GIANNINI · FOUNDATION
OF AGRICULTURAL ECONOMICS
UNIVERSITY OF CALIFORNIA

Impacts on California Agriculture of a Ban on Rice Straw Burning

B. Delworth Gardner
Richard E. Howitt
Charles Goodman

Giannini Foundation Information Series No. 90-1
Division of Agriculture and Natural Resources
PRINTED OCTOBER 1990

The Giannini Foundation Information Series, initiated in 1963, publishes reports of timely interest for specific readerships. Reports are numbered serially within years. Single copies of this report may be ordered free of charge from Agriculture and Natural Resources Publications, 6701 San Pablo Ave., Oakland, CA 94608. Order by report number (Information Series 90-1).

Other publications of the Giannini Foundation and all current publications of foundation members are listed in the *Giannini Reporter* issued annually in the summer.

INTRODUCTION

The burning of agricultural residues, particularly rice straw, has long been an issue of public concern in California's Sacramento Valley. Especially during days of autumn temperature inversions, the smoke in the atmosphere from burning is regarded by some as a serious health hazard and by nearly all residents as a public nuisance. Strong pressures have resulted in stringent regulations over agricultural burning, but a growing number of voices advocate a strict prohibition on burning.

The prospect of a burning ban is worrisome to rice growers since burning is not only the most cost-effective way of disposing of the straw, but it also destroys organisms that cause rice diseases, particularly stem rot. Thus, it is argued that a ban on burning would reduce rice yields, increase production costs, and could threaten the economic viability of the California rice industry.

However, no one knows the total economic effects of a burning ban. This report makes a start in addressing the issue. Given what is known about the expected impacts on rice yields and the costs of growing and marketing rice absent residue disposal by burning, what shifts in rice and competing crops would occur? How would California farmer profits be affected? And what losses would be suffered by consumers from resulting higher rice prices?

Obviously, factors affecting the profitability of growing rice in California are complex and diverse. Especially critical are the world market for rice and the current income and price support policies of the federal government. Both have shifted significantly in recent years. Exports of California rice are much lower than in the 1970s and early 1980s, and world market prices are also much lower. Also, rice farmers get a much larger fraction of their incomes from direct government payments than they did in the 1970s and early 1980s. This changing context means that the burning ban issue must be considered within a broader economic and policy framework.

RICE IN THE CALIFORNIA AGRICULTURAL ECONOMY

California produces about 25 percent of the rice grown in the nation and ranks second to Arkansas as a rice-growing state (Rominger, 1986). About half of the state's production is exported, however. Approximately 65 percent of the rice grown in the state is medium grain, 25 percent is short grain, and 10 percent is long grain (Cook and Moore, 1986). Among the medium grains are varieties with very early, early, intermediate, and late maturities (California Rice Growers, 1984). All are short-statured varieties with a stem length less than 38 inches at maturity. However because more nitrogen is applied to the semi-dwarf varieties grown than would be economically feasible with long-stem varieties, the total amount of straw produced is about the same.

In recent years, rice has been California's third most valuable field crop after cotton and wheat. In 1984, the crop produced a gross farm value of $250 million and contributed $91 million to exports (Cook and Moore, 1986), down from a peak farm value in 1981 of $418 million and exports of $320 million.

Over 90 percent of the state's production is located in the Sacramento Valley. The most important rice-producing counties, in order of value of output, are Colusa, Butte, Glenn, Sutter, Yolo, and Sacramento.

Yields are higher in California than in other rice-growing states giving California has an absolute cost advantage per hundredweight (cwt) at the farm gate for all three grain lengths, even though California per-acre costs of production are higher (Cook and Moore, 1986). However, assembling, handling and milling costs are higher in California than in competing states like Arkansas and Louisiana, but drying costs are lower (Wailes and Holder, 1986).

Considering all cost aspects, including transportation costs to market, Cook and Moore (1986, p. 182) summarize:

> California-produced rice can be competitive in the states west of the Rocky Mountains; however, on the other side of the Continental Divide, our (California) rice is at a competitive disadvantage. There, we must rely on carving out a market niche for our medium-grain rice, looking for a price premium due to quality, taste, and label recognition.

Given this tenuous marketing situation, California rice producers must be sensitive to any technology or policy that will increase their costs and reduce their competitive position.

Although California is free from some of the serious pest problems which are troublesome in other rice growing regions, diseases do exist that can reduce yields significantly (California Rice Growers, 1984). The most important one associated with straw burning is stem rot, a fungus disease that invades the sheath and stem of the rice plant. Surveys indicate that stem rot causes a 5 to 8 percent loss in yield.

The organism that causes stem rot disease overwinters as sclerotia in loose straw or standing stubble. It floats to the top when rice fields are flooded in the spring and invades the rice seedlings. Burning in the fall, followed by moldboard plowing, is the most effective practice in preventing the disease (California Rice Growers, 1984). Delaying burning until spring is not as effective, both because stem rot losses are higher and because the straw is often not dry enough to get a good burn. However, when the fall harvest is late, it is difficult to burn before the winter rains; then growers burn in the spring.

Incorporating the straw residue into the soil significantly increases the amount of disease the following year. Removing the straw by cutting the stubble below the level of stem rot infection, baling it, and removing the loose straw can be just about as effective in controlling disease as burning, but this alternative is costly.

The Rice Research Board funded several research projects from 1979 until 1983 in an attempt to find economic uses for rice straw. Potential uses include feed for livestock, material for fiberboard, energy generation, conversion to sugar syrup and yeast protein, and making pulp for paper and for various industrial products (California Rice Growers, 1984). However, none of these appears to be economically feasible on a large scale.

The Rice Research Board has also supported research studies to find ways of reducing the quantity of smoke entering the atmosphere. These studies concluded that: (1) High moisture content increases smoke and, therefore, burning when the straw contains 12 percent or less moisture is recommended. (2) With clear weather and straw that has been spread, a field can be burned three days after harvest. (3) Burning between 10 a.m. and 5 p.m. produces the least smoke. (4) Burning against the wind produces about half as much smoke as burning with the wind. By using the appropriate burning procedures, reductions over preregulated burning methods can be as much as 80 percent for particulate matter, over 65 percent for gaseous hydrocarbons, and over 80 percent for carbon monoxide (California Rice Growers, 1984).

The next section describes the model used here to analyze the economic impacts of a burning ban. Some readers may wish to move directly to sections reporting results of the analysis.

