et al., 1991) Eighty percent of the stomatal deposited nitric acid and none of the surface deposited acid was assimilated by pine. Dasch (1989) observed in oak that the amount of foliar deposited nitric acid vapor absorbed by the plant was a function of stomatal conductance. Over the range of environmental conditions studied, only a small fraction of the nitric acid present on the leaf surface was absorbed by the plant. The majority remained on the leaf surface unchanged, and therefore was washed off onto the soil by subsequent precipitation. No foliar lesions or loss in productivity were reported in either study. The daytime concentration of nitric acid in Bakersfield (3.37 ug m^{-3}; see Table 4 in the main body of this report) is less than 0.1% of the highest concentration used by Dasch (i.e., 281 ug m^{-3}). The total deposition to crop canopies at a given concentration of nitric acid varies little between plant species (Meyers and Hicks, 1988). Therefore, at concentrations currently observed in the San Joaquin Valley, it is doubtful that crop productivity on a regional scale would be adversely impacted by the dry deposition of nitric acid. It must be mentioned, however, that no studies have been conducted to quantify the actual amount of acidic materials dry-deposited on leaf surfaces in the valley during the growing season.

In crops irrigated by overhead sprinklers, where leaves would be periodically washed, the small amount of nitric acid entering the soil would have little effect on soil pH or nutrient content. Total nitrogen deposited on the soil from nitric acid during the growing season in three different states (i.e., Tennessee, Pennsylvania, Illinois) ranged from 0.2 to 1.0 kg ha^{-1} (Meyers and Hicks, 1988). Localized occurrences of foliar lesions may develop in sprinkler-irrigated crops because the pH of the water can be lowered at the leaf surface by dissolving dry-deposited particles which have accumulated on the leaf surface (e.g., NO_3^-, SO_4^{2-}). It is unclear whether these changes in leaf surface chemistry would lead to a reduction in cuticular integrity and a subsequent increase in pathogen infection efficiency.

The limited information available suggests that acidic rain has the potential to influence the interaction between plants and pathogens and to alter epidemics of plant diseases (Van Bruggen et al., 1986; Martin et al., 1987). Acidic precipitation may modify host-parasite relationships by influencing host resistance, pathogen virulence or inoculum density of the pathogen. Campbell et al., (1988) studying the influence of acidity level on four plant pathogens, concluded that the disease response to acidity is system-dependent. In that, the degree of pathogen-related disease development depended on the acidity of the precipitation, duration of exposure and whether lesions induced by acidic deposition predisposed different plant species to greater disease sensitivity.

C. Effects of Wet Deposition on Cool Season Crops

Crops grown in the autumn and winter months experience lower levels of dry-deposited acidic compounds than do summer grown crops (ARB, 1987). However, these cool seasons crops may be exposed to frequent episodes of acidic fog or rain. At selected sites in southern California, the pH of fog may range from 2.0 to 4.9 (Jacob et al., 1985; Hoffman, 1984), and rain from pH 3.3 to 6.0 (ARB, 1988). In comparison, the pH of precipitation in Tulare County during 1990 ranged from 4.8 to 7.0 (NADP, 1991). Characteristically, low volume rain events occurring in the fall or spring often result in the most acidic rain events (NADP, 1991). The degree to which wet deposition injures plants depends upon pH rather than the chemical composition of the event (DuBay and Heagle, 1987). That is to say, the mechanism of injury is comparable whether the pH of precipitation is a result of high NO_3^- or SO_4^{2-} content. Although ambient fog and rain in the valley will generally contain more nitric acid than sulfuric acid (Hoffman, 1984; Trumble and Walker, 1991), results from studies of both types of acidic precipitation are relevant to crops grown in the San Joaquin Valley.

The effects of acidic fog on the productivity of a number of crop plants have been evaluated experimentally (Table 1). Multiple exposures to fog at a pH of 2.8 (or more acidic) adversely affected several crop plants (e.g. onion, carrot, broccoli, bell pepper, orange, lettuce, alfalfa, radish, spinach, strawberry, potato, wheat). Growth and yield reductions were found to be associated with a decrease in whole-plant photosynthesis attributed to a reduction in leaf area as opposed to a dysfunction in carbon metabolism in bell pepper (Takemoto et al., 1988a). In contrast, reduced photosynthesis in lima bean (Trumble and Walker, 1991) and broccoli (Takemoto et al., 1989a) was associated with the development of foliar injury, presumably due to a necrosis of mesophyll cells (site of photosynthesis). Conversely, photosynthesis in strawberry was not influenced by acidic fog despite the development of interveinal necrosis (Takemoto et al., 1989b). Apparently, the physiological response to highly acidic fog differs between plant species although the threshold of injury is consistently around pH 3.0. This suggests that very localized injury to crop plants may occur on rare occasions when ambient levels of fog acidity are high enough to cause visible symptoms and thereby reduce the marketability of a few sensitive crops (NAPAP, 1989). However, there is no evidence to indicate that the frequency of highly acidic fog events in the San Joaquin Valley is sufficient to elicit such a response in the major crop plants grown there.

Extensive research efforts have focused on the effects of acidic rain alone and in concert with other environmental stresses on crop health (Bell, 1986). Treatment levels usually ranged from pH 2.0 to 6.0 under both field and controlled environment conditions (e.g. Bell and Ashenden, 1987). Responses frequently varied between species, as well as between varieties within species. As a consequence of the wet winters and very dry summers in the San Joaquin Valley, only the crops grown in the autumn and winter are exposed to potentially significant amounts of wet acidic deposition. Thus, it is inappropriate to extrapolate beyond the studies specifically addressing the response of cool season crops to acidic rain.

Table 1. Acidity of Fog Required for Adverse Effects to Selected Agricultural Crops[1]

Crop	*pH*	*Effect*	*Reference*
Alfalfa	1.6	Yield Change (+ or -)	Musselman & Sterret (1988)
"	1.7	Injury; Yield Reduced	Takemoto et al., (1988c)
"	2.0	Injury; Yield Reduced	Temple et al., (1987)
"	2.7	Chlorophyll Loss	Takemoto et al., (1988b)
Bean	1.6	Yield Reduced	Musselman & Sterret (1988)
"	2.4	Foliar Injury	Musselman & Sterret (1988)
"	2.8	Foliar Injury	Bytnerowicz et al., (1986)
Bell Pepper	1.7	Injury; Yield Reduced	Takemoto et al., (1988a)
Broccoli	2.2	Yield Reduced	Olszyk et al., (1987)
Celery	1.7	Foliar Injury	Takemoto et al., (1988)
Lettuce	2.3	Foliar Injury	Takemoto et al., (1988c)
Onion	1.8	Foliar Injury	Olszyk et al., (1987)
"	2.4	Foliar Injury	Musselman & Sterret (1988)
Orange	1.6	Height Reduced	Musselman & Sterret (1988)
"	2.1	Foliar Injury	Musselman & Sterret (1988)
Potato	1.8	Foliar Injury	Olszyk et al., (1987)
Radish	2.6	Foliar Injury; Growth Increased	Musselman & Sterret (1988)
Tomato	1.7	Foliar Injury; Yield Reduced	Takemoto et al., (1988c)
"	2.6	Foliar Injury	Musselman & Sterret (1988)
Wheat	1.8	Foliar Injury	Olszyk et al., (1987)

1 After Olszyk et al., (1989)

Acidic rain at a pH of 2.5 applied at 30 mm week^{-1} for eight weeks reduced the aboveground biomass of pea by 31%, as compared to the control treatment at pH 5.6 (Ashenden and Bell, 1989). Kumar (1988) found that the seed yield of pea was reduced in response to acidic rain at pH 2.5, and the yield reduction was associated with fewer pods plant^{-1} and seeds pod^{-1}. These results imply that reproductive processes may be sensitive to acidic precipitation. Wertheim and

Craker (1988) found that both pollen viability and stigma receptivity were reduced by acid rain in corn (i.e., a warm season crop). It is not known whether reproduction in winter blooming crops, such as almond, is adversely affected by acidic fog or rain.

