

Maintaining the Competitive Edge
in
California's Rice Industry
(Revised)



University of California
Agricultural Issues Center

April, 1994

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Contents

Preface	iv
Executive Summary	v
I. Introduction	1
II. The California Rice Industry	5
III. Demand for California Rice	11
IV. Supply Factors: Yields, Costs and Constraints	15
V. Rice Production and Natural Resource Use	23
VI. Future Competitiveness of California Rice	39

Preface

This is one of a series of Competitive Edge reports produced by the UC Agricultural Issues Center. These publications are designed to explore issues faced by selected California agricultural industries during the 1990's and beyond.

This report concerned with the California rice industry was prepared under the guidance of a joint UC-industry study group. Members of that group, who helped to plan the report and contributed extensively to it, are listed following the title page. Special thanks are due to Elmer Learn, who served as first chair of the study group and wrote much of the material on demand for rice; and to Charles V. Moore of the UC Center for Cooperatives who developed the section on supply and provided much information for the rest of the report.

Substantial contributions were made by UC Cooperative Extension staff working with the rice industry. We are particularly grateful to James Hill, Extension agronomist at the Davis campus; Steven C. Scardaci, rice farm advisor for Colusa, Glenn and Yolo Counties; and Jack Williams, rice farm advisor for Sutter-Yuba and Placer-Nevada Counties.

We also are grateful to the panel of reviewers for their careful consideration and many helpful suggestions. The reviewers were:

Colin Carter, Dept. of Agricultural Economics at UC, Davis.

Francis DuBois, retired rice grower and consultant.

Marshall Lee, Environmental Monitoring and Pest Management Branch, California Department of Pesticide Regulation. Lee also contributed substantially to the section on water quality.

David Long, President, Rice Growers Association of California.

Richard Rominger, Winters farmer and Deputy Secretary of Agriculture, USDA.

Henry Schacht, agricultural communicator and consultant.

Ray Coppock's efforts as writer and editor were essential in bringing this project to completion. Finally, much credit goes to Joyce Perz for her patience and skill in designing and producing the document.

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EXECUTIVE SUMMARY

Within global and U.S. rice markets, the California rice industry occupies a special niche. Because of this state's rice-growing conditions and advanced agricultural technology, growers here produce very high per-acre yields of high quality rice. This is the industry's chief competitive strength. California specializes in medium-grain, japonica-type rice, which provides a clear advantage in some markets and potential markets (Japan, for example), but not in others. Virtually all California rice is grown on certain areas of heavy soil in the Sacramento Valley.

Because California rice growers operate in an increasingly crowded, urbanizing and environmentally-conscious state, they must cope with resource constraints that increase costs and could limit the industry's competitiveness. In the future, this could influence competitiveness even more than governmental trade and farm policy decisions.

Highlights:

- California markets about 20 percent of rice grown in the U.S.; most comes from Delta states in the South. However, California is the only U.S. producer of high-quality, japonica-type rice.
- Within the U.S., consumer demand for rice has increased substantially since 1970 and still trends upward. The domestic outlook for California rice is most promising (1) for table use in Western states where there is a transportation cost advantage, (2) for food processing and brewing and (3) in smaller market niches with demand for high-quality, brand-identified japonica-type rice.
- Internationally, the possibility of some opening of the Japanese market—via the GATT or otherwise—is extremely important to California. This state is one of the few regions in a position to export high quality, japonica-type rice, which the Japanese require.
- In costs per unit of yield of paddy rice, California rice growers fare better than the South. However,

drying, storage, hauling and milling costs in California are higher than in the South. Also, rates of mill out-turn (conversion from paddy to milled rice) in California compare unfavorably with the South.

- The most immediate resource constraint on California rice growers comes from newly-mandated air pollution controls, which will eliminate most field burning during the next few years. Without new technology, this will almost certainly increase costs as well as decrease yields somewhat.
- Water quality problems caused by use of herbicides have been largely solved; however, regulatory pressure to further improve water quality will continue.
- Depending on persistence and severity of the drought and on competing demands for water, scarcity of irrigation water may limit future output of California rice.
- California is in position to benefit from any move toward liberalization in the Japanese rice market, and from increased demand in more affluent rice markets elsewhere in the world; but it is critically important to maintain the state's reputation for quality and dependability of rice exports.
- If government support programs are phased down or out in the U.S. (as well as other rice-growing regions), California rice acreage probably would drop but the state would retain its competitive advantages and sizable acreages would still be planted.
- Research focused on specific problems and on an integrated, "systems" approach to production and marketing is one important way to maintain the California rice industry's competitive edge.

Introduction

This report looks at issues that the California rice industry will face during the next 20 years. It considers this state's current position in the world rice market and probable future pressures for change in production, processing and marketing of California rice. It concludes with suggestions for possible action—by the industry, by educational institutions such as the University of California and by state and national governments—to sustain or to enhance this important part of California's agricultural economy.

The World Rice Market

In total production, rice is second only to wheat among the world's important food crops; but, unlike wheat, almost all rice is consumed within the country where it is grown. International trade typically accounts for only 3 to 4 percent of world rice production. More than half of the world's rice output is in the two most populous nations, China and India.

Although United States' rice output is less than 2 percent of the world's total, this nation provides almost 20 percent of all international exports. However, Thailand is the largest rice exporter, shipping almost twice as much as the U.S. (See Section IV.)

Within the United States, rice is an important commercial crop in six states—Arkansas, California, Louisiana, Texas, Mississippi and Missouri. Arkansas is the leading producer with more than 40 percent of the U.S. total. California ranks second with slightly more than 20 percent.

The California rice industry grows mostly medium-grain varieties and a smaller amount of short-grain. Both are temperate-zone japonica-type rice. In the trade, names of medium-grain varieties commonly contain the word "rose"; short-grain varieties are often identified as "pearl." Also grown in California are small acreages of premium-quality japonica-type rices, including M-401, publicly developed, and Kokuho Rose, a privately patented variety.

Long-grain (indica-type) rice, usually grown in the tropics or the southern U.S., has been used to create new varieties for California conditions. Both cold-tolerance and cooking quality proved to be problems. During the last decade, long-grain varieties accounted for as much as 17% of California rice acreage, but the plantings are smaller today. (24,000 acres in 1990.)

However, domestic market niches for long-grain and other specialty California rices are being promoted within the industry.

Domestic consumption increased during the 1980's, and the trend is upward. Currently, less than half of U.S. rice production is exported; in California, less than one third. Nevertheless, a strong export market will continue to be important to the prosperity of both the U.S. and California rice industries. Especially for California, rice exports will be largely determined by agricultural and trade policies of key Pacific nations. They also will be influenced by developments in the European and Middle Eastern markets, by the outcome of the Uruguay Round of GATT (General Agreement on Tariffs and Trade) negotiations, and by federal farm programs.