THE CALIFORNIA AGRICULTURAL RESOURCES MODEL (CARM)[1]

CARM is a quadratic programming model designed to study the intrastate regional impacts of changes in product prices and input costs, policies, and resource constraints on the location, profitability, and production of the principal California crops. CARM does not provide unconditional long-range forecasts. Rather, it is most useful in answering "what-if" questions: e.g., What might happen in the short term if "A" occurs? Thus, CARM is intended to supplement other types of evaluations of agricultural issues. The model assesses the economic consequences of specific scenarios, such as the one under consideration here, a ban on rice straw burning. It does not and cannot make definitive policy judgments.

The maximand in the objective function is the sum of producer and consumer surpluses, a standard measure of net economic welfare. Producer surplus, as employed in CARM, essentially measures the difference between producer revenues and variable costs, so it also indicates profitability and contribution to producer wealth. Consumer surplus is a measure of the net benefits captured by consumers as prices change due to shifts in product supply.[2]

The objective function is quadratic in revenue and cost because it maximizes the area between linear demand and supply curves. The model implicitly assumes a competitive economic system where individual consumers and producers are price takers, i.e., they do not individually influence the prices of what they buy and sell.

Linear demand and supply curves were chosen because they meet a minimum standard of plausibility consistent with a manageable computational burden and available data. The statewide demands correspond to the market demand curves of a competitive industry, with the regional supply curves being associated with price-taking firms operating within such a system.[3] The regional cost functions consist of linear and nonlinear portions, reflecting increasing costs with rising production of a given activity. For example, costs increase when operations expand onto less suitable lands.

The objective function incorporates farmers' assumed behavior of generating an economically efficient product mix at least cost (given production and market conditions). Accurate calibration will occur only when what is optimal from

---

[1] The material in this section is discussed more fully in Howitt and Gardner (1986).

[2] It should be explicitly recognized that the important matter of health care costs and even nuisance costs associated with straw burning are not considered here. Although important, these matters were beyond the scope of this study. Thus, this analysis must not be construed as a complete welfare analysis of the effects of a burning ban.

[3] This point deserves some elaboration. Even though individual farmers are price takers and face perfectly elastic demand curves consistent with a perfectly competitive market, the demand curves facing the aggregate industry at the state level are not perfectly elastic. Therefore, CARM utilizes demand curves that have some slope, meaning that larger quantities of a commodity can only be sold at a lower price. In the case of rice, California producers supply a significant portion of rice in the markets they serve, particularly the export markets. Thus, the assumption of some slope in the demand function is quite appropriate.

the farmer's point of view also is considered optimal from the model's point of view. Thus, the positive quadratic programming methods utilized in CARM employ declining marginal revenue functions and replicate farmer reactions without excessive use of *ad hoc* constraints.

Howitt and Mean (1985) developed a method for estimating empirically the unknown supply relations by calibrating a base-year cropping pattern without additional constraints. A rational farmer maximizes profits by equating price with rising marginal costs due to declining marginal physical products and increasing risks. The combined effects of these assumptions are implied in the farmer's crop-allocation decision, and the model treats these relationships as an implicit cost function. Then, a second unconstrained run of the model will exactly replicate the base-year cropping pattern. With the regional crop constraints relaxed and with quadratic revenue and cost functions incorporated, the model will respond to alternative scenarios in a gradual manner, without the inbred volatility characteristics of many linear models.

CARM divides the state into 17 reasonably homogeneous agricultural production regions (Figure 1). Because data are available at the county level, county boundaries are generally followed except when a more homogeneous specification is needed. About 94 percent of the state's rice is grown in Region 5.

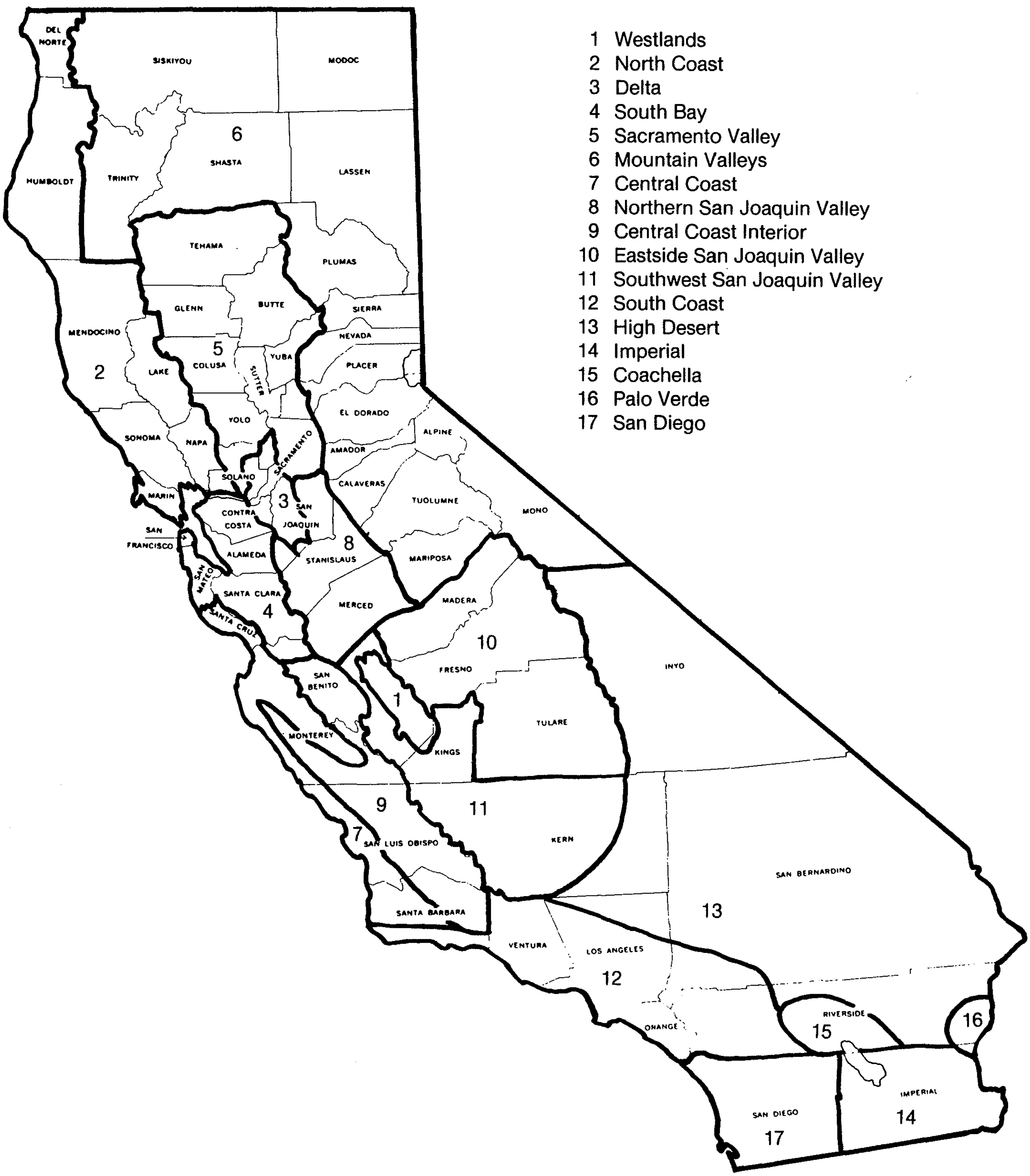
The CARM regional data base was developed from the annual county agricultural commissioners reports. Conversion of the data base from a county to a regional basis involved estimation of the subcounty crop distributions for those counties spanning two or more CARM regions. The regional data base included a given crop if that region produced at least 1 percent of the state total for that crop, or 1,000 acres, whichever was smaller. The CARM crop list (Table 1) includes the significant annual field crops in California, as well as fruit and nut crops and important short-term perennials, such as alfalfa hay and irrigated pasture. The 47 annual crops included in the model accounted for roughly 95 percent of the state's acreage and crop value in 1986.