Yields increased by 47%, relative to the control, in spring wheat when it was irrigated with acidic rain at pH 3.0 (Zvara et al., 1990). Abouguendia et al. (1988) reported that the yields of wheat, canola and alfalfa were not affected and total plant biomass increased with 12 weekly applications of acidic rain at a pH of 2.5. The authors attributed the increase in biomass to additional nutrients provided by the treatments. Ashenden and Bell (1987) calculated from experimental results that yield reductions of 10 to 30% were expected in barley in response to the critical pH range of rainfall of 3.5 to 4.5. In contrast, no significant effects of rain acidity on yield, or yield components were observed in barley (Enyedi and Kuja, 1986) or oat (Pell and Puente, 1987).

Foliar applied acidic rain treatments with a pH of 2.5 did not adversely affect either the carbon fixation physiology or plant morphology of spinach, as compared to the control with a pH of 4.5 (Linskens et al., 1989). A simulated rain with a pH value of 3.3 applied three times weekly was required to elicit a 10% reduction in biomass of radish (Jacobson et al., 1988). Olsen et al., (1987) demonstrated a decrease in root mass in radish at pH 4.0, and the authors suggested that such effects could impair the plant's ability to withstand a number of environmental stresses. There were no measurable effects of rain acidity on tuber weight, number or quality in potato (Pell et al., 1987). Foliar injury was observed in cabbage at a pH of 3.0, which could reduce its marketability (Enyedi and Kuja, 1986).

Walnut exhibited a higher incidence of necrotic spots on leaves when it was exposed to acidic treatments of pH 3.5 or lower on a daily basis. Foliar lesions were a result of epicuticular surface breakdown, however, the implications to yield reduction or predisposal to pathogen infection were not addressed (Rinalto and Raddi, 1989). Valencia orange exhibited no foliar lesions or change in fruit quality and an increase in yield in response to acidic treatments of pH 4.0 (Hart et al., 1986).

D. Summary and Conclusions

More than a decade of research on a number of crop species has demonstrated that high levels of dry and wet acidic deposition can result in crop yield reductions. However, such responses usually require frequent, short-term peak concentrations which probably do not occur on a regional scale in rural areas of the San Joaquin Valley. Generally, results reveal that the overall impacts of acidic precipitation on agricultural production and potential production are limited to occasional occurrences of very localized injury in sensitive crops close to major sources of pollutants which contribute to acidic precipitation (Ludlow and Smit, 1988).

Experimental evidence using simulated acidic precipitation demonstrated that a threshold hydrogen ion concentration (pH) was required before plants were injured by acidic fog or rain. The threshold pH associated with growth and yield reductions was either the same or more acidic than that responsible for visible injury. Injury generally increased proportional to increasing deposition. It is noteworthy that there have been no documented cases of yield reductions in commercially grown field crops attributed to acidic deposition (NAPAP, 1989).

The sulfur and nitrogen input from acidic deposition may supplement the required fertilizer amendments on intensively managed agricultural land and provides nutritional enrichment of land under low levels of management, such as grasslands. Such nutritional enhancement may or may not benefit natural, unmanaged vegetation systems in California. Even when the cost of lime needed to neutralize the wet deposition of acidity to agricultural soils is considered, a net benefit to croplands from acidic deposition is probable because of sulfur and nitrogen inputs (NAPAP, 1989). Data were not found describing the long-term consequences of acidic deposition on agricultural soil and potential leaching of acid-soluble elements such as aluminum (Al) and iron (Fe) into ground water, which has been postulated to occur in aquatic and forest ecosystems (ARB, 1988a, Bell, 1986).

The primary effects of acidic deposition and associated pollutants on some agricultural crops are well understood under research conditions. Additive effects of ambient concentrations of ozone and highly acidic fog (i.e., pH 2.0 or more acidic) on reducing plant vigor have been observed (e.g., Takemoto et al., 1988a). Ponderosa pine seedlings exposed to dry acidic deposition treatments were more susceptible to ozone injury (Temple et al., 1992). Interacting factors do exist that individually or in concert may affect the accuracy of yield estimates. These include dose rates, recovery intervals, temperature, moisture and the presence of pests, diseases or other pollutants that affect plant responses. Information on the interactions between abiotic and biotic stresses with acidic deposition and gaseous pollutants, as well as information on the relative sensitivity of a wider range of annual and perennial species would be needed to develop more accurate and comprehensive estimates of crop loss due to acidic deposition.

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APPENDIX B

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$TITLE  CARM-CES MODEL ARB RUNS
* CES AIR POLLUTION MODEL: PROGRAM--R HOWITT , MARCH 1992
* SEPERATE ENERGY COSTS FOR WATER
* ENDOGENOUS CROP PRICES

$OFFSYMLIST OFFSYMXREF
 OPTION LIMROW = 0
 OPTION LIMCOL = 0

 option iterlim =40000
 option reslim = 20000

SETS I ACTIVITIES
      /'ALFA-HAY  '  (ACRES)
       'ALFA-SEED '  (ACRES)
       'ALMONDS   '  (ACRES)
       'APPLE+PEAR'  (ACRES)
       'APRICOTS  '  (ACRES)
       'ASPARAGUS '  (ACRES)
       'AVOCADOS  '  (ACRES)
       'BARLEY    '  (ACRES)
       'BARLEY-IRR'  (ACRES)
       'BEANS-DRY '  (ACRES)
       'BROC+CAULI'  (ACRES)
       'CANTALOUPE'  (ACRES)
       'CARROTS   '  (ACRES)
       'CELERY    '  (ACRES)
       'CITRUS    '  (ACRES)
       'CORN      '  (ACRES)
       'COTTON    '  (ACRES)
       'GRAINHAY  '  (ACRES)
       'GRAINSORGH'  (ACRES)
       'GRAPE-DRY '  (ACRES)
       'GRAPE-TABL'  (ACRES)
       'GRAPE-WINE'  (ACRES)
       'LETTUCE   '  (ACRES)
       'ONIONS-DRY'  (ACRES)
       'PASTURE   '  (ACRES)
       'PEACH+NECT'  (ACRES)
       'PLUMS     '  (ACRES)
       'POTATOES  '  (ACRES)
       'PRUNES    '  (ACRES)
       'RICE      '  (ACRES)
       'SAFFLOWER '  (ACRES)
       'SILAGE    '  (ACRES)
       'SUGARBEETS'  (ACRES)
       'TOMATO-PRO'  (ACRES)
       'WALNUTS   '  (ACRES)
       'WHEAT     '  (ACRES)
       'WHEAT-IRR '  (ACRES)
       'XFIELDCROP'  (ACRES)
       'XFRUITVEG '  (ACRES)
       'XTREENUTS '  (ACRES)/
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*        M(I)     NON KEY PROCESSES/WHT,RI/
*        CT(I)      KEY CROP  /COT/
       J        INPUTS                     /'LAND','WATER','CAPITAL','OTHER'/
       J1(J)       INPUTS NEST1            /'LAND','WATER'/
       P(J1)    RESOURCE SUB SET           /'WATER'/
       R(J1)    KEY RESOURCE               /'LAND'/
       J2(J)       INPUTS NEST2            /'CAPITAL', 'OTHER'/
       N        TOP LEVEL NEST             /FX, VAR/


     D MARKETS FOR ACTIVITIES
      /'@ALFA-HAY '
       '@ALFA-SEED'
       '@ALMONDS  '
       '@APPLE+PEA'
       '@APRICOTS '
       '@ASPARAGUS'
       '@AVOCADOS '
       '@BARLEY   '
       '@BEANS-DRY'
       '@BROC+CAUL'
       '@CANTALOUP'
       '@CARROTS  '
       '@CELERY   '
       '@CITRUS   '
       '@CORN     '
       '@COTTON   '
       '@GRAINHAY '
       '@GRAINSORG'
       '@GRAPE-DRY'
       '@GRAPE-TAB'
       '@GRAPE-WIN'
       '@LETTUCE  '
       '@ONIONS-DR'
       '@PASTURE  '
       '@PEACH+NEC'
       '@PLUMS    '
       '@POTATOES '
       '@PRUNES   '
       '@RICE     '
       '@SAFFLOWER'
       '@SILAGE   '
       '@SUGARBEET'
       '@TOMATO-PR'
       '@WALNUTS  '
       '@WHEAT    '
       '@XFIELDCRO'
       '@XFRUITVEG'
       '@XTREENUTS'/