California's export market also is affected by consumer preferences for different classes of rice. World-wide, the most common rice varieties are of the long grain (indica or javanica) class. Almost all rice grown in tropical areas and most in the southern U.S. is long grain. Most California rice is of the japonica (medium and short grain) class, which is the temperate-zone type usually grown in Japan, Korea, northern China and, on a smaller scale, in Australia and Europe.

In countries where rice is not a historic food staple, consumers show only limited preference for indica or japonica rice. More traditional rice consumers, however, treat the two kinds of rice as essentially different commodities. Thus, the similarity between California's japonica varieties and rice grown in Japan and Korea makes those markets especially important for the rice industry in this state. Japan's recent consideration of possible rice imports could be an important development. (See Section III.)

Resource Requirements

Although it is produced under various conditions throughout the world, most rice—and all in the United States—is grown in standing water for much of the season. Thus, a plentiful supply of water and relatively impermeable soil are almost essential for efficient rice production anywhere in the world.

During the past two decades, short statured or semi-dwarf rice varieties have been bred that respond well to fertilizer, increasing the yield of grain compared to straw. Besides revolutionizing the California rice industry, this improvement has been a major factor in the so-called "Green Revolution" that has led to much greater food self-sufficiency in many developing nations, despite population growth and improved diets.

But it has also led to a need for better management in rice culture and to environmental concerns resulting from the increased use of fertilizers and pesticides.

In California, as much or more than anywhere else, environmental and resource issues are crucially important to rice culture and the rice industry. As will be discussed in Section V, California's competitive status may depend on how well the industry is able to deal with concerns about air and water quality, multiple use wetlands, competition for water supply.

The California Rice Industry

Rice Market Channels

Figure 1 shows California's rice marketing system from farm production to the final consumer. The milled rice supply goes into several domestic and export market channels.

Direct use as food is the largest domestic outlet for California rice. The beer brewing industry is a major domestic market, with two breweries taking 4.7 million hundredweight (213 million kg) of milled rice. One of those breweries is the largest single rice buyer in the U.S. Processing, primarily for breakfast cereals, is also important.

Export is the major alternative market for the California rice industry's product. In recent years, all export sales of California rice have been through foreign commercial buyers, often with government financial help.

Byproducts offer still another outlet. Rice mill byproducts, including rice bran and millfeed, have traditionally been fed to livestock. However, in recent years some of the bran has been moving into the breakfast cereal market. There is also a possible future market for rice bran oil for human consumption. Rice hulls are sold to poultry farms for litter and are also used for industrial products such as fruit juice filter material. Also, rice hulls can be used as fuel for power generation or cogeneration plants, two of which are either in operation or under construction in the Sacramento Valley.

"Paddy Rice" is unmilled rice as it comes from the field, also known as **"rough rice."**

"Brown rice" is hulled but not yet milled, with the bran remaining.

"Milled rice," also called **"white rice,"** has been hulled and milled, with the bran removed.

Invariably, some of the rice kernels are broken during milling. Thus:

"Head rice" is the proportion of unbroken whole kernels after milling.

"Brokens" indicates the proportion of broken kernels.

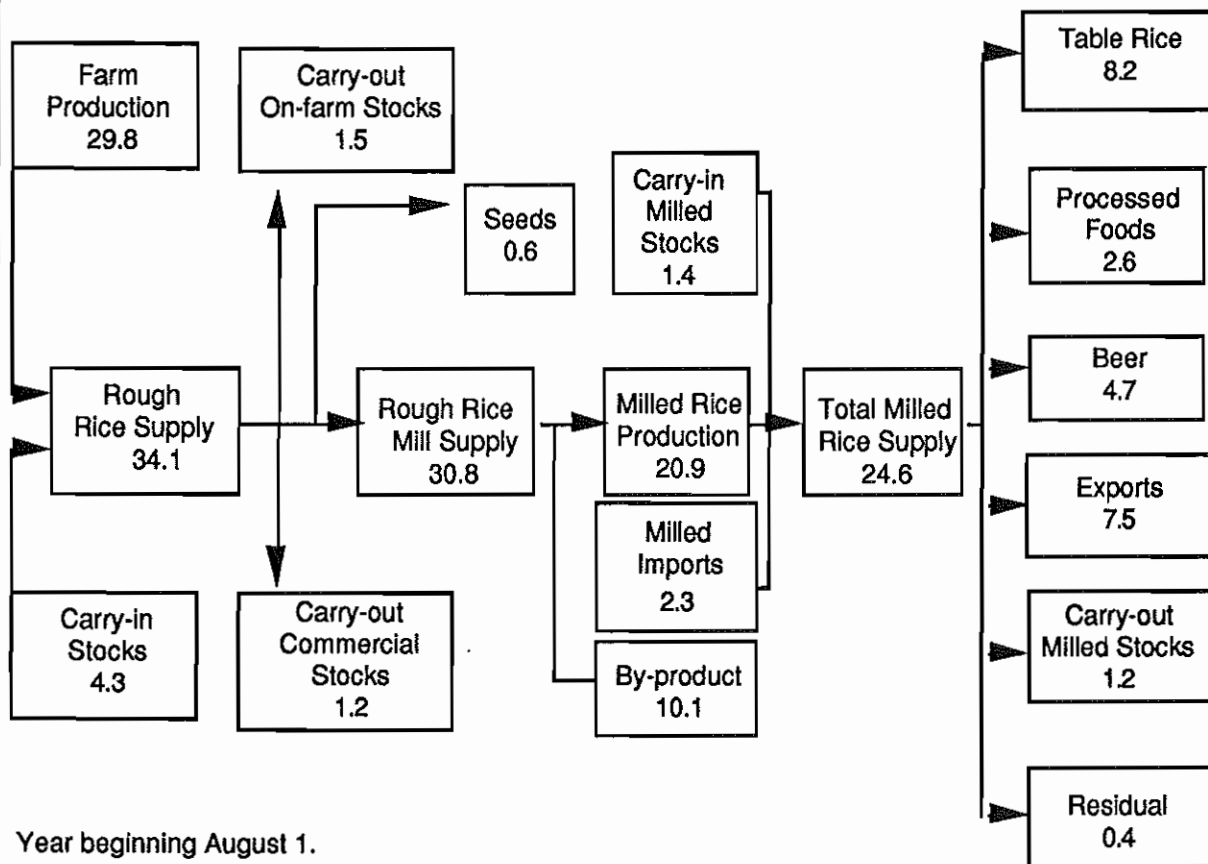
Typically, 100 pounds (45 kg) of paddy rice milled in California results first in 80 pounds (36 kg) of brown rice and then in 69 pounds (31 kg) of milled rice—of which 55 pounds (25 kg) is head rice and 14 pounds (6.3 kg) is brokens.

Today, 95 percent of all California rice is grown in the Sacramento Valley north of Sacramento. (See Table 1.)