Table 1. CARM Crops

Alfalfa Hay	Lettuce
Alfalfa Seed	Green Limas-Processing
Almonds	Nectarines
Apples	Oats
Apricots	Olives
Asparagus	Onions-Dry
Avocados	Oranges
Barley-Dryland	Pasture-Irrigated
Barley-Irrigated	Peaches
Beans-Dry	Pears
Broccoli	Plums
Cantaloupes	Potatoes
Carrots	Prunes
Cauliflower	Pistachios
Celery	Rice
Corn-Field	Safflower
Cotton	Silage-Corn
Grain Hay	Sugar Beets
Grain Sorghum	Tomatoes-Fresh
Grapefruit	Tomatoes-Processing
Grapes-Raisin	Walnuts
Grapes-Table	Wheat-Dryland
Grapes-Wine	Wheat-Irrigated
Lemons	

CARM uses arithmetic means of prices and yields of various crops for each region, averaged over the years 1973-77, except for the prices of fruit and nut crops. Because these crops have more volatile prices, a 10-year mean was employed. Cost data were obtained from cost-of-production sheets developed at the county level by University of California Cooperative Extension, and from crop budgets developed by the UC Davis Budget Generator program. Several other sources and expert

Figure 1. California Agricultural Resources Model (CARM)



personnel were consulted as checks on these cost data.

Right-hand side supplies of ground water, nitrogen fertilizer, fuel and labor were set at levels that ensured sufficient capacity. Land and ground water stocks and surface water supplies were estimated for each region from data obtained from government agencies, such as the U.S. Department of Agriculture Soil Conservation Service and the California Department of Water Resources.

The demand equations were developed and extended from earlier work by Adams (1979) and King, Adams, and Johnston (1978). A set of regression equations was estimated for each crop, where price was assumed to be a function of the real California crop price in 1978 dollars, California production in 1978, other U.S. production in 1978, real U.S. disposable personal income in 1978, and export exchange rates where appropriate. Most of the time series spanned the period 1969-1984.

CARM's programming tableau consists of 300 cropping activities and uses a nonlinear programming algorithm suitable for large, sparse matrices.

The ability of farmers to make cropping-pattern shifts in response to changes in crop profitability depends importantly on whether or not they are enrolled in government programs. Enrollment imposes a set-aside requirement that generally ranges between 10 and 35 percent of some historical base acreage. Under the Food Security Act of 1985 (FSA85), enrollment rates in California were much higher in 1986 and after, than they were under the previous farm bill. A majority of California farmers growing rice and cotton participated in federal programs, attracted especially by some new features of FSA85. Table 2 reports farmer and acreage enrollment figures in California program crops in 1986. Over 85 percent of the cotton acreage and 90.1 percent of the rice acreage was enrolled.[4] By 1988 virtually all rice and cotton acres were under their respective programs.

Table 2. Percentage of Enrollment in Commodity Farm Programs in California, 1986

Crop	Farms	Average
	Percent	
Wheat	29.4	53.8
Corn	22.7	40.7
Sorghum	18.3	34.9
Barley	22.5	46.8
Oats	20.2	36.3
Cotton	63.9	85.1
Rice	80.2	90.1

These enrolled producers are guaranteed the equivalent of the original loan rate as a minimum price for their program crops. In addition, they receive a deficiency payment representing the difference between the target price and market price or loan rate, whichever is higher, subject to a payment limitation of $50,000 per person. No firm data are available, but it is widely believed that the payment limitation is circumvented as farmers approach the limit. Farm entities are "created" by dividing acreages among family members or employees in such a way that each entity may receive up to the $50,000 payment limit (Nuckton, 1989). If this is true, then it is the target price that is guaranteed and therefore guides planting production decisions.[5] For this reason, we use the target price to represent the revenue received on all units of program crops produced. For those producers who elect to stay out of government programs, the relevant marginal price guiding production decisions is the expected market price which varies from year to year. Market prices utilized in this study were average annual California prices for the three years 1984-86, deflated by the Consumer Price Index. These estimated 1986 market prices and the target prices for the various program crops are found in Table 3.

[4] Some features of the FSA85 such as the 50/92 provision, Conservation Reserve Program, and the "sodbuster" and "swampbuster" programs have not been widely used in California and, therefore, will be ignored in the analysis.

[5] Minimum target prices for rice are $11.90 per cwt in 1986, $11.66 in 1987, $11.30 in 1988, $10.95 in 1989, and $10.71 in 1990. The target deficiency payment rate will be equal to the target price minus the average market price received by farmers during the first five months of the marketing year, or the loan rate, whichever is higher.

Table 3. Market and Target Prices Utilized in CARM Analysis of Rice Straw Disposal Alternatives

Crop	Average Market Price[a]	1986 Target Price
Barley	$2.53/bu	$2.60/bu
Corn	2.93/bu	3.03/bu
Cotton	0.653/lb	0.81/lb
Grain Sorghum	2.59/bu	2.88/bu
Oats	1.92/bu	1.60/bu
Rice	5.13/cwt	11.90/cwt
Wheat	3.42/bu	4.38/bu

[a] Average of 1984-86 California prices, put in 1986 dollars using the CPI index; prices used were from the California Crop and Livestock Reporting Service.