     MAP(I,D) ACTIVITY-MARKET RELATIONSHIPS
      /'ALFA-HAY  '.'@ALFA-HAY '
       'ALFA-SEED '.'@ALFA-SEED'
       'ALMONDS   '.'@ALMONDS  '
       'APPLE+PEAR'.'@APPLE+PEA'
       'APRICOTS  '.'@APRICOTS '
       'ASPARAGUS '.'@ASPARAGUS'
       'AVOCADOS  '.'@AVOCADOS '
       'BARLEY    '.'@BARLEY   '
       'BARLEY-IRR'.'@BARLEY   '
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'BEANS-DRY '.'@BEANS-DRY'
'BROC+CAULI'.'@BROC+CAUL'
'CANTALOUPE'.'@CANTALOUP'
'CARROTS   '.'@CARROTS  '
'CELERY    '.'@CELERY   '
'CITRUS    '.'@CITRUS   '
'CORN      '.'@CORN     '
'COTTON    '.'@COTTON   '
'GRAINHAY  '.'@GRAINHAY '
'GRAINSORGH'.'@GRAINSORG'
'GRAPE-DRY '.'@GRAPE-DRY'
'GRAPE-TABL'.'@GRAPE-TAB'
'GRAPE-WINE'.'@GRAPE-WIN'
'LETTUCE   '.'@LETTUCE  '
'ONIONS-DRY'.'@ONIONS-DR'
'PASTURE   '.'@PASTURE  '
'PEACH+NECT'.'@PEACH+NEC'
'PLUMS     '.'@PLUMS    '
'POTATOES  '.'@POTATOES '
'PRUNES    '.'@PRUNES   '
'RICE      '.'@RICE     '
'SAFFLOWER '.'@SAFFLOWER'
'SILAGE    '.'@SILAGE   '
'SUGARBEETS'.'@SUGARBEET'
'TOMATO-PRO'.'@TOMATO-PR'
'WALNUTS   '.'@WALNUTS  '
'WHEAT     '.'@WHEAT    '
'WHEAT-IRR '.'@WHEAT    '
'XFIELDCROP'.'@XFIELDCRO'
'XFRUITVEG '.'@XFRUITVEG'
'XTREENUTS '.'@XTREENUTS'/
```

```
* KY is a subset of J on which we normalize the Leontieff coefficients
```

```
KY(I,J) KEY INPUTS
 /'ALFA-HAY  '.'LAND      '
  'ALFA-SEED '.'LAND      '
  'ALMONDS   '.'LAND      '
  'APPLE+PEAR'.'LAND      '
  'APRICOTS  '.'LAND      '
  'ASPARAGUS '.'LAND      '
  'AVOCADOS  '.'LAND      '
  'BARLEY    '.'LAND      '
  'BARLEY-IRR'.'LAND      '
  'BEANS-DRY '.'LAND      '
  'BROC+CAULI'.'LAND      '
  'CANTALOUPE'.'LAND      '
  'CARROTS   '.'LAND      '
  'CELERY    '.'LAND      '
  'CITRUS    '.'LAND      '
  'CORN      '.'LAND      '
  'COTTON    '.'LAND      '
  'GRAINHAY  '.'LAND      '
  'GRAINSORGH'.'LAND      '
  'GRAPE-DRY '.'LAND      '
  'GRAPE-TABL'.'LAND      '
  'GRAPE-WINE'.'LAND      '
  'LETTUCE   '.'LAND      '
  'ONIONS-DRY'.'LAND      '
  'PASTURE   '.'LAND      '
```

```
 'PEACH+NECT'.'LAND        '
 'PLUMS     '.'LAND        '
 'POTATOES  '.'LAND        '
 'PRUNES    '.'LAND        '
 'RICE      '.'LAND        '
 'SAFFLOWER '.'LAND        '
 'SILAGE    '.'LAND        '
 'SUGARBEETS'.'LAND        '
 'TOMATO-PRO'.'LAND        '
 'WALNUTS   '.'LAND        '
 'WHEAT     '.'LAND        '
 'WHEAT-IRR '.'LAND        '
 'XFIELDCROP'.'LAND        '
 'XFRUITVEG '.'LAND        '
 'XTREENUTS '.'LAND        '/


GR CROP GROUPS
 /FL FIELD CROPS,
  FO FODDER,
  FV FRUITS AND VEG/

MAP1(I,GR) ACTIVITY-CROP_GROUPS RELATIONSHIPS
 /'ALFA-HAY  '.'FO'
  'ALFA-SEED '.'FO'
  'ALMONDS   '.'FV'
  'APPLE+PEAR'.'FV'
  'APRICOTS  '.'FV'
  'ASPARAGUS '.'FV'
  'AVOCADOS  '.'FV'
  'BARLEY    '.'FL'
  'BARLEY-IRR'.'FL'
  'BEANS-DRY '.'FL'
  'BROC+CAULI'.'FV'
  'CANTALOUPE'.'FV'
  'CARROTS   '.'FV'
  'CELERY    '.'FV'
  'CITRUS    '.'FV'
  'CORN      '.'FL'
  'COTTON    '.'FL'
  'GRAINHAY  '.'FO'
  'GRAINSORGH'.'FL'
  'GRAPE-DRY '.'FV'
  'GRAPE-TABL'.'FV'
  'GRAPE-WINE'.'FV'
  'LETTUCE   '.'FV'
  'ONIONS-DRY'.'FL'
  'PASTURE   '.'FO'
  'PEACH+NECT'.'FV'
  'PLUMS     '.'FV'
  'POTATOES  '.'FL'
  'PRUNES    '.'FV'
  'RICE      '.'FL'
  'SAFFLOWER '.'FL'
  'SILAGE    '.'FO'
  'SUGARBEETS'.'FL'
  'TOMATO-PRO'.'FL'
  'WALNUTS   '.'FV'
  'WHEAT     '.'FL'
  'WHEAT-IRR '.'FL'
```

```
           'XFIELDCROP'.'FL'
           'XFRUITVEG '.'FV'
           'XTREENUTS '.'FV'/


           NM(J)  NORMALIZING INPUT /'LAND' /


         G REGIONS  /SAC,NSJV,CSJV,SSJV,IMP,SCOA,NCOA,NEAST,SEAST/

         W   WATER TYPES   / GWATER, SWATER /


 ALIAS (I,K)
 ALIAS (J,L)
 ALIAS (G,Q)
 ALIAS (N,NN)
 ALIAS ( J1, JJ1)
 ALIAS ( J2, JJ2)


 SCALAR  SUB1  NEST1 ELASTICITY       /  0.2/
 SCALAR  SUB2  NEST2 ELASTICITY       /  0.7/
 SCALAR  SUB3  TOP LEVEL ELASTICITY  / 0.5 /

* DATA FOR THE 1990 CARM MODEL

$INCLUDE carmdat9.gms

$ONTEXT
****DATA MODIFICATIONS***********
 PARAMETER    RHS(G,J)
              X(I,G,J)
              V(I,G)
              C(I,G,J) ;

      X(I,G,J) = X(I,G,J) * 0.001 ;


     X(I,G,'CAPITAL')$X(I,G,'LAND') =  C(I,G,'LAND') * 0.25 *
                                       X(I,G,'LAND') ;
     X(I,G,'OTHER'  )$X(I,G,'LAND') =  C(I,G,'LAND') * 0.25 *
                                        X(I,G,'LAND') ;


     C(I,G,'CAPITAL')$X(I,G,'LAND') =  1.0 ;
     C(I,G, 'OTHER')$X(I,G,'LAND')  =  1.0 ;