Total rice milling capacity in the state is 42 million hundredweight (1,905 million kg) yearly, about half of which is owned by cooperatives. The equipment in these mills is the most modern in the world except for totally automated mills in Japan. California mills produce regular milled or brown rice. Because of differences in rice types, they do not make instant or parboiled rice, as southern mills do.

FIGURE 1. Market Channels for California Rice with Estimated Flows for 1988/89
(A normal year reflecting the Federal Market Loan Program)

million/cwt



Year beginning August 1.

Figures in parentheses are rough basis; other (except by-products) are milled basis.

Source: Economic Research Service, USDA.

Table 1
Rice Acreage and Yields, California
(Paddy rice at 13% moisture)

County	1975		1980		1985		1990	
	Acres Harvest	Yield Lbs/AC	Acres Harvest	Yield Lbs/Ac	Acres Harvest	Yield Lbs/Ac	Acres Harvest	Yield Lbs/Ac
Sacramento Valley								
Butte	91,900	5,600	104,000	6,550	72,000	7,410	58,750	7,900
Colusa	127,500	6,000	138,000	6,560	98,000	7,300	88,800	7,400
Glenn	65,100	6,100	77,000	6,750	61,000	7,350	62,900	7,500
Placer	6,800	5,300	10,000	6,200	10,500	7,100	12,200	7,900
Sacramento	14,200	5,500	18,000	6,100	11,000	7,790	9,600	7,800
Sutter	98,700	5,900	98,000	6,600	65,000	7,460	69,600	7,600
Tehama	500	5,600	200	6,000	2,000	6,500	1,300	6,000
Yolo	35,700	5,800	36,000	6,300	25,500	6,940	25,000	7,760
Yuba	24,200	5,800	34,000	6,400	23,000	7,300	27,900	8,380
San Joaquin Valley								
Fresno	22,600	5,000	11,000	5,600	6,400	6,170	6,200	6,380
Kern	8,400	4,900	4,500	4,000	800	6,750	600	6,340
Kings	1,000	4,900	4,000	5,000				
Madera	500	4,400	400	6,000				
Merced	12,100	5,800	12,000	6,200	8,400	7,640	5,300	7,440
S. Joaquin	10,500	5,700	8,000	6,000	4,900	6,630	4,950	8,000
Stanislaus	3,200	5,400	4,700	5,790	2,600	6,850	2,430	7,440
Tulare	2,100	4,800	5,200	5,100				
Total	525,000	5,800	565,000	6,440	390,000	7,300	385,000	7,600

Source: California Department of Food and Agriculture Field Crop Statistics

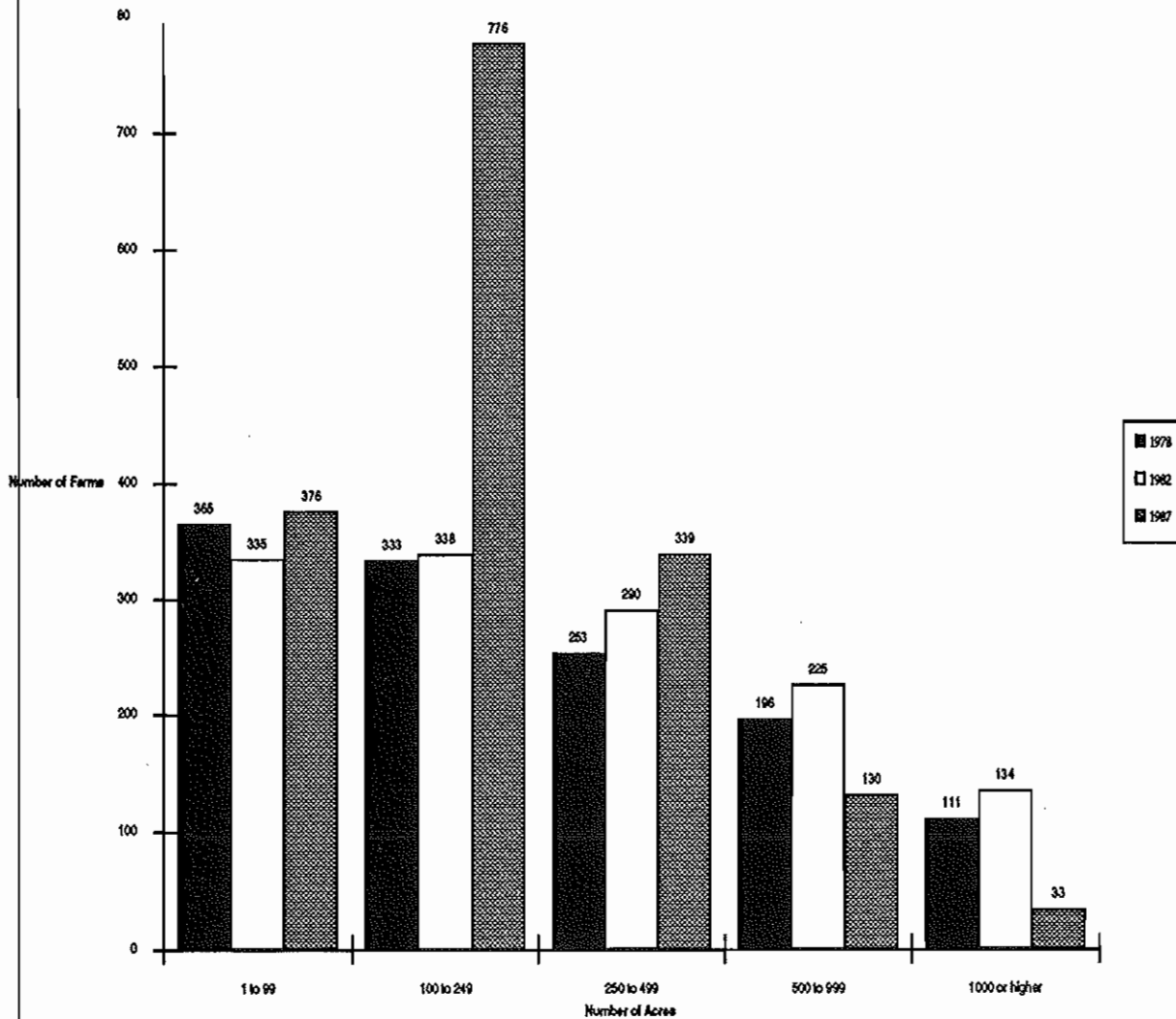
Farm Size

The number of rice farms in California has increased in recent years and the average size is smaller. U.S. Census of Agriculture figures indicating these trends are shown in Figure 2. The primary reason for the change appears to be the Food Security Act of 1985, which limited the dollar amount of federal program payments that an individual farm operator could receive. The size of farm that could generate this upper limit was about 200 acres (81 ha) of rice.

As Figure 2 shows, the reported number of 500-acre-or-less rice farms in California increased substantially between 1978 and 1987, and the number of larger units declined.