If the Secretary of Agriculture determines the supply of a program crop is excessive, an acreage reduction program (ARP), or a paid diversion program, or both, may be implemented. For rice, the Secretary must try to apply ARP such that the carryover will not be more than 30 million cwt. Acreage limitations cannot exceed 35 percent of the rice base acreage. The 35 percent ARP effective in 1986 is reflected in the acreage figures programmed by CARM.

Another attractive feature of the FSA85 was the marketing certificate program (USDA, 1986). To reduce the budgetary costs to the federal treasury, value-in-kind in government stocks were offered rather than dollar deficiency payments. Beginning August 1, 1986, the Commodity Credit Corporation made loan deficiency payments to rice farmers in the form of negotiable generic marketing certificates. Holders could exchange their certificates for commodities which they had pledged as collateral for a CCC price-support loan or for available commodities in CCC inventory. Active markets in certificates have developed so the holders can convert them into cash when desired.

Other Relevant Matters

In the Sacramento Valley, soils vary a great deal. Many of the heavy clay soils in the region are suitable only for rice. On the lighter soils, other crops can be economically substituted for rice as prices and costs change. CARM allocates acreage among crops on the basis of their economic profitability, not their agronomic suitability, so the latter must be handled as a constraint on the total area that can go to substitute crops. After consulting soil maps of the area, rice and soils specialists, and published reports, it was assumed that 40 percent of the soils in the rice area should be constrained to growing only rice, or possibly some irrigated pasture. Therefore CARM allocated land only between rice and pasture on this 40 percent. On the remaining 60 percent CARM allocated acreage among the crops on the CARM list if the profitability criterion so dictated.

Another matter is the cost of fallowing land in the event that farmers rotate fallow in their cropping regime and/or enroll in government programs that require them to set aside a portion of their base acreage. Extension farm advisors and rice growers in the area indicated that the annual costs of maintaining fallow rice land were $45 per acre. Fallow rice comes into play in the incorporation-rotation run discussed below.

If a ban on rice straw burning were imposed, what options do farmers have for disposing of their straw? Here we model several alternatives, although it must be emphasized that none is considered to be economically feasible on a broad scale in the rice-growing region. However, there is some justification for the selection of the various options and underlying assumptions.

Run 1: Incorporation with No Rotation and a Resulting Drop in Yields

One way of responding to a burning ban is to treat the rice crop like many other small grains and simply plow the rice straw back into the soil (incorporation). The most significant economic effects of incorporation are the costs of the practice itself and the decline in yields due to increased incidence of stem-rot disease. Both may be influenced by whether or not rice is rotated with other crops. For the incorporation runs, a per-acre cost of $26.15 was added to the cost of production to represent the cost of chopping the straw with a shear-bar chopper (University of California, UC, 1981, p. 60).

Experimental studies from a number of fields in the northern Sacramento Valley show that, over a nine-year period, yield losses after soil incorporation from stem-rot disease range from eight and 24 percent annually (UC, 1981, p. 19). Because of this large range we made two runs: The first (Run 1) assumes a 10 percent decline in rice yields in Region 5, and the second (Run 1a) assumes a 20 percent yield decline also in Region 5.

Run 2: Incorporation and Rotation with No Change in Rice Yield

If crops are rotated with rice, the stem-rot inoculum does not persist, and yields are not necessarily lower than those under a straw-burning regime (UC, 1981, p. 20) A Cooperative Extension farm adviser working in the region suggested wheat as the rotating crop followed by fallow and then rice.

Run 3: Straw Disposal Cost Added to Total Variable Costs

Run 3 assumes that rice farmers bear the cost of getting the straw off the field by picking it up, baling, collecting, and placing it on the roadside where it can be priced. These costs range between $20 and $25 per ton (UC, 1981, p. 67).[6] The midpoint of $22.50 per ton was selected and assuming a 3-ton per acre yield, the resulting cost would be $67.50 per acre. This amount was added to the variable costs of $380 per acre for growing rice in Region 5 in 1986.

Run 4: Disposal Cost Subtracted from Total Variable Cost

It is presently highly problematic that markets will develop for utilizing rice straw for building materials or in electrical co-generation, apparently the most promising alternative. However, a Massachusetts firm is planning a co-generation plant near Woodland that will use rice straw as one of the fuels. Preliminary discussions about the price paid for rice straw suggest about $30 per ton.

[6] It is assumed that these costs include the land costs used for storing the straw until it is disposed of.

Because of the conjectural nature of this option, particularly considering the tremendously large quantities of straw available each year, the model run was preformed mainly for comparative purposes. But many factors operate to change relative costs to rice farmers, so any such favorable development could produce results similar to those generated by this run. Accordingly, Run 4 assumes that the disposal cost added to variable cost in Run 3 is subtracted from variable cost for Run 4.[7]

[7] Subtracting the per acre rice-straw disposal costs from variable cost may be too heroic and, if so, makes this run more profitable than it should be compared to the base run. The net gains to farmers, compared to the base run, should be the difference between the revenues they get from the rice straw (approximately $90 per acre) and what it costs them to remove it (approximately $67.50). The difference ($22.50 per acre) is less than the removal costs ($67.50). However, if we assume that the farmer is legally obligated to remove the straw, whether or not a market exists, then the marginal benefits of a market for the straw would be the entire revenue ($90.00), which is more than the removal cost. Thus, the assumption used here of substracting only the removal costs ($67.50) from variable cost straddles the two figures ($22.50 and $90.00) that could have been used, depending on whether or not straw removal was legally mandated.

RESULTS

Results from the modeling effort will be presented as follows: (1) acreage shifts statewide and in Region 5 resulting from alternative responses following a burn ban, as represented by Runs 1 through 4; (2) a breakdown of the rice acreage response into two categories: (a) that in government programs and (b) that acreage which would remain out of government programs under the various scenarios; (3) the implied changes in the rice price under the several runs; (4) shifts in the use of selected factor inputs under the four scenarios; and (5) changes in producer and consumer surpluses resulting from the burning ban under the respective options.

Statewide Acreage Shifts Resulting from a Burning Ban

The principal anticipated effect of a ban on rice straw burning would be to make rice production relatively less profitable, unless a good market for the straw developed.