     RHS(G,'LAND')     = SUM(I, X(I,G,'LAND')) ;

     RHS(G,'WATER')    = SUM(I, X(I,G,'WATER')) ;

     RHS(G,'CAPITAL') = SUM(I,X(I,G,'CAPITAL')) * 1.25 ;
     RHS(G,'OTHER' )  = SUM(I,X(I,G,'OTHER')) * 1.25 ;

     C(I,G, 'LAND' )$X(I,G,'LAND')   =  C(I,G,'LAND') * 0.5 ;

      V(I,G)   = V(I,G) * 1.0 ;
```

```
     V('PASTURE  ',G) = V('PASTURE',G) * 2.0 ;

$OFFTEXT

*******************************************************************

* LINEAR PROGRAM TO CALCULATE RESOURCE AND PMP DUALS
*********************************************************************
 VARIABLES  LX(I,G)   ACRES  PLANTED
            LINPROF    LP PROFIT

 PARAMETER RR(I,G,J) REGIONAL LEONTIEFF COEFFICIENTS
           NET(I,G)  NET RETURNS
           CL(I,G)   LINEAR COST ;

  RR(I,G,J)$X(I,G,'LAND') = (X(I,G,J)/X(I,G,"LAND"));

  CL(I,G) = SUM(J,(C(I,G,J)*RR(I,G,J))) ;

   NET(I,G) =
    YB(I,G)*V(I,G) - SUM(J,RR(I,G,J)*C(I,G,J));


*  DISPLAY  CL,RR, NET;

 POSITIVE VARIABLE LX;
 EQUATIONS RESOURCE(G,J)   CONSTRAINED RESOURCES
           CALIBU(I,G)      UPPER CALIBRATION CONSTRAINTS
           CALIBL(I,G)      LOWER CALIBRATION  CONSTRAINTS
           LPROFIT         LP OBJECTIVE FUNCTION;

 RESOURCE(G,J)..     SUM(I,RR(I,G,J)*LX(I,G))    =L= RHS(G,J);
 CALIBU(I,G)$(NET(I,G) GT 0 )..        LX(I,G) =L= X(I,G,"LAND")*1.001;
 CALIBL(I,G)$(NET(I,G) LT 0 )..        LX(I,G) =G= X(I,G,"LAND")*1.001;

 LPROFIT.. SUM((I,G),((V(I,G)*YB(I,G))-CL(I,G))*LX(I,G)) =E= LINPROF;

 MODEL CALIBRATE /RESOURCE,CALIBU,CALIBL,LPROFIT/;

  SOLVE CALIBRATE   USING LP MAXIMIZING LINPROF;

* DISPLAY LX.L, LX.M;


*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*
*                            DEMAND EQUATIONS                            *
*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*

PARAMETERS KEY(I)    TOTAL QUANTITY OF KEY ACTIVITY
           P1(I)     WEIGHTED AVERAGE PRICE BY ACTIVITY
           Q1(I)     QUANTITY OVER ALL REGIONS OF ACTIVITY
           PBASE(D) BASE YEAR PRICE (WEIGHTED AVERAGE BY REGIONS)
           RMC(I,G) REGIONAL MARKETING COST
           QN(D)      TOTAL QUANTITY OF ACTIVITY (ALL TECHNOLOGIES)
           INT(D)    INTERCEPT OF DEMAND EQUATION
           PHI(D)  SLOPE OF DEMAND EQUATION
           REG(I,G) REGIONAL PRICE DIFFERENCE;
```

```
KEY(I) =
   SUM(G,SUM(J$KY(I,J), X(I,G,J)));

P1(I)$KEY(I) =
   SUM(G,(V(I,G)*SUM(J$KY(I,J),X(I,G,J)))) / KEY(I) ;

Q1(I) =
   SUM(G,(YB(I,G)*SUM(J$KY(I,J),X(I,G,J))));

PBASE(D) =
   SUM(I$MAP(I,D),P1(I)*Q1(I)) / SUM(I$MAP(I,D),Q1(I));

REG(I,G) =
   SUM(D$MAP(I,D),(PBASE(D)-V(I,G)));

RMC(I,G)$((REG(I,G) GT 0.01) OR (REG(I,G) LT -0.01)) =
   REG(I,G) ;

QN(D) =
   SUM(I$MAP(I,D),SUM(G,SUM(J$KY(I,J),X(I,G,J))* YB(I,G)));

PHI(D)$FLEX(D) =
   (FLEX(D)*PBASE(D))/QN(D);

INT(D) =
   PBASE(D) - PHI(D) * QN(D) ;


DISPLAY  INT, PHI, PBASE, QN, RMC;



*********************************************************************
*CALCULATION OF THE  C E S      PARAMETERS

*********************************************************************
*  TOP LEVEL

PARAMETER    LU(I,G,J)    PMP DUAL VALUE UPPER
             LL(I,G,J)    PMP DUAL VALUE LOWER
             FLG(I,G)     FLAG FOR BIG NEGATIVES
             X(I,G,J)     ADJUSTED BASE QUANTITIES
             OP(G,J)    LAND OPP COST
             RHS2(G,J)   REDUCED RHS
             RHSW(G,W)   WATER SOURCES
             NR(G)      REGION COUNTER
              TO(I,G)    TOTAL OUTPUT
             CS(I,G,J)   COST PLUS OP COST
             V(I,G)      ADJUSTED REVENUE
             CN(I,G,N)   TOP LEVEL COSTS
             CON(I,G)    CONSTANT SCALE PARAMETER (TOP)
             XX(I,G,N)   NEST  TOTAL
             NORM(I,G)   NORMALIZATION COST
             ETA1(I,G)     FUNCTION OF SUB1
             ETA2(I,G)     FUNCTION OF SUB2
             ETA3(I,G)     FUNCTION OF SUB3
             GAM1(I,G)     ONE OVER ETA1
             GAM2(I,G)     ONE OVER ETA2
```

```
          GAM3(I,G)     ONE OVER ETA3
          BETA1(I,G,N)   RUTHERFORD SHARE PARAMETERS
          BETA(I,G,N)   SHARE PARAMETERS ;


             LU(I,G,"LAND") = CALIBU.M(I,G) ;
             OP(G,J) = RESOURCE.M(G,J) ;
    LL(I,G,"LAND")$((-CALIBL.M(I,G)) LT (C(I,G,'LAND') +OP(G,'LAND')))
                        = CALIBL.M(I,G) ;
    FLG(I,G)$((- CALIBL.M(I,G)) GT (C(I,G,'LAND') + OP(G,'LAND')))  = 1.0 ;
             X(I,G,J)$(FLG(I,G) EQ 1) = 0 ;
             RHS2(G,J) = SUM (I, X(I,G,J) ) ;
             RHSW(G,W) = BREAK(G,W) * RHS2(G,'WATER') ;
             TO(I,G) = YB(I,G)*X(I,G,"LAND") ;
             CS(I,G,J) = C(I,G,J) + OP(G,J) + LU(I,G,J) +LL(I,G,J) ;
             V(I,G)   = V(I,G)   ;
             CN(I,G,N) = 1.0 ;
             XX(I,G,"FX") = SUM(J1, (X(I,G,J1)* CS(I,G,J1)) ) ;
             XX(I,G,"VAR") = SUM(J2,( X(I,G,J2)* CS(I,G,J2)) ) ;
             NORM(I,G) = CS(I,G,"LAND") ;
             ETA1(I,G) = (SUB1 - 1)/ SUB1 ;
             ETA2(I,G) = (SUB2 - 1)/ SUB2 ;
             ETA3(I,G) = (SUB3 - 1)/ SUB3 ;
             GAM1(I,G) = 1/ ETA1(I,G) ;
             GAM2(I,G) = 1 / ETA2(I,G) ;
             GAM3(I,G) = 1 / ETA3(I,G) ;