FIGURE 2. Acreage Distribution of Rice Farms in California

Figure 2 Acreage Distribution of Rice Farms in California



Source: U.S. Census of Agriculture

Largely as a result of this trend to smaller acreages, the total number of what the Census lists as rice farms increased from 1,257 in 1978 to 1,654 in 1989. Actual operating units very probably were larger. However, farm size figures recorded by the Agricultural Stabilization and Conservation Service, which administers the federal support program, are not available in comparable form.

Meanwhile, total rice acreage in the state declined between 1975 and 1989, as shown in Table 1.

Federal Farm Programs

The 1990 Food, Agriculture, Conservation and Trade Act, patterned after the 1985 farm legislation, provides a price/income support and production adjustment program for rice producers. An overwhelming majority of growers elect to participate and comply with this federal program. Price support is

California Rice Industry's Roots Are In Butte County

During the latter part of the 1800s, the Sacramento Valley's heavy soils and plentiful water led to sporadic experiments in rice growing, using mostly long-grain South American rice varieties which required a very long growing season. None of these plantings matured properly until 1908, when a Japanese rice variety, planted near Biggs by W.W. Mackie, a United States Department of Agriculture researcher, produced a successful crop. Within a year or two, rice of the medium-grain Japanese type was being grown commercially not only in Butte County but as far south as the San Joaquin Valley. In 1909, experimental plots at Biggs produced 7,955 pounds per acre (8,912 kg/ha) of a Japanese variety called Wataribune. The average yield of 31 plots was 3,486 pounds per acre (3,905 kg/ha).

During the next decade, the California rice industry expanded steadily—mostly in the Sacramento Valley where soils and water supply were generally more suitable, but with 10 to 15 percent of the state's output from San Joaquin Valley localities with heavy soils and a water supply. (Since the 1970s, rice acreage in the southern San Joaquin Valley has almost disappeared because rice was planted there primarily as a land reclamation crop, and also be-

cause of constraints on the water supply.)

The first rice crops were planted into dry soil and intermittently irrigated. As a result, existence of the industry was soon threatened by a weed pest—watergrass, which literally took over fields after two or three years of consecutive planting to rice. In 1924, the practice of seeding into water was introduced to partially solve the problem. Today, water seeding combined with herbicides, developed in the 1960s, permits continuous production of rice in the same field.

As the industry developed during the 1910s and 1920s, water supply was crucial. Irrigation districts were organized throughout the Sacramento Valley, largely to provide rice growers with Sacramento River and Feather River water. In the mid-1950s, additional districts were formed along the west side of the Valley, to be served by the federal Tehama-Colusa Canal.

Over the years, rice marketing organizations developed along with field production. Grower cooperatives were launched even before World War I and in the following decades the Rice Growers Association and Farmers Rice Cooperative became giants of the industry. In addition, smaller

paddy rice cooperatives as well as independent rice millers and marketers have played important roles.

Government marketing programs also have helped shape the rice industry in California, as elsewhere in the U.S. Starting with the agricultural adjustment programs of the 1930s, California rice growers have adapted to varying patterns of acreage allotments, target prices and similar economic arrangements.

As a commercial crop in California, rice has benefitted from research programs supported by both rice growers and public agencies. In 1912, the Rice Experiment Station was established at Biggs, staffed by the USDA on land contributed by the industry. In later years, University of California agronomists, plant breeders and pest control experts became involved. The USDA operated the station until the early 1950s, when UC Davis, took over direction of the research program. In 1969, the Rice Research Board was organized under authorization of the California Department of Agriculture and the grower-financed California Cooperative Rice Research Foundation, Inc. was set up to support research and maintain the experiment station.

When harvested, short and medium grain rice typically contains 22 to 24 percent moisture (18-21 percent for long grain). It must be dried to 12 to 13 percent to prevent spoilage. Drying and storage take place either on farm or in commercial facilities. In California, most commercial rice storage is in horizontal (flat) facilities, where it is not possible to separate rice from different farms or different qualities from the same farm. On the other hand, the quality of California-grown rice generally is less affected by damage from weather, weeds ("red rice"), insects and diseases. This is an advantage in supplying premium markets.

provided by purchase agreements and nonrecourse loans, with important marketing loan repayment provisions. (When the adjusted world market price falls below the market loan rate, rice growers have the option to repay price support loans at a rate up to 30 percent lower than the price support level.) In 1991, the loan rate was \$6.50 per cwt (14.3 cents/kg).

Deficiency payments, using the target price concept devised in earlier legislation, also provide income support. If the weighted market price for the first five months of the rice marketing year is below the target price, the difference (i.e., deficiency payment) is paid to growers—subject to payment limitations. In 1991, the target price for rice was set at \$10.71 per cwt (23.6 cents/kg).

To be eligible for these loans and payments, producers must comply with any Acreage Reduction Program (ARP) announced by the Secretary of Agriculture. Each year, carryover stocks and potential demand (foreign and domestic) for rice is determined and participating farmers are required to set aside a certain percentage of their base acreage. Due to variation in carryover supplies and international demand and to changes in the program, the setaside was 20 percent in 1990 and only 5 percent in 1991. For 1992, it is zero, with a 15% allowance for planting to other crops without losing rice "history."

III

Demand for California Rice

Domestic Demand

Rice has never been a staple in the diets of most Americans, whether eaten directly, in processed form such as cereals, or in brewed products. Today's U.S. per capita consumption of about 21 pounds (9 1/2 kg) per year is tiny compared to Japan's 150 pounds (68 kg) or Indonesia's 320 pounds (145 kg). Still, the importance of rice in American diets has risen in recent decades—an increase of more than 100 percent in per capita consumption since 1970. This trend, which many expect to continue, is attributed to nutritional considerations, to the influence of recent immigration patterns, to increasingly varied American eating habits and to more consumption of value-added products such as microwavable rice. However, certain offsetting factors should be kept in mind:

- Recent studies have demonstrated special nutritional qualities of rice, particularly the high fiber content and cholesterol-lowering effects of rice bran; but the same benefits also are attributed to other foods such as oat bran.

- The high level of rice consumption by recent immigrants from Southeast Asia, Latin America and the Middle East clearly has influenced the level of per capita consumption in the United States and particularly in California. However, the dominant position of table rice in the diets of these families may fade as their incomes rise and as they become more adapted to the American culture.

Still, it is likely that changing dietary patterns will lead to further increases in nationwide per capita consumption, especially in states which now eat relatively little rice. Whether this upward trend will match the increase since 1970 is unclear.

However, when combined with a projected 10 percent growth in total U.S. population, a per capita consumption increase of even 20 to 30 percent would create a significantly larger domestic market for rice.

Rice For Direct Consumption

About 60 percent of the rice consumed in the U.S. is used as whole grain table rice. For this segment of the market, effective demand for California rice east of the Rocky Mountains is limited to the relatively few consumers who prefer japonica rice. In a typical year, only 16 percent of the domestic shipments of California rice for direct food use go to states and territories (Puerto Rico) outside the Pacific region; 60 percent are within California.