Table 4 reports the modeled statewide acreage shifts resulting from responses

Table 4. Statewide Acreage Shifts Attributable to Various Responses to Rice Straw Disposal Alternatives[a]

Crop	Base Acreage	Run 1 (yield down 10%) Acreage	% Chg	Run 1a (yield down 20%) Acreage	% Chg	Run 2 (incorpor-ation with rotation) Acreage	% Chg	Run 3 (straw disposal cost added) Acreage	% Chg	Run 4 (market-able rice straw) Acreage	% Chg
Alfalfa	1,021,029									1,017,240	-0.4
Alfalfa Seed	86,740	87,299	0.6	86,460	-0.3			89,070	2.7	85,675	-1.2
Almonds	418,204									417,121	-0.3
Apricots	20,515							20,573	0.3	20,340	-0.9
Barley-Dryland	251,510	252,781	0.5	250,516	-0.4			255,606	1.6	242,391	-3.6
Barley-Irrigated	180,496	181,834	0.7	179,794	-0.4	181,410	0.5	183,047	1.4	178,488	-1.1
Beans-Dry	158,835									158,136	-0.4
Corn	266,936							267,967	0.4	263,067	-1.4
Grain Hay	292,227	304,263	4.1	292,227	-0.8	299,922	2.6	329,732	12.8	270,904	-7.3
Grain Sorghum	27,941	28,864	3.3	27,110	-3.0	28,093	0.5	31,428	12.5	22,281	-20.3
Oats	29,944	30,496	1.8	29,646	-1.0	30,192	0.8	31,959	6.7	26,949	-10.0
Pasture-Irrigated	974,952			970,985	-0.4			984,590	1.0	955,743	-2.0
Prunes	69,913									69,668	-0.4
Rice	384,923	376,952	-2.1	400,528	4.1	304,824	-20.8	342,490	-11.0	489,822	27.3
Safflower	97,710							97,892	0.3	97,271	-0.4
Silage-Corn	143,097									142,508	-0.4
Sugar Beets	186,122									185,355	-0.4
Tomatoes-Processing	210,683									210,121	-0.3
Wheat-Dryland	186,847	187,610	0.4			187,341	0.3	188,721	1.0	182,982	-2.1
Wheat-Irrigated	548,896							552,139	0.6	544,558	-0.8

[a]If acreage changed by 0.3 percent or more crop was included in list.

incorporated in the various runs. The table includes changes in acreage only for those crops where the percentage change exceeded 0.3 percent.

Run 4, representing a decrease in the variable costs of rice production due to the assumed market demand for straw, produces the greatest changes in acreage. Rice acreage *increases* by 27.3 percent, or nearly 105,000 acres. Crops giving up significant acres to rice under this scenario are grain hay (21,323), irrigated pasture (19,209), dryland barley (9,119), grain sorghum (5,660), irrigated wheat (4,338), corn (3,869), dryland wheat (3,865), alfalfa (3,789), oats (2,995), irrigated barley (2,008), almonds (1,083), and alfalfa seed (1,065).[8]

Run 2 (incorporation and rotation) produces the next largest response in rice acreage, a 20.8 percent *reduction*, or a decline of just over 80,000 acres. The additional costs imposed by the rotation regime cuts into the profitability of growing rice relative to several substitute crops. Grain hay, barley, and dryland wheat are the largest acreage gainers.

Run 3 (an increase in the variable costs of rice production from collecting and transporting straw to the roadside) results in a *decline* of rice acreage of 11.0 percent, or 42,433 acres. Grain hay and grain sorghum gain significantly in acreage.

Runs 1 and 1a (rice straw incorporation with a 10 percent and 20 percent reduction in rice yield in Region 5, respectively) produce the smallest responses in rice acreage. Run 1 produces a 2.1 percent *decrease* while Run 1a *increases* rice acreage by 4.1 percent statewide. This unexpected result comes from the interplay of the relationships among yield, cost, price, acreage, and tonnage incorporated in this model.

As rice yields decline, the tonnage of production on a given acreage declines, the supply curve shifts to the left, and rice prices rise. In affecting per acre revenue, the price rise tends to partially offset the effect of cost increases due to the yield decline. In the case of Run 1 where the assumed decline in yield was 10 percent in Region 5, the increased per cwt revenue (from base $11.90 to $11.96, or 0.5 percent) was not enough to offset the increase in unit production costs (from base $5.12 to $5.89, or 15 percent). Thus, in the case of Run 1, the relative profitability of growing rice declined in Region 5. The slight increases in acreage in Regions 1, 3, 8, 10, and 11, which were

Table 5. Statewide Acres, Tonnage, and Yields of Rice—Computer Runs Base, 1 and 1a

	Land in Rice (acres)	Percent Change from Base	Production (tons)	Percent Change from Base	Yield (cwt/acre)	Percent Change from Base
Base	360,101		1,341,375		3.725	
Run 1 (10% yield loss)	346,904	-0.037	1,162,822	-0.133	3.352	-0.100
Run 1a (20% yield loss)	369,023	0.025	1,099,689	-0.180	2.980	-0.200

[8] The results assume that growers remain in the government programs under this scenario in the same proportions as they were in the base run. In reality, of course, they may opt to get out of the program, in which case the set-aside acreage could go into rice and other crops. We had no way of appraising the elasticity of remaining in the government programs given the assumptions of the various scenarios.

assumed not to be affected by the burning ban, were swamped by the decreases in Region 5. Therefore, rice acreage declined statewide. The significant gainers in acreage in Run 1 were grain hay and sorghum.

In the case of Run 1a, however, the increases in rice acreage in Regions 1, 3, 8, 10, and 11 in response to the higher rice price were larger than under Run 1. However, rice acreage also increases in Region 5 where the proportionate decline in production was slightly less than the decline in yield (Table 5). Therefore, a more extensive planting of stem rot-infested acres was needed to produce the optimal output. The large yield loss resulted in a tonnage reduction of 18.0 percent, far larger than the acreage increase of 2.5 percent (Table 5). The significant acreage losers statewide in Run 1a are pasture and barley.

In summary, what is evident in these statewide acreage data is that a ban on rice straw burning will result in substantial changes in rice acreage due to the substitution potential between rice and other crops. As expected, the crops most affected are pasture and other field crops, such as barley, wheat, corn, and sorghum. The crops which have high per-acre values, such as fruits, nuts, and even tomatoes and sugar beets, are not significantly affected.