*    RUTHERFORD SHARE FORMULAE FOR TOP LEVEL

         BETA1(I,G,N)$XX(I,G,N)   = ( XX(I,G,N)**(1/SUB3))
                /SUM(NN,  XX(I,G,NN) ) ;


*    SCALING THE BETAS

       BETA(I,G,"FX")$X(I,G,'LAND') = 1 /(1 + (BETA1(I,G,"VAR")/BETA1(I,G,"FX"

          BETA(I,G,"VAR")$X(I,G,'LAND') = 1 - BETA(I,G,"FX") ;


*  SETTING THE  SCALE PARAMETER BY TOTAL OUTPUT

        CON(I,G)$X(I,G,'LAND') = TO(I,G) / (SUM(N, BETA(I,G,N)*
              ((XX(I,G,N)+0.0001)** ETA3(I,G)))** GAM3(I,G)) ;



*******NEST PARAMETERS*******************************

*     DEFINE THE NEST PARAMETERS


  PARAMETER
          A(I,G,N)  NEST SCALE PARAMETER
         A1(I,G,N)

          B1(I,G,J) NEST RUTHERFORD PARAMS
```

```
          B(I,G,J)  INPUT SHARE PARAMS     ;

*    RUTHERFORD SHARE FORMULAE FOR THE NESTS

         B1(I,G,J1)$( X(I,G,J1) GT 0 AND CS(I,G,'LAND') GT 0)
              = ((X(I,G,J1)**(1/SUB1)) * CS(I,G,J1)/CS(I,G,"LAND"))
                /SUM(JJ1, (X(I,G,JJ1)*(CS(I,G,JJ1)/CS(I,G,"LAND")) ) ) ;

         B1(I,G,J2)$( X(I,G,J2) GT 0 AND CS(I,G,'LAND') GT 0)
              = ((X(I,G,J2)**(1/SUB2)) * CS(I,G,J2)/CS(I,G,"CAPITAL"))
                /SUM(JJ2, (X(I,G,JJ2)*(CS(I,G,JJ2)/CS(I,G,"CAPITAL")) ) ) ;


*    SCALING THE BETAS FOR THE NESTS

        B(I,G,"LAND")$B1(I,G,"LAND") = 1 /(1 + (B1(I,G,"WATER")
                                         /B1(I,G,"LAND"))) ;

          B(I,G,"WATER")$B(I,G,'LAND') = 1 -  B(I,G,"LAND") ;

        B(I,G,"CAPITAL")$B1(I,G,"CAPITAL") = 1 /(1 + ( B1(I,G,"OTHER")
                                         /B1(I,G,"CAPITAL"))) ;

          B(I,G,"OTHER")$B(I,G,'CAPITAL') = 1 -  B(I,G,"CAPITAL") ;




*  SETTING THE  SCALE PARAMETER BY TOTAL OUTPUT


  A1(I,G,"FX")$XX(I,G,"FX") =  (SUM(J1$(B(I,G,J1) AND
  X(I,G,J1) )
  ,B(I,G,J1) *  ((X(I,G,J1))** ETA1(I,G)))** GAM1(I,G)) ;


  A1(I,G,"VAR")$XX(I,G,"VAR") =  (SUM(J2$(B(I,G,J2) AND
               X(I,G,J2) ), B(I,G,J2)*
              ((X(I,G,J2))** ETA2(I,G)))** GAM2(I,G)) ;



   A(I,G,"FX")$(XX(I,G,"FX") AND A1(I,G,"FX")) = XX(I,G,"FX") / A1(I,G,"FX") ;




   A(I,G,"VAR")$(XX(I,G,"VAR") AND A1(I,G,"VAR")) =
                     XX(I,G,"VAR")/A1(I,G,"VAR") ;

* DISPLAY   B,A,A1,BETA,CON,XX,CS;
  DISPLAY   FLG,RHSW,RHS2 ;
*****************************************************************
**   CALCULATE THE PMP COST FUNCTION COEFFICIENTS
```

```
   PARAMETER    ALPH(I,G,J)    COST INTERCEPT
                GAM(I,G,J)     COST SLOPE ;

   ALPH(I,G,J) = C(I,G,J) - LU(I,G,J) + LL(I,G,J) ;
   GAM(I,G,J)$((LU(I,G,J) NE 0) AND( X(I,G,J) NE 0) )  =
             (2* LU(I,G,J))/X(I,G,J) ;
   ALPH(I,G,'WATER ' )  = 0.0 ;

  DISPLAY  ALPH, GAM ;

*****************************************************************

*       CES     PROGRAMMING SOLUTION FOR BASE YEAR

*****************************************************************


 VARIABLES  XN(I,G,J) RESOURCE ALLOCATION
            XW(G,W)  REGIONAL WATER SOURCES
            TPROFIT  TOTAL PROFIT ;

 POSITIVE VARIABLE XN;

 EQUATIONS
          INPUTL(G,J)     LAND INPUTS
          INPUTW(G,J)     WATER INPUTS
          WATCON(G,W)    WATER CONSTRAINT
          PROFIT        PROFIT DEFINITION ;

 INPUTL(G,'LAND ')..    SUM(I, XN(I,G,'LAND ') )  =L= RHS2(G,'LAND ');

 INPUTW(G,'WATER ')..  SUM(I,XN(I,G,'WATER ')) =L= SUM(W, XW(G,W) );

 WATCON(G,W)..           XW(G,W)  =L= RHSW(G,W)  ;


 PROFIT.. TPROFIT =E=

   SUM(D,(INT(D)* SUM(I$MAP(I,D),  SUM(G, (CON(I,G)* (  BETA(I,G,"FX")

  *( A(I,G,"FX") * (SUM(J1$(X(I,G,J1) AND B(I,G,J1)), B(I,G,J1)

 *((XN(I,G,J1)+0.0001)** ETA1(I,G)))**GAM1(I,G)))**ETA3(I,G)+BETA(I,G,"VAR")

 *(A(I,G,"VAR") * (SUM(J2$(X(I,G,J2) AND B(I,G,J2)), B(I,G,J2)*

 ((XN(I,G,J2)+0.0001)** ETA2(I,G)))** GAM2(I,G)))**ETA3(I,G)  )** GAM3(I,G)) )))


   + 0.5*PHI(D)*SQR(  SUM(I$MAP(I,D),  SUM(G, (CON(I,G)* (  BETA(I,G,"FX")

  *( A(I,G,"FX") * (SUM(J1$(X(I,G,J1) AND B(I,G,J1)), B(I,G,J1)

 *((XN(I,G,J1)+0.0001)** ETA1(I,G)))**GAM1(I,G)))**ETA3(I,G)+BETA(I,G,"VAR")

 *(A(I,G,"VAR") * (SUM(J2$(X(I,G,J2) AND B(I,G,J2)), B(I,G,J2)*

 ((XN(I,G,J2)+0.0001)** ETA2(I,G)))** GAM2(I,G)))**ETA3(I,G)  )** GAM3(I,G)) )
                                             )))
```

```
   -SUM((I,G), RMC(I,G)*  CON(I,G)* (  BETA(I,G,"FX")

  *( A(I,G,"FX") * (SUM(J1$(X(I,G,J1) AND B(I,G,J1)), B(I,G,J1)

 *((XN(I,G,J1)+0.0001)** ETA1(I,G)))**GAM1(I,G)))**ETA3(I,G)+BETA(I,G,"VAR")

 *(A(I,G,"VAR") * (SUM(J2$(X(I,G,J2) AND B(I,G,J2)), B(I,G,J2)*

 ((XN(I,G,J2)+0.0001)** ETA2(I,G)))** GAM2(I,G)))**ETA3(I,G) )** GAM3(I,G) )

   -SUM((I,G,J)$X(I,G,J),ALPH(I,G,J)*XN(I,G,J)
   + 0.5*GAM(I,G,J)*SQR(XN(I,G,J)))

  - SUM( (G,W), XW(G,W) * WATCST(G,W) )     ;