Thus, population, income or other demographic changes in the middle and eastern parts of the U.S. will have little effect on demand for California rice, unless there are significant changes favoring this state in production/processing technology or in nationwide transportation costs. One potential source of increased demand for California rice is the relatively recent introduction to California of long-grain indica-japonica cross-bred varieties.

Rice for Processing and Brewing

Use of domestic rice in processed foods, especially cereals, more than doubled between 1971 and 1987, with much of the increase during the past few years. This is undoubtedly due in part to health-related concerns and may not be sustainable. Still, processing is an important domestic market for rice—especially for California, since more than half of the rice used in U.S. cereal production traditionally has been medium grain.

Brewing of beer accounts for about 20 percent of total domestic use of rice, roughly one-third as much as is consumed directly. While this use has trended upward over time it has not been as stable as either direct or processed food use. During the past two decades, estimated yearly amounts of milled rice used in brewing have varied from as low as 4.1 million cwt (186 million kg) in 1971/72 to 9.1 million cwt (413 million kg) in 1982/83.

Currently, California's share of rice sold in the U.S. for processed foods and brewing is almost 40 percent. That is double this state's share of total U.S. production. However, only a relatively small portion of California rice used in processing is whole-grain ("head") rice; the remainder is the lower valued broken grains.

Due to increasing population and to changing tastes that favor rice consumption, it is reasonable to project a substantial increase in total U.S. demand for table rice. What about U.S. demand for table rice from California? Population in this state and in the Pacific Region certainly will continue to increase. However, the overall effect on demand remains uncertain because of the already relatively high per capita use of rice by Western consumers and the potential for changes in diet by those who are currently the highest users of rice. On the other hand, U.S. demand for processed rice products clearly is rising and because of its high quality rice, California supplies much of this particular market.

International Demand

The international competitiveness of California rice depends as much on politics as on economics. In most important rice producing and consuming countries, agricultural and trade policies largely determine the amount and price of rice imported or exported. Furthermore, in many countries trade is managed through government marketing boards or other public agencies.

In addition, the international market for rice is very "thin"; less than 4 percent of the rice produced in the world is consumed outside the country where it is produced. There are relatively few international traders. There is not, as in the case of wheat and corn, an active marketplace where price is determined by a large number of traders who interpret changing market forces.

Any move by Japan to permit rice imports would substantially affect the market. This is particularly important for California's high quality japonica rice because of the market differentiation between japonica and indica varieties. Japonica rice is strongly preferred by consumers in Japan, South Korea and parts of northern China (as well as various countries in the Mediterranean). None of these Asian countries import much rice because their agricultural policies aim at achieving rice self-sufficiency.

Japan, by far the largest potential import market, has pursued a policy of rice self-sufficiency for many decades. As one result, Japanese consumer prices greatly exceed the price at which rice is traded on world markets. The current world price for rice is actually lower than the theoretical "free market" price, due to (1) export subsidies and quasi-subsidies used by

the European Community, the U.S. and other exporters and (2) import trade barriers. Still, rice sells in Japan for several times the world price that would exist even in the absence of subsidies.

Defenders of the Japanese policy, including a potent farmers' lobby, say there is a strong consumer preference for the unique quality of Japanese-produced rice. Others say that there is little difference between Japanese and California-produced japonica-type rice, which has been readily accepted by Japanese expatriates. Without imports to Japan it is impossible to test these claims or to estimate the price difference that could lead to significant use of California-grown rice by Japanese consumers. Another unknown, perhaps equally important, is the potential response of Japanese rice growers to substantially lower domestic prices, which might result from increased imports.

IV

Supply Factors: Yields, Costs and Constraints

Domestic Supply

In addition to future demand, the competitive position of California's rice industry will depend on how effectively its advantages—higher yields and higher quality—are exploited and its disadvantages—higher costs and environmental constraints—are dealt with. These factors will determine rice production in California.

Competition for sales within the total rice market (indica and japonica) will come both from overseas and from within the U.S. (Arkansas, Louisiana, Mississippi, Missouri, Texas). As Table 2 shows, Arkansas, specializing in indica, leads the nation in rice production by far; but California is the leading U.S. producer of medium-grain rice. Arkansas and Louisiana also grow some medium-grain rice, but California currently has an advantage in quality-conscious markets. (See Section VI.)

Yields Versus Acreage

Rice production trends in California, as elsewhere, reflect both the amount of land planted and yields per acre. Rice acreage in the state has fluctuated, declining from as high as 600,000 (242,915 ha) in the early 1980s—an unusual circumstance, resulting from purchases by South Korea due to a severe shortfall of rice—to less than 320,000 (129,500 ha) in 1991, a drought year. Government programs of acreage control are also an important factor in determining the acreage.

Rice yields in California, however, have shown a generally steady upward trend, with some weather-caused variations. In the 1970s, yields reached a plateau of about 55 cwt/acre

(6,162 kg/ha). At that time, only tall stature varieties were available. In 1979 and 1980, the new short stature varieties were introduced and, as Figure 3 shows, the trend in yields has been upward since. The average in 1991 was 80 cwt/acre (8,963 kg/ha).