Region 5 Acreage Shifts Resulting from a Burning Ban

Recall that Region 5 has approximately 94 percent of the state's rice acreage. For this reason, model results for Region 5 should not differ markedly from the statewide results (Table 6). However, some of the

Table 6. Region 5 Acreage Shifts Attributable to Various Responses to Rice Straw Disposal Alternatives[a]

Crop	Base Acreage	Run 1 (yield down 10%) Acreage	% Chg	Run 1a (yield down 20%) Acreage	% Chg	Run 2 (incorporation with rotation) Acreage	% Chg	Run 3 (straw disposal cost added) Acreage	% Chg	Run 4 (marketable rice straw) Acreage	% Chg
Alfalfa	69,393							70,337	1.4	67,524	-2.7
Alfalfa Seed	1,184	1,278	7.9	1,168	-1.4	1,244	5.0	1,481	25.1	588	-50.4
Almonds	92,406									91,109	-1.4
Apricots	1,405	1,439	2.4			1,428	1.6	1,475	5.0	1,193	-15.1
Barley-Dryland	30,043	30,364	1.1					31,085	3.5	27,957	-6.9
Barley-Irrigated	4,944	5,017	1.5			4,990	1.0	5,180	4.8	4,470	-9.6
Beans-Dry	49,670							50,211	1.1	48,592	-2.2
Corn	72,691							74,979	3.1	68,253	-6.1
Grain Hay	42,284	61,711	45.9	37,877	-10.4	55,794	32.0	97,071	129.6	0	-100.0
Grain Sorghum	11,698	12,141	3.8			11,980	2.4	13,105	12.0	8,902	-23.9
Oats	5,772	6,601	14.4	5,676	-1.7	6,323	9.5	8,359	44.8	1,319	-77.2
Pasture-Irrigated	150,193	153,677	2.3			152,589	1.6	161,033	7.2	128,240	-14.6
Rice	360,101	346,905	-3.7	369,023	2.5	270,661	-24.8	312,088	-13.3	473,625	31.5
Safflower	14,972							15,391	2.8	14,120	-5.7
Silage-Corn	14,015							14,187	1.2	13,672	-2.4
Sugar Beets	45,824									45,136	-1.5
Tomatoes-Processing	75,796									75,144	-1.0
Wheat-Dryland	88,761							89,918	1.3	85,457	-3.7
Wheat-Irrigated	139,979							141,808	1.3	135,420	-3.3

[a]If acreage changed by 1.0 percent or more crop was included in list.

percentage shifts within the region are considerably different from and are mostly larger than those at the state level. Table 6 includes acreages for crops that change by 1 percent or more from the base run under the various scenarios.

Run 4 (the favorable rice straw market) projects a large *increase* in rice acreage (31.5 percent), while Runs 2 and 3 project sizeable *decreases* (24.8 percent and 13.3 percent, respectively). Runs 1 and 1a show the same anomaly of a respective decrease and increase in rice acreage as described above at the statewide level and for the same reasons.

Crops that fluctuate in acreage to accommodate the shifts in rice acreage among the various runs are primarily pasture, grain hay (which moves sharply among the runs indicating that it must be a close substitute for rice in Region 5), dryland barley, dryland and irrigated wheat, and corn.

Rice Acreage In and Out of Government Programs

CARM also divides the government program crops into acreage that is expected to be under governmental support prices and that which is producing for the free market, receiving the world market price (Table 7). Table 7 also subdivides acreage between that on which substitute crops can be grown and that on which only rice (and some irrigated pasture) can be grown.

Base-year figures indicate that only about 7.7 percent of the acreage in Region 5 was producing for the free market in 1986. In all runs except 4 (the favorable rice straw market), the model predicts that 100 percent of the acreage will be under government support programs with the required set-asides. In the Run 4 scenario, however, 26.6 percent of the acreage under government programs returns to the free market. The model predicts that rice becomes so attractive with marketable rice straw that some farmers choose to forego government support payments in order to be free to plant all the rice acreage they desire.

The Market Price for Rice on the Base and Other Runs

Table 8 reports model predictions for the market price for rice under the base runs and the various alternative scenarios. All but Run 4 (marketable rice straw) produce a higher price than in the base year. In Run 4, rice is so profitable that more is produced so that the price falls from $5.13 per cwt in the base year to $4.97 per cwt, still only a modest decline.

Table 7. Region 5, Rice Acreage in and Out of the Government Program, Base Year and Various Runs

		Base 86	Run 1	Run 1a	Run 2	Run 3	Run 4
Substitutable Acreage	Covered by Program	199,424	191,725	213,844	162,397[a]	156,909	192,663
	Not Covered	16,637	0	0	0	0	125,784
Non-Substitutable Acreage	Covered by Program	132,949	155,179	155,719	108,264[b]	155,179	155,179
	Not Covered	11,091	0	0	0	0	0
Total Region 5 Rice Acreage	Covered by Program	332,373	346,904	369,023	270,661	312,088	347,841
	Not Covered	27,728	0	0	0	0	125,784
Statewide Rice Acreage		384,923	376,952	400,528	304,824	342,490	489,822

[a]In addition to this acreage in the rice program are 54,132 acres of fallow and 54,132 acres of wheat grown in rotation.
[b]In addition to this acreage in the rice program are 72,177 acres of fallow in rotation.

Table 8. Market Price for Rice in the Base Year and in Various Runs

	Price($/cwt)
Base Year	$5.13
Run 1 (yield down 10 percent)	5.19
Run 1a (yield down 20 percent)	5.22
Run 2 (incorporation with rotation)	5.25
Run 3 (straw disposal cost added)	5.19
Run 4 (marketable rice straw)	4.97

Levels of Selected Input Use for the Various Runs

CARM also projects the use level of several inputs: land in crops, labor, ground water, surface water, nitrogen, and fuel (Table 9). Except for ground water, the changes in input use are not significantly different from the base year. The percentage changes for Region 5 tend to be somewhat greater than for the state as a whole. However, the percentage of ground water used does change markedly from the base year in Run 2 (a 22.9 percent decrease—when rice production is cut back because of the high cost of rice straw disposal) and in Run 4 (a 20.9 percent increase—when rice straw can be profitably marketed). These percentage figures translate into 529,499 acre-feet less ground water utilized in Run 2 than in the base year and 482,637 acre-feet more in Run 4.

These substantial changes reflect that rice is a heavy user of water, so when acreage increases or is cut back ground water use changes accordingly.[9] If rice became less profitable as in Run 2 (or if government payments ended) and if the decrease in rice production persisted, ground water tables could rise, with the possibility of water-logged soils and other drainage problems. However, ground water could become available for other uses in the area and possibly for export to other areas if transfer restrictions were removed. The opposite situation would hold if rice profitability increased as in Run 4 and the favorable conditions were to persist over time. Ground water tables would then be drawn down, pumping costs would increase, and eventually—if additional surface water were not available—profitable agriculture could not be sustained without controls on ground water use. Such controls would then change the cropping patterns and the agricultural economy of the region.

Note that surface water utilization does not change from the base year in the various runs. This is not surprising in that surface water use is tightly controlled by legal and administrative rules that establish water rights and contracts. When demand for water shifts, it is usually ground water that takes up the slack. Model results confirm this.