********************************************************************
* INITIAL VALUES
  XN.L(I,G,J)  =  X(I,G,J) ;

  XN.FX(I,G,J)$(X(I,G,J) EQ 0 ) = 0.0 ;

 MODEL PRODUCTION /INPUTL,INPUTW,PROFIT,WATCON/;

 SOLVE PRODUCTION USING NLP MAXIMIZING TPROFIT;


* DISPLAY  LINPROF.L,TPROFIT.L, TO;


* DISPLAY  INPUT.M,RESOURCE.M, XN.L,X  ;
********************************************************************
SET KR RESULTS COLUMNS /BASE,CES,PERCENTDIF/;

PARAMETER RESULTS(I,G,J,KR) RESOURCE ALLOCATION SUMMARY;

 RESULTS(I,G,J,"BASE") = X(I,G,J);
 RESULTS(I,G,J,"CES") = XN.L(I,G,J);
 RESULTS(I,G,J,"PERCENTDIF")$X(I,G,J) =
    ((XN.L(I,G,J) - X(I,G,J)) / X(I,G,J))*100;

OPTION RESULTS:3:3:1;
DISPLAY RESULTS;

*----------------------------------------------------------------------*

PARAMETERS  PRI(D)     MARKET PRICE
            PRO(I,G)   REGIONAL PRODUCTION PER ACTIVITY
            QA(D)      COMMODITY PRODUCTION
            CST(I,G)   REGIONAL COST PER ACTIVITY
            PSUR(I,G)  REGIONAL PRODUCER SURPLUS PER ACTIVITY
            PS(G)      PRODUCER SURPLUS
            CSUR       CONSUMER SURPLUS CHECK
            CS         CONSUMMER SURPLUS;

 PRO(I,G) =   CON(I,G)* (  BETA(I,G,"FX")

  *( A(I,G,"FX") * (SUM(J1$(X(I,G,J1) AND B(I,G,J1)), B(I,G,J1)

 *((XN.L(I,G,J1)+0.0001)** ETA1(I,G)))**GAM1(I,G)))**ETA3(I,G)+BETA(I,G,"VAR")
```

```
*(A(I,G,"VAR") * (SUM(J2$(X(I,G,J2) AND B(I,G,J2)), B(I,G,J2)*
((XN.L(I,G,J2)+0.0001)** ETA2(I,G)))** GAM2(I,G)))**ETA3(I,G) )** GAM3(I,G) ;

QA(D) = SUM(I$MAP(I,D), SUM(G,PRO(I,G))) ;

PRI(D) =
   INT(D) + PHI(D) * QA(D) ;

CST(I,G) = SUM(J, XN.L(I,G,J) * C(I,G,J) )
             + XN.L(I,G,"WATER") * WATCST(G,"SWATER")   ;

PSUR(I,G) =
   (SUM(D $MAP(I,D), PRI(D)) - RMC(I,G)) * PRO(I,G) - CST(I,G);

PS(G) =
  SUM(I, PSUR(I,G));

CSUR = SUM(D, 0.5*(INT(D)- PRI(D)) * QA(D)) ;

*  CS  =  TPROFIT.L - SUM(G, PS(G)) ;

DISPLAY PRI, PRO, QA, PSUR, PS, CSUR ;

*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*

* SUMMARY : TOTAL ACRES BY REGIONS AND CROP GROUPS

PARAMETERS  GRAC(G,GR) REGIONAL CROP-GROUPS ACRES;

 GRAC(G,GR) =
   SUM(I$MAP1(I,GR), XN.L(I,G,"LAND"));

OPTION GRAC:0;