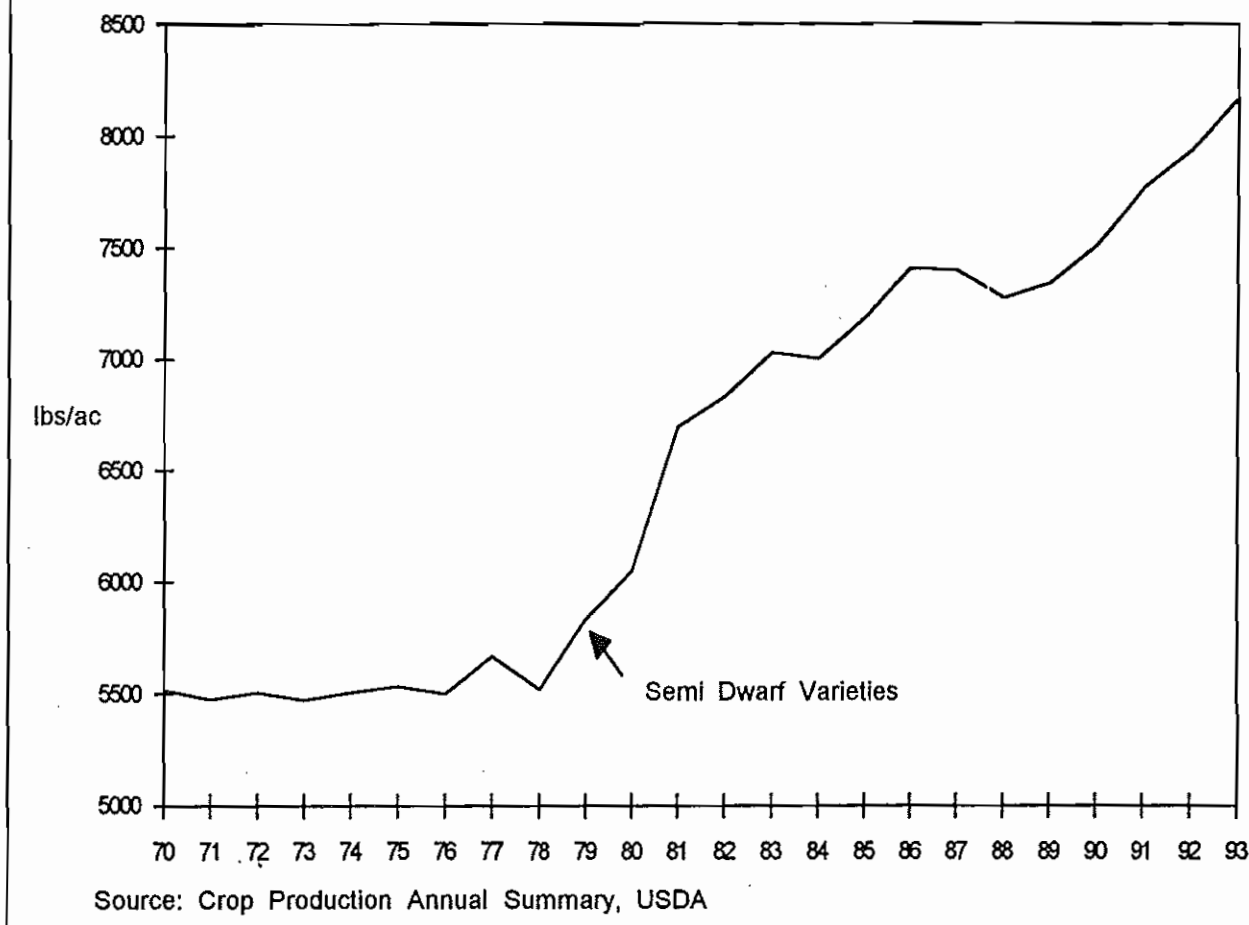
The average yield levels that have been achieved by California's rice growers are high—substantially higher than those in Southern rice-growing regions or elsewhere in the world. These extremely high yields, resulting from a favorable climate, carefully tailored rice varieties and intensive farming methods, are the chief source of the industry's competitive strength. However, a levelling off at some point appears inevitable, probably in the low to mid 80-cwt range. (See Section VI.)

Table 2
Rice Production by State
1,000 CWT

State	1980	1985	1987	1989	1991	1993
LONG GRAIN						
ARKANSAS	43,591	50,712	45,259	57,458	58,328	53,928
CALIFORNIA	0	3,834	2,592	2,630	1,168	1,145
LOUISIANA	8,875	14,418	12,079	13,128	12,500	14,648
MISSISSIPPI	9,086	10,058	10,098	13,395	12,320	12,985
MISSOURI	2,100	3,415	3,420	4,056	4,641	4,557
TEXAS	24,310	17,970	15,547	18,874	20,180	15,801
MEDIUM GRAIN						
ARKANSAS	8,050	3,809	7,656	6,322	8,392	8,007
CALIFORNIA	28,080	18,628	22,496	26,000	26,489	34,112
LOUISIANA	11,893	5,838	7,031	8,360	12,235	9,460
MISSOURI	191	48	144	52	51	0
TEXAS	432	141	324	392	400	294
SHORT GRAIN						
ARKANSAS	974	276	110	60	60	159
CALIFORNIA	7,221	6,006	2,847	3,760	693	1,014
TOTAL	144,803	134,913	129,603	154,487	157,457	156,110

Source: Crop Protection Annual Summary, USDA

FIGURE 3 Rice Yield Trend in California



Resource Constraints

California has the most stringent air and water pollution controls of any of the five major rice-producing states. Enforcement of state water quality standards for irrigation return flows into the Sacramento River already has forced major changes in pesticide use and irrigation management. During the next few years, even more changes will be imposed by air pollution control regulations.

Even now, these state programs are generally more restrictive than those required by federal air and water quality standards. Meanwhile, political and legislative pressure is being applied to make them even more stringent. There also is increasing pressure on the water supply; much depends on the persistence and severity of the current drought.

Clearly, the future supply of California rice will be determined in part by these environmental constraints, and by the industry's response to them. This challenge is discussed in detail in Section V.

Rice Industry Costs

Comparative costs of rice production and processing within the U.S. are available from a study by the University of Arkansas (Wailes and Holder), updated here and in Tables 3 and 4 with information from a Economic Research Service cost survey in 1988. Costs of hauling, storing, drying and milling are taken directly from the Wailes and Holder study without adjustment for price changes. This may underestimate absolute costs, but the relative cost levels in the various states are unaffected.

This updated analysis indicates that:

- In on-farm average costs per hundred weight of paddy rice yield, California ranks at the lower end of U.S. rice-growing states. The study figures are California, \$6.08/cwt (13.4 cents/kg); Arkansas, \$6.78 cwt (14.9 cents/kg); Texas, \$6.89/cwt (15.2 cents/kg); Delta, \$6.91/cwt (15.2 cents/kg); Louisiana, \$6.91/cwt (15.2 cents/kg). "Arkansas" means the non-Delta parts of that state. The "Delta" is parts of Arkansas, Mississippi and Louisiana with common production practices and yields. Although Texas has high water costs, introduction of a new variety has raised its average yield.

- In drying and storage costs, California has the highest average for medium-grain output. The study figures are Arkansas, \$1.99 per cwt of milled grain (4.4 cents/kg); Texas, \$2.12 (4.7 cents/kg); Louisiana, \$2.37 (5.2 cents/kg); Delta, \$2.45 (5.4 cents/kg); California, \$2.49 (5.5 cents/kg). Since rice drying technology is the same throughout the U.S., drying costs are a function of local labor costs, natural gas rates and the relative economics of on-farm versus central dryers. Traditionally, California growers are charged for a minimum of 9 months of storage whereas in the south storage charges are paid monthly.

An important point in regard to drying is California's relatively low conversion rates for paddy rice to milled rice (mill out-turn). In the South, on average, 1.67 pounds of long-grain paddy rice produces one pound of milled rice; in California, the comparable figure is 1.96. For medium-grain rice, the averages are 1.6 pounds of paddy rice for one pound of milled rice in the South and 1.78 in California; and for short-grain rice, 1.55 pounds in the South and 2 in California. Thus, mill out-turn is a disadvantage for the competitive position of California rice.

- In costs of hauling to the dryer per cwt of milled grain, California is high. This is largely because of labor costs for truck drivers and lower mill out-turns. The study figures are California, 65 cents (1.43 cents/kg); Texas, 61 cents (1.34 cents/kg); Delta, 31 cents (0.68 cents/kg); Arkansas, 27 cents (0.59 cents/kg); Louisiana, 24 cents (0.53 cents/kg.)