Model Changes in Producer and Consumer Surpluses

In many ways the bottom line of the analysis is what might happen to the agricultural economy of the region and state if a ban on straw burning were to occur. Much depends on what happens to farmer incomes, which in turn has linkages to the products which farmers buy and sell. CARM calculates changes in what is known as "producer surplus,"

[9] A reviewer pointed out that 90 percent of California rice uses surface water from both federal and state projects and thus shifts in rice acreage may not produce the changes in ground water utilization indicated by the CARM results. The authors question this conclusion. The marginal costs of using surface water are lower than pumping ground water. Therefore, surface water supplies will likely be utilized first and ground water will be considered "residual," satisfying demands after surface supplies have been exhausted. Thus, shifting acreages of crops which have disparate water demands will shift utilization of ground water just as CARM assumes. Experience with droughts in the area, when ground water utilization expanded sharply, confirms this view.

Table 9. Levels of Selected Input Use in Base Year and for Various Runs—Region 5 and Statewide

Crop	Base Year	Run 1 (yield down 10%) Predicted	% Chg	Run 1a (yield down 20%) Predicted	% Chg	Run 2 (incorporation with rotation) Predicted	% Chg	Run 3 (straw disposal cost added) Predicted	% Chg	Run 4 (marketable rice straw) Predicted	% Chg
Land Used (1000 acres)											
Region 5	1,693,872	1,716,989	1.4	1,716,983	1.4	1,716,983	1.4	1,716,983	1.4	1,716,983	1.4
State	9,344,042	9,367,158	0.2	9,367,153	0.2	9,376,153	0.2	9,367,153	0.2	9,367,153	0.2
Labor Used (1000 hours)											
Region 5	28,320,771	27,999,798	-1.1	27,630,058	-2.4	27,259,275	-3.7	28,308,259	0.0	29,010,917	2.4
State	383,954,999	303,664,992	-0.1	383,263,106	-0.2	382,918,333	-0.3	384,021,134	0.0	381,375,650	0.2
Ground Water Used (1000 acre-feet)											
Region 5	2,313,790	2,280,523	-1.4	2,362,386	2.1	1,784,291	-22.9	2,160,336	-6.6	2,796,427	20.9
State	10,918,965	10,903,654	-0.1	10,979,333	0.6	10,411,705	-4.6	10,801,960	-1.1	11,392,818	4.3
Surface Water Used (1000 acre-feet)											
Region 5	3,060,000	3,060,000	0.0	3,060,000	0.0	3,060,000	0.0	3,060,000	0.0	3,060,000	0.0
State	18,013,688	18,018,878	0.0	18,015,392	0.0	18,023,943	0.1	18,006,146	0.0	17,977,221	-0.2
Total Water Used (1000 acre-feet)											
Region 5	5,373,790	5,340,523	-0.6	5,422,386	0.9	4,844,291	-9.9	5,220,336	-2.9	5,856,427	9.0
State	28,932,653	28,225,533	0.0	28,994,724	0.2	28,435,648	-1.7	28,808,106	-0.4	29,370,039	1.5
Nitrogen Used (1000 tons)											
Region 5	72,365	73,002	0.9	72,591	0.3	68,178	-5.8	73,617	1.7	74,538	3.0
State	405,537	406,282	0.2	405,822	0.1	401,565	-1.0	406,729	0.3	407,431	0.5
Fuel Used (1000 dollars)											
Region 5	34,826,140	34,317,880	-1.5	34,099,760	-2.1	32,303,400	-7.2	34,314,260	-1.5	37,194,674	6.8
State	210,680,015	210,274,653	-0.2	210,767,787	-0.3	208,307,239	-1.1	210,310,142	-0.2	212,912,766	1.1

which in essence represents changes in net income (revenues less the opportunity costs of production). The model also calculates changes in "consumer surplus," which represents the consumers' marginal valuations for a commodity above what they must pay for it. Table 10 reports producer surplus in Region 5 and for the state, and the statewide combined producer and consumer surpluses.

Region 5 rice farmers lose over $19.3 million in producer surplus under the conditions associated with Run 1 (10 percent yield loss) compared to the base-run conditions. Statewide, the loss is slightly less at about $19.1 million, for there are additional substitution possibilities at the state level that would reduce producer losses. The sharper yield losses (i.e., 20 percent) associated with Run 1a increases the producer surplus losses suffered by rice farmers to over $31.8 million in Region 5 and over $31.5 million statewide.

The crop rotation scenario (Run 2) has producer surplus losses approximating those of Run 1 with $18.8 million in Region 5 and $18.4 million statewide. In Run 3, where disposal costs are borne by the farmers, the loss is $22.1 million in Region 5 and $21.85 million statewide. But rice farmers gain producer surplus under conditions of Run 4 when they are paid for their rice straw. The gains are $27.3 million in Region 5 and $26.8 million statewide.

A better perspective can be obtained by calculating the changes in producer surplus per acre of rice grown. In Run 1, for example, with 346,904 acres of rice, the $19.3 million loss of producer surplus amounts to $43.20 per acre. A rice farmer with 1,000 acres of rice would lose some $43,204, not an inconsequential sum. If such losses in producer surplus occurred, there would be a sharp reduction in farmer wealth as land values would fall. Of course, the opposite conclusions would hold for Run 4 (marketable rice straw) where gains in producer surplus occur.

When rice prices fall, *ceteris paribus*, rice farmers lose producer surplus; but lower prices mean gains in surplus for consumers. Producer and consumer surpluses also change for all the substitute crops. Table 10 shows the combined effects on all producers and consumers from changes in rice and other crops in the various scenarios. Run 1 has a combined loss of $21 million; Run 1a, $35 million; Run 2, $20 million; Run 3, $22 million; and Run 4 a combined gain of $28 million.

Table 10. Region 5 and Statewide—Producer and Consumer Surplus in Base Year and for Various Runs

	Region 5 Rice Producer Surplus	Statewide Rice Producer Surplus	Statewide Consumer Producer Surplus
		---thousands---	
Base	$169,191	$176,020	$6,434,000
Run 1 (yield down 10 percent)	149,877	156,944	6,413,000
Run 1a (yield down 20 percent)	137,323	144,474	6,399,000
Run 2 (incorporation with rotation)	150,349	157,638	6,414,000
Run 3 (straw disposal cost added)	147,095	154,170	6,412,000
Run 4 (marketable rice straw)	196,466	202,825	6,462,000

SUMMARY AND CONCLUSIONS

This study analyzes the effects of a ban on burning rice straw in the principal rice-growing area of California. The California Agricultural Resources Model is utilized to project the effects of a ban on acreage, tonnage, and prices on rice and various other crops and on producer and consumer surpluses. Five alternative responses that farmers might make to a burning ban are considered: (1) incorporating the straw in the soil with an assumed rice yield reduction of 10 percent, (1a) incorporating with an assumed rice yield reduction of 20 percent, (2) rotating rice with fallow and wheat with no reduction in rice yields, (3) removing straw from the field with farmers bearing the removal costs, and (4) removing straw from the field with farmers receiving $30 per ton for the straw.