DISPLAY GRAC;
```

APPENDIX C

County Crop Yields for 1990 Under Alternative Ozone Standards
(Lbs per Acre)

Crop	County	1990	0.04ppm	0.025ppm
ALFALFA	HALAMEDA	11059	11402	11402
ALFALFA	HAMADOR	1024	1076	1137
ALFALFA	HBUTTE	21461	22555	22676
ALFALFA	HCOLUSA	76500	80398	80830
ALFALFA	HCONTRA CO	19500	20030	20030
ALFALFA	HFRESNO	714000	750386	801734
ALFALFA	HGLENN	111118	116781	117407
ALFALFA	HHUMBOLDT	840	856	856
ALFALFA	HIMPERIAL	1874050	1950804	1950804
ALFALFA	HINYO	24660	25917	27597
ALFALFA	HKERN	875000	919591	1004921
ALFALFA	HKINGS	307586	323261	333435
ALFALFA	HLAKE	1500	1528	1528
ALFALFA	HLASSEN	156300	164265	169139
ALFALFA	HLOS ANGEL	53400	56121	64794
ALFALFA	HMADERA	239440	251642	264135
ALFALFA	HMERCED	538800	566258	573289
ALFALFA	HMODOC	118250	124276	127964
ALFALFA	HMONO	38500	40462	41958
ALFALFA	HMONTEREY	17300	17343	17343
ALFALFA	HPLUMAS	17545	18439	18538
ALFALFA	HRIVERSIDE	404451	421016	421016
ALFALFA	HSACRAMENT	55300	58118	61369
ALFALFA	HSAN BENIT	19520	20367	20367
ALFALFA	HSAN BERNA	127000	133472	136900
ALFALFA	HSAN JOAQU	428000	448094	448094
ALFALFA	HSAN LUIS	22680	23221	23221
ALFALFA	HSANTA BAR	27877	29000	29000
ALFALFA	HSANTA CLA	5600	5843	5843
ALFALFA	HSHASTA	65000	68312	70340
ALFALFA	HSIERRA	1743	1832	2008
ALFALFA	HSISKIYOU	372735	391730	403353
ALFALFA	HSOLANO	99360	101893	101893
ALFALFA	HSTANISLAU	264000	277454	280899
ALFALFA	HSUTTER	33099	34786	34973
ALFALFA	HTEHAMA	28600	30058	30219
ALFALFA	HTRINITY	300	306	306
ALFALFA	HTULARE	945000	993159	1057770
ALFALFA	HYOLO	208080	218684	219835
ALFALFA	HYUBA	5569	5853	5884
ALFALFA	SFRESNO	11654	12248	13086
ALFALFA	SGLENN	107	112	113
ALFALFA	SIMPERIAL	2843	2959	2959
ALFALFA	SKINGS	6353	6677	6887
ALFALFA	SLASSEN	169	178	183
BEANS-DRY	BUTTE	4606	5155	5322
BEANS-DRY	COLUSA	9880	11056	11415
BEANS-DRY	FRESNO	13900	15555	19162
BEANS-DRY	GLENN	5383	6024	6219
BEANS-DRY	KERN	15100	16899	22468

BEANS-DRYKINGS	2037	2280	2496
BEANS-DRYMADERA	4180	4678	5680
BEANS-DRYMERCED	5200	5820	6277
BEANS-DRYMONTEREY	2260	2260	2260
BEANS-DRYORANGE	536	600	1168
BEANS-DRYRIVERSIDE	231	259	292
BEANS-DRYSACRAMENT	1450	1623	1808
BEANS-DRYSAN JOAQU	38920	43555	43896
BEANS-DRYSAN MATEO	75	75	75
BEANS-DRYSANTA BAR	3558	3914	3914
BEANS-DRYSANTA CLA	1062	1173	1173
BEANS-DRYSOLANO	14625	15585	15585
BEANS-DRYSTANISLAU	39150	43812	46928
BEANS-DRYSUTTER	15104	16903	17451
BEANS-DRYTEHAMA	885	990	1022
BEANS-DRYTULARE	16000	17905	21879
BEANS-DRYVENTURA	9061	10140	11866
BEANS-DRYYOLO	3416	3823	3976
CANTALOUPFRESNO	351000	402350	553565
CANTALOUPIMPERIAL	145428	163710	163710
CANTALOUPKERN	31800	36452	54063
CANTALOUPKINGS	15563	17840	21384
CANTALOUPMERCED	55530	63654	70772
CANTALOUPORANGE	28	32	33
CANTALOUPRIVERSIDE	30347	34787	41754
CANTALOUPSAN BERNA	211	242	310
CANTALOUPSTANISLAU	15600	17882	19632
CORN-SWEECONTRA CO	5090	5215	5215
CORN-SWEEHUMBOLDT	48	48	48
CORN-SWEEKINGS	6034	6242	6533
CORN-SWEELOS ANGEL	3233	3344	3565
CORN-SWEEORANGE	2842	2904	2904
CORN-SWEERIVERSIDE	34943	36146	36508
CORN-SWEESACRAMENT	1600	1655	1751
CORN-SWEESAN BERNA	1093	1131	1179
CORN-SWEESAN DIEGO	1800	1860	1860
CORN-SWEESANTA CLA	7425	7681	7703
CORN-SWEESUTTER	557	574	574
CORN-SWEEVENTURA	6857	7093	7252
COTTON FRESNO	251000	267779	356673
COTTON IMPERIAL	7914	8372	9503
COTTON KERN	188000	200567	282055
COTTON KINGS	140771	150181	183632
COTTON MADERA	25771	27494	35872
COTTON MERCED	44500	47475	56908
COTTON RIVERSIDE	9388	9931	11272
COTTON TULARE	79448	84759	111808
GRAPES-ALALAMEDA	3435	3705	3705
GRAPES-ALAMADOR	5643	6205	7404
GRAPES-ALCALAVERAS	360	396	405
GRAPES-ALCONTRA CO	2130	2279	2279
GRAPES-ALEL DORADO	2645	2909	3824
GRAPES-ALFRESNO	1964950	2160765	2655960
GRAPES-ALKERN	619085	680779	888862
GRAPES-ALKINGS	33159	36464	40856
GRAPES-ALLAKE	7900	8268	8268
GRAPES-ALMADERA	706749	777179	934785
GRAPES-ALMARIPOSA	94	103	113
GRAPES-ALMENDOCINO	39779	39840	39840
GRAPES-ALMERCED	132712	145938	159134

GRAPES-ALMONTEREY	100076	100694	100694
GRAPES-ALNAPA	114304	119247	119247
GRAPES-ALNEVADA	527	580	762
GRAPES-ALPLACER	247	272	325
GRAPES-ALRIVERSIDE	100881	110934	121302
GRAPES-ALSACRAMENT	37200	40907	48804
GRAPES-ALSAN BENIT	6570	7225	7318
GRAPES-ALSAN BERNA	4114	4524	4947
GRAPES-ALSAN DIEGO	400	440	486
GRAPES-ALSAN JOAQU	353500	388728	397123
GRAPES-ALSAN LUIS	35942	38138	38138
GRAPES-ALSANTA BAR	30729	33791	33964
GRAPES-ALSANTA CLA	3875	4262	4290
GRAPES-ALSANTA CRU	240	250	250
GRAPES-ALSOLANO	7702	8206	8206
GRAPES-ALSONOMA	111921	112093	112093
GRAPES-ALSTANISLAU	168000	184742	201448
GRAPES-ALTULARE	523480	575647	702434
GRAPES-ALYOLO	7905	8693	9093
GRAPES-RAFRESNO	1541000	1694567	2082920
GRAPES-RAKERN	208085	228822	298762
GRAPES-RAKINGS	19202	21116	23659
GRAPES-RAMADERA	220000	241924	290984
GRAPES-RAMERCED	9812	10790	11766
GRAPES-RASAN BERNA	25	28	30
GRAPES-RATULARE	246530	271098	330808
GRAPES-TAFRESNO	77200	84894	104349
GRAPES-TAKERN	160000	175945	229723
GRAPES-TAKINGS	4247	4671	5233
GRAPES-TAMADERA	38717	42576	51209
GRAPES-TARIVERSIDE	93806	103154	136199
GRAPES-TASAN BERNA	2288	2516	2751
GRAPES-TASAN JOAQU	17500	19244	19660
GRAPES-TATULARE	175800	193319	235898
GRAPES-WIALAMEDA	3435	3705	3705
GRAPES-WIAMADOR	5643	6205	7404
GRAPES-WICALAVERAS	360	396	405
GRAPES-WIFRESNO	346750	381305	468691
GRAPES-WIKERN	251000	276013	360378
GRAPES-WIKINGS	9710	10678	11964
GRAPES-WILAKE	7900	8268	8268
GRAPES-WIMADERA	448032	492681	592592
GRAPES-WIMARIPOSA	94	103	116
GRAPES-WIMENDOCINO	39779	39840	39840
GRAPES-WIMERCED	122900	135148	147369
GRAPES-WIMONTEREY	100076	100694	100694
GRAPES-WINAPA	114304	119247	119247
GRAPES-WINEVADA	527	580	762
GRAPES-WIRIVERSIDE	7075	7780	8507
GRAPES-WISACRAMENT	37200	40907	48804
GRAPES-WISAN BENIT	6570	7225	7318
GRAPES-WISAN BERNA	1801	1981	2166
GRAPES-WISAN DIEGO	400	440	486
GRAPES-WISAN JOAQU	336000	369484	377463
GRAPES-WISAN LUIS	35942	38138	38138
GRAPES-WISANTA BAR	30729	33791	33964
GRAPES-WISANTA CLA	3875	4262	4290
GRAPES-WISANTA CRU	240	250	250
GRAPES-WISOLANO	7702	8206	8206
GRAPES-WISONOMA	111921	112093	112093

GRAPES-WI	STANISLAU	168000	184742	201448
GRAPES-WI	TULARE	101150	111230	135729
GRAPES-WI	YOLO	7905	8693	9093
LEMONS	FRESNO	11360	11999	12641
LEMONS	IMPERIAL	9632	10174	10409
LEMONS	KERN	32000	33800	35849
LEMONS	ORANGE	10942	11558	11819
LEMONS	RIVERSIDE	69422	73328	75022
LEMONS	SAN BERNA	1361	1438	1545
LEMONS	SAN DIEGO	47900	50595	52350