- Costs of milling vary a good deal among the five regions depending on grain type, economies of scale, mill technology, and wage rates. However, California has the highest milling costs for all three grain types, primarily due to its unionized labor force. Arkansas has the lowest. The figures for milling medium-grain rice are: Arkansas, \$2.37 per cwt (\$0.052/kg);

Table 3
Summary of Cost of Production, Drying, Trucking and Milling Rice
by Grain Type and State (milled basis)
 \$/cwt milled basis

Grain Type	Arkansas	California	Delta	Louisiana	Texas
LONG GRAIN					
Production	14.08	15.02	14.55	15.55	14.13
Dry, Store, Truck, Mill	5.21	6.60	5.84	5.69	5.97
Total	19.29	21.62	20.39	21.24	20.10
MEDIUM GRAIN					
Production	13.49	13.47	13.94	14.90	13.54
Dry, Store, Truck, Mill	4.63	5.65	5.22	5.08	5.32
Total	18.12	19.12	19.16	19.98	18.86
SHORT GRAIN					
Production	13.07	15.80	13.50	0	0
Dry, Store, Truck, Mill	4.24	5.90	4.80	0	0
Total	17.31	21.90	18.30	0	0

Sources: Wailes and Holder, University of Arkansas; Economic Research Service

Delta, \$2.46 (\$0.054/kg); Louisiana, \$2.47 (\$0.054/kg); Texas, \$2.59 (\$0.057/kg); California, \$2.69 (\$0.059/kg).

Table 3 summarizes the results of the updated study, listing total costs for milled rice in the five major U.S. rice-growing regions. This analysis indicates that California is one of the highest-cost producing areas in the U.S. for all three types of rice. The non-Delta portion of Arkansas is the low-cost area for all types of rice, followed by Texas for long and medium grain, and the Delta for short grain.

To estimate overall competitive advantage, transportation costs must be added to production and milling costs. A look at typical trucking rates indicates that California rice producers have a transportation advantage primarily to West Coast cities, with a disadvantage to Chicago, and even to Denver. However, comparative freight rates to New York are close to break-even. (See Table 4.)

Table 4
Trucking Rates for Packaged Rice
by Destination / Shipping Point
dollars / cwt

Destination	Sacramento	Houston		Arkansas	
	Rate	Rate	Difference	Rate	Difference
Chicago	4.65	2.52	[2.13]	1.60	[3.05]
New York	3.65	3.80	0.15	3.41	[0.24]
Los Angeles	1.09	3.57	2.48	4.30	3.21
Phoenix	2.10	3.52	1.42	4.52	2.42
Denver	3.15	3.01	[0.14]	3.07	[0.08]

[] indicates cost disadvantage for California
Source: Wailes and Holder, University of Arkansas

Rice varieties from the International Rice Research Institute (IRRI) at Los Banos in the Philippines are the source of the recent rapid increase in rice yields throughout the world. With the possible exception of China, which has developed hybrid rice, IRRI will be the seminal source of future yield gains. It can be argued, however, that the main stumbling block to higher world production is not genetic but rather government policies in developing countries, which show a strong tendency to tax agriculture and depress market prices to maintain cheap food for urban consumers. If such programs are not changed, many countries that are now self-sufficient or net exporters of rice may become net importers by the next century, as their population growth exceeds yield increases.

To summarize: In total costs of growing, processing and marketing rice, the California industry can directly compete in the domestic market only in states west of the Continental Divide. Farther east, California must rely on carving out a market niche for medium grain rice, looking for a price premium due to quality, taste and label recognition. Meanwhile, California's chief competitive strength in the domestic rice market is high per-acre yields, as well as lower transportation costs to the western states.

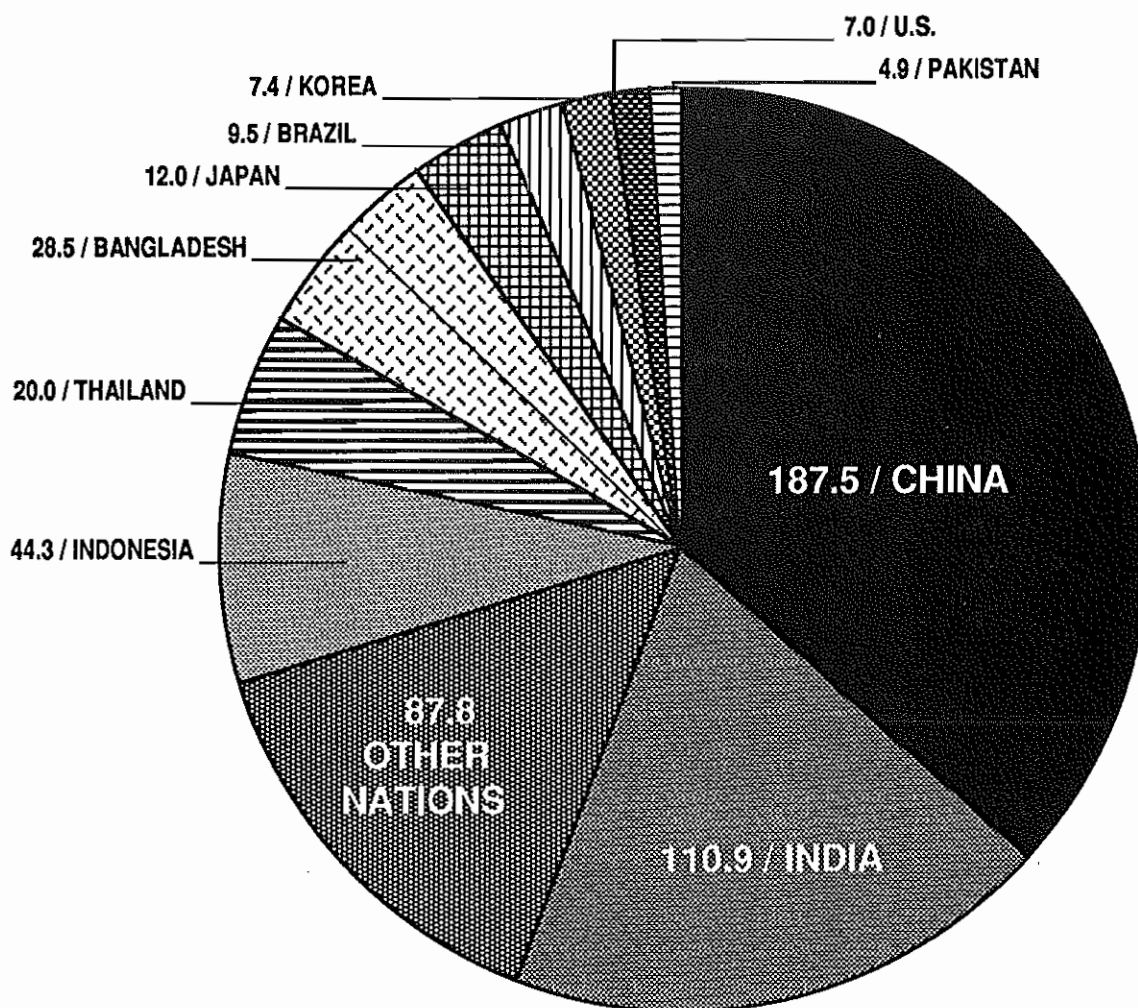
International Supply

Outside of the U.S., medium grain, japonica-type rice is grown in Japan, Korea, Taiwan, China north of Shanghai, southern Brazil, the Mediterranean region and Australia. As shown in Figure 4, China is the world's largest rice producer—as well as consumer—followed by India. In fact, a 3.5 percent shortfall in China's production would equal the entire U.S. rice crop.