The principal findings of the modeling effort are:

- In all runs except 4, the model predicts that all of the rice acreage in the state will be grown under the government price support program. However, under Run 4, because of the very favorable per acre returns assumed and the high opportunity costs associated acreage set-asides required for participation in the government programs, 26.6 percent of the rice acreage returns to the free market.
- At the statewide level, a ban on rice straw burning in Region 5 can be expected to reduce the acreage in rice in Runs 1 (2.1 percent), 2 (20.8 percent), and 3 (11 percent), but will increase it in Runs 1a (4.1 percent) and 4 (27.3 percent). Model results show that rice acreage varies substantially under the assumptions of the various runs due to the substitution possibilities of rice with other crops. Those most affected are pasture and other field crops such as barley, wheat, corn, and sorghum. The large increase in rice acreage in Run 4 is associated with corresponding reductions in acreage of grain hay, irrigated pasture, and dryland barley. The rice acreage decline in Run 2 is associated with corresponding increases in grain hay, barley, and dryland wheat. High value per acre crops such as fruits, nuts, and tomatoes, are not significantly affected. Note, however, that Runs 1 and 1a are the most likely to actually occur, that the projected effects on rice acreage and on other crops are not large under those assumptions.
- The demand functions facing California growers are sufficiently elastic that acreage shifts among the various crops have little effect on market prices.
- In Region 5, land in crops, labor, surface water, nitrogen, and fuel utilized are not materially affected by the ban on rice straw burning, and existing supply conditions can easily accommodate any shifts in demand. However, ground water is one input that must be carefully monitored if a burning ban is imposed. Ground water demand is significantly affected by cropping patterns, and especially rice acreage. Were rice acreage to substantially decline, the demand for ground water would decline

and water tables in the area would rise, potentially creating drainage problems. On the other hand, were rice acreage to increase in the face of a very profitable market for rice straw, ground water tables would fall and pumping costs would increase.

- Even though acreage shifts may not be large under the most likely scenarios (1 and 1a), changes in producer and consumer surpluses could be significant. Per unit costs of producing rice would rise significantly if a ban on straw burning were imposed and rice farmers would lose between $19.3 million (Run 1) and $31.5 million (Run 1a) if incorporation is practiced. If rotation of rice with fallow and wheat is practiced, the loss in producer surplus in Region 5 would be $18.8 million, indicating that this might be the least costly way for farmers to respond to a burning ban.
- When changes in consumer surplus for California crop consumers are added to producer surplus, changes in the economic cost varies between $20 million (Run 2) and $35 million (Run 1a). Of course, producers and consumers gain in the unlikely event that a vigorous market develops for rice straw in the Region 5 area.

The analysis showed that a ban on rice straw burning will be costly to growers in the main rice growing regions. If no adjustments in crop rotation are made, regional average returns to land and management for producers will drop by 19 percent (Run 1a). However, if shifts in rotations are adopted, the cost to producers can be reduced by over a third, to an 11 percent drop in returns. Producers bear 94 percent of the costs of a burning ban, and given the current market, are only able to pass on six percent of the impact to rice consumers. Under the enrollment levels and program provisions in the 1986 base year, no savings in government program payments are predicted from the changed rice acreage.

The $20 million annual cost of a ban, using the least cost rotational alternative, should be weighed against the unintended health and aesthetic losses from lower air quality due to rice straw burning.

REFERENCES

Adams, R. M. *A Quadratic Programming Approach to the Production of California Field and Vegetable Crops Emphasizing Land, Water, and Energy Use.* Ph.D. thesis, Department of Agricultural Economics, University of California, Davis, 1979.

California Rice Growers. *1969-1984, Sixteen Years of Research Progress.* Sixteenth Annual Report to the California Rice Growers by the Rice Research Board, 1984.

Cony, Ann. "California Farmers Sign to 'Retire' Land in Conservation Program." *Sacramento Bee,* June 5, 1986.

Cook, M. L. and C. V. Moore. "The Rice Sector." In *Impacts of Farm Policy and Technological Change on U.S. and California Agriculture,* Harold O. Carter, ed. Proceedings of a symposium sponsored by the University of California, Agricultural Issues Center, June 2-3, 1986, pp. 173-195.

Howitt, R. E. and P. Mean. *Positive Quadratic Programming Models.* Working Paper No. 85-10, Department of Agricultural Economics, University of California, Davis, 1985.

Howitt, R. E. and B. Delworth Gardner. "Modeling Production and Resource Interrelationships among California Crops in Response to the 1985 Food Security Act." In *Impacts of Farm Policy and Technological Change on U.S. and California Agriculture.* Harold O. Carter, ed. Proceedings of a symposium sponsored by the University of California, Agricultural Issues Center, June 2-3, 1986, pp. 271-293.

King, Gordon A., Richard M. Adams, and Warren E. Johnston. *Selected California Vegetable and Field Crop Price-Forecasting Equations.* Unpublished supplement to *Some Effects of Alternative Energy Policies on California Crop Production.* University of California, Giannini Foundation of Agricultural Economics, Research Report No. 326, July 1978.

Nuckton, Carole Frank. "Farm Program Conflicts: The $50,000 Case." *Choices,* Fourth Quarter, 1989, pp. 34-35.

Rominger, Richard E. "Production Adjustment Issues." In *Impacts of Farm Policy and Technological Change on U.S. and California Agriculture.* Harold O. Carter, ed. Proceedings of a symposium sponsored by the University of California, Agricultural Issues Center, June 2-3, 1986, pp. 196-200.

Stucker, Barbara C. and Keith J. Collins. The Food Security Act of 1985. Economic Research Service, Agriculture Information Bulletin No. 497, U.S. Department of Agriculture, January 1986.

U.S. Department of Agriculture. Selected Speeches and News Releases, July 18-July 25, 1986, pp. 16-17.

University of California. *Agricultural Residue Management: A Focus on Rice Straw.* A Report of the Residue Management Task Force, August 1981.

Wailes, Eric J. and Shelby Holder. *A Study of the Spatial Organization of the U.S. Rice Industry.* University of Arkansas, Fayetteville, Staff Paper No. 1486, March 1986, pp. 20.