LEMONS	SAN LUIS	14797	15630	15780
LEMONS	SANTA BAR	18517	19559	19847
LEMONS	TULARE	38800	40983	42996
LEMONS	VENTURA	356922	377003	392894
LETTUCE	FRESNO	282600	282605	285420
LETTUCE	IMPERIAL	427856	427857	427913
LETTUCE	KERN	146300	146302	148817
LETTUCE	MONTEREY	1414307	1414311	1414311
LETTUCE	ORANGE	11249	11249	11321
LETTUCE	RIVERSIDE	212850	212850	212850
LETTUCE	SACRAMENT	250	250	250
LETTUCE	SAN BENIT	67671	67672	67682
LETTUCE	SAN BERNA	534	534	543
LETTUCE	SAN LUIS	205830	205831	205831
LETTUCE	SANTA BAR	154474	154476	154496
LETTUCE	SANTA CLA	15825	15825	15842
LETTUCE	SANTA CRU	104347	104347	104347
LETTUCE	STANISLAU	3740	3740	3750
LETTUCE	VENTURA	79300	79301	79375
ONIONS	CONTRA CO	277	289	289
ONIONS	FRESNO	379400	409785	422979
ONIONS	IMPERIAL	207152	218149	218149
ONIONS	KERN	156500	169034	194130
ONIONS	LOS ANGEL	38800	41908	51090
ONIONS	MODOC	29942	31809	31809
ONIONS	MONTEREY	5905	5938	5938
ONIONS	ORANGE	463	469	469
ONIONS	RIVERSIDE	20795	22429	22429
ONIONS	SAN BENIT	20317	21944	22022
ONIONS	SAN BERNA	111	114	114
ONIONS	SAN JOAQU	31800	32215	32215
ONIONS	SANTA CLA	4550	4741	4741
ONIONS	SISKIYOU	10164	10798	10798
ONIONS	STANISLAU	16600	17612	17612
ORANGES	BUTTE	684	743	743
ORANGES	FRESNO	310800	343267	372576
ORANGES	IMPERIAL	5607	6132	6132
ORANGES	KERN	255500	282190	317253
ORANGES	MADERA	52512	57997	60896
ORANGES	ORANGE	77485	84656	84656
ORANGES	RIVERSIDE	256895	283731	321975
ORANGES	SAN BERNA	66116	73023	90740
ORANGES	SAN DIEGO	141200	155950	158694
ORANGES	SAN LUIS	1101	1175	1175
ORANGES	TULARE	1291000	1425861	1519954
ORANGES	VENTURA	195311	215714	226270
POTATOES	HUMBOLDT	7974	7979	7979
POTATOES	KERN	421800	495412	495412
POTATOES	MODOC	129884	147403	147403
POTATOES	MONTEREY	20000	20011	20011

POTATOES	RIVERSIDE	76749	98926	98926
POTATOES	SAN JOAQU	32550	35137	35137
POTATOES	SISKIYOU	161386	183154	183154
RICE	BUTTE	372408	382179	383736
RICE	COLUSA	334628	343408	344807
RICE	FRESNO	19800	20319	21391
RICE	GLENN	244177	250584	251604
RICE	KERN	1850	1898	2035
RICE	MERCED	19700	20217	20579
RICE	PLACER	48200	49465	51384
RICE	SACRAMENT	39340	40372	42153
RICE	SAN JOAQU	19800	20319	20420
RICE	STANISLAU	9040	9277	9443
RICE	SUTTER	271631	278759	279894
RICE	TEHAMA	3900	4002	4019
RICE	YOLO	97000	99545	100807
RICE	YUBA	116834	119900	120388
SILAGE	CONTRA CO	10500	10536	10536
SILAGE	FRESNO	293000	294306	302476
SILAGE	GLENN	72000	72321	72490
SILAGE	HUMBOLDT	1136	1136	1136
SILAGE	KERN	281000	282253	293563
SILAGE	KINGS	308265	309639	312532
SILAGE	MADERA	129200	129776	132747
SILAGE	MARIN	25239	25239	25239
SILAGE	MERCED	1511000	1517737	1527448
SILAGE	RIVERSIDE	17302	17379	17815
SILAGE	SACRAMENT	187000	187834	191716
SILAGE	SAN BERNA	40300	40480	41745
SILAGE	SAN DIEGO	1365	1371	1388
SILAGE	SAN JOAQU	782000	785487	787111
SILAGE	SANTA BAR	23518	23623	23637
SILAGE	SISKIYOU	7950	7985	8074
SILAGE	SONOMA	58871	58888	58888
SILAGE	STANISLAU	1294000	1299769	1308086
SILAGE	SUTTER	70000	70312	70477
SILAGE	TEHAMA	9425	9467	9489
SILAGE	TULARE	2010000	2018962	2069202
SILAGE	YUBA	21360	21455	21505
SORGHUM	GGLENN	3680	3686	3687
SORGHUM	GKERN	1820	1823	1841
SORGHUM	GMERCED	184	184	185
SORGHUM	GSAN JOAQU	462	463	463
SORGHUM	GSOLANO	367	367	367
SORGHUM	GSUTTER	2005	2008	2016
SORGHUM	GTULARE	8100	8112	8162
SORGHUM	GYOLO	1056	1058	1059
SUGAR	BEEBUTTE	59597	60149	61252
SUGAR	BEECOLUSA	174800	176418	179654
SUGAR	BEEFRESNO	512000	521412	591061
SUGAR	BEEGLENN	238702	240911	245330
SUGAR	BEEIMPERIAL	1013555	1026449	1052238
SUGAR	BEEKERN	358000	364581	393560
SUGAR	BEEKINGS	19282	19636	21448
SUGAR	BEEMADERA	37200	37884	42531
SUGAR	BEEMERCED	365000	371710	399311
SUGAR	BEEMODOC	13639	13890	15067
SUGAR	BEEMONTEREY	108000	108257	108771
SUGAR	BEESACRAMENT	132000	133533	136598
SUGAR	BEESAN BENIT	34503	35137	36611

SUGAR BEESAN JOAQU	696000	708794	735069
SUGAR BEESANTA CLA	28084	28392	29009
SUGAR BEESOLANO	393104	397111	405126
SUGAR BEESTANISLAU	72800	74138	79643
SUGAR BEESUTTER	131590	132808	135244
SUGAR BEETEHAMA	3360	3422	3637
SUGAR BEETULARE	119000	121187	136955
SUGAR BEEYOLO	140150	141711	144833
TOMATOES-CONTRA CO	420	420	420
TOMATOES-FRESNO	127400	129427	129427
TOMATOES-HUMBOLDT	19	19	19
TOMATOES-IMPERIAL	15961	15961	15961
TOMATOES-KINGS	24000	24000	24000
TOMATOES-MERCED	82675	82809	82809
TOMATOES-MONTEREY	74286	74286	74286
TOMATOES-ORANGE	28935	29587	29587
TOMATOES-RIVERSIDE	2490	2491	2491
TOMATOES-SACRAMENT	7200	7237	7237
TOMATOES-SAN BERNA	120	123	123
TOMATOES-SAN DIEGO	114100	114126	114126
TOMATOES-SAN JOAQU	73800	73886	73886
TOMATOES-SANTA CLA	3350	3356	3356
TOMATOES-STANISLAU	67400	67738	67738
TOMATOES-SUTTER	223	224	224
TOMATOES-TULARE	10700	10775	10775
TOMATOES-COLUSA	683200	706887	706887
TOMATOES-CONTRA CO	130000	132250	132250
TOMATOES-FRESNO	3692000	3847568	3993811
TOMATOES-IMPERIAL	334900	344084	344084
TOMATOES-KERN	170000	177163	187157
TOMATOES-KINGS	90090	93886	94680
TOMATOES-MERCED	240000	250113	250764
TOMATOES-MONTEREY	90000	90321	90321
TOMATOES-ORANGE	7400	7608	7608
TOMATOES-RIVERSIDE	28281	29057	29057
TOMATOES-SACRAMENT	219000	228228	234643
TOMATOES-SAN BENIT	128413	132211	132211
TOMATOES-SAN JOAQU	871000	895516	895516
TOMATOES-SANTA BAR	13598	13803	13803
TOMATOES-SANTA CLA	60800	62532	62532
TOMATOES-SOLANO	615731	625560	625560
TOMATOES-STANISLAU	365000	378750	378750
TOMATOES-SUTTER	439992	455247	455247
TOMATOES-YOLO	1713000	1770495	1770495
WHEAT AMADOR	328	353	353
WHEAT BUTTE	30680	31022	31022
WHEAT COLUSA	95040	95040	95040
WHEAT CONTRA CO	6220	6220	6220
WHEAT FRESNO	152241	166612	167903
WHEAT GLENN	73769	73769	73769
WHEAT IMPERIAL	167375	175621	175621
WHEAT KERN	90400	98934	103954
WHEAT KINGS	156323	171079	172005
WHEAT LAKE	210	210	210
WHEAT LASSEN	1000	1094	1126
WHEAT MADERA	72020	77003	77003
WHEAT MERCED	39300	39634	39634
WHEAT MODOC	5283	5782	5947
WHEAT MONTEREY	1460	1506	1506
WHEAT RIVERSIDE	21597	23636	23949

WHEAT	SACRAMENT	88092	89489	89489
WHEAT	SAN BENIT	7200	7732	7732
WHEAT	SAN JOAQU	173000	173000	173000
WHEAT	SAN LUIS	2915	2977	2977
WHEAT	SANTA BAR	562	602	602
WHEAT	SANTA CLA	8000	8592	8592
WHEAT	SHASTA	3655	3677	3677
WHEAT	SISKIYOU	29328	32097	32146
WHEAT	SOLANO	109656	109656	109656
WHEAT	STANISLAU	18900	19355	19355
WHEAT	SUTTER	44390	44650	44650
WHEAT	TEHAMA	11300	11366	11366
WHEAT	TULARE	158800	173790	176930
WHEAT	YOLO	163676	168765	168765
WHEAT	YUBA	4327	4352	4352