Between 1970 and 1986, as a result of the Green Revolution, the world land area planted to rice expanded by 11 percent while total production increased by 52 percent. Average

FIGURE 4 World Rice Production 1987

Million Metric Tons

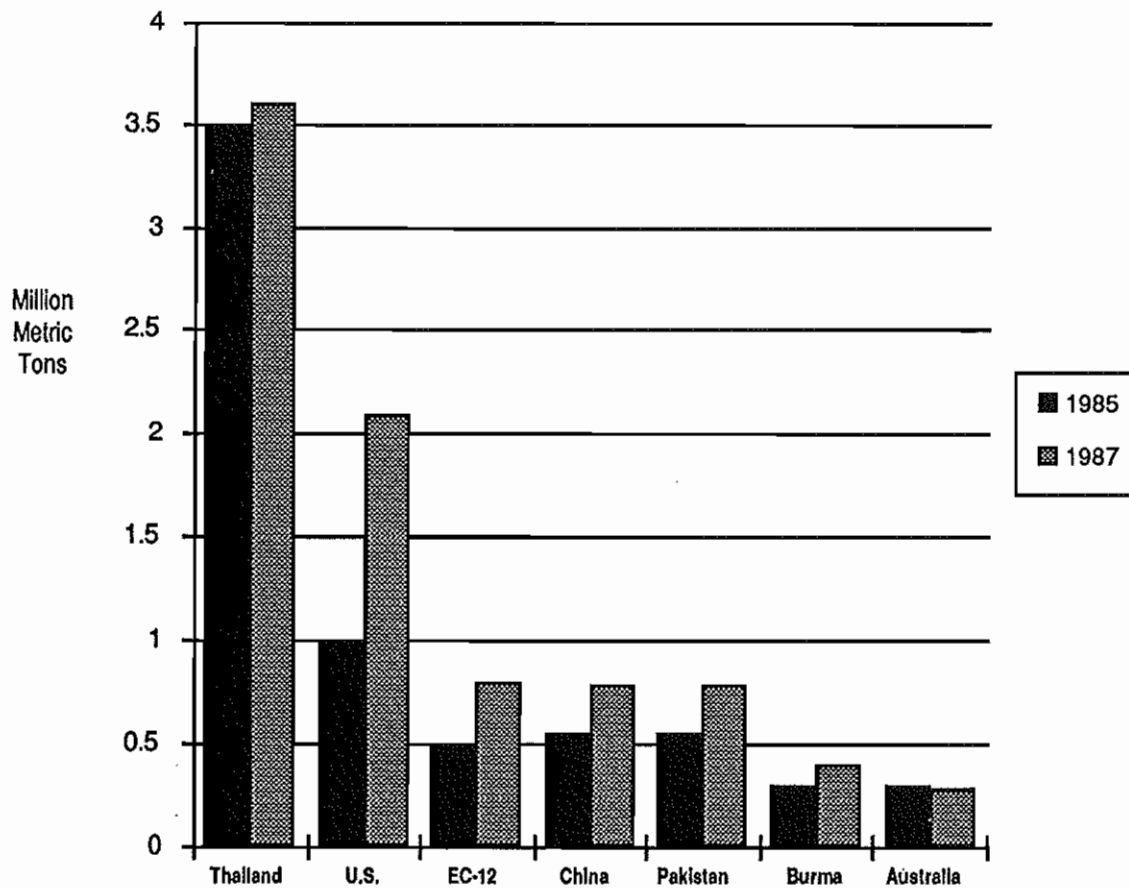


SOURCE: IRRI Rice Almanac, 1993-95

yields apparently increased 2.5 to 3 percent per year. There also has been a trend toward more uniform production. In 1970, the range among rice yields in the four highest yielding countries was more than 30 cwt per acre (3,368 kg/ha); in 1986, it was slightly over one cwt (112 kg/ha).

The rate of growth in world rice production has slowed in recent years. This is partly because of a smaller

Figure 5 Major Rice Exporters



Source: Rice Situation ERS, USDA, various years

The price and income policies of the two major exporters—Thailand and the U.S.—illustrate the truism that poor countries tax agriculture and wealthy countries subsidize it. Until 1986, Thailand imposed an export tax on rice. When the US initiated its Market Loan Program, Thailand removed the tax in order to remain competitive. Meanwhile, Thailand's export prices have generally been set below those of the U.S.

increase in area planted, and movement onto more marginal soils and into cooler climatic zones. In addition, rice researchers are reporting instances of declining rice production due to continuous cropping of short-season varieties.

Major rice exporters of the world are shown in Figure 5. Thailand has been the leader for many years. Thailand's role as the world cost leader for high quality rice is borne out by a recent study by the Kyoto University Faculty of Agriculture. (Kamegai et al). This study estimated California's cost of producing brown rice as \$12.25 per cwt (\$0.27/kg) and the average for Thailand as \$8.51 per cwt (\$0.19/kg). The cost in Japan was reported as almost ten times California's—\$111.58 per cwt (\$2.46/kg).

V

Rice Production and Natural Resources

Sacramento Valley rice land is a mainstay of the regional economy, providing value to acreage with little other economic use. Its half million acres or so of irrigated and cultivated soil contribute to the Valley's environment. Open space, a disappearing resource in many parts of the state, is one obvious benefit of rice farming. Rice fields also provide feeding areas for enormous numbers of waterfowl. On the other hand, rice cultivation practices can degrade air and water quality, and rice irrigation competes for an increasingly scarce water supply. These resource issues will strongly influence the future of the rice industry.

Air Quality

On each acre of rice land, about four tons of rice straw remain after harvest. Currently, most of this residue is disposed of by burning it in the field, thus contributing to atmospheric pollution.

Public concern over rice straw burning in California has been on the increase since at least the 1950s. Recent legislation (AB 1378, 1991) has launched a "phase down" program, in which the burning will be reduced by 10 percent annually until the year 1998. At that time, a maximum of 25 percent of the planted acreage (or 125,000 acres, whichever is less) could be burned—but even then only under special permits.

Burning Practices: The Rationale

Historically, it was assumed that the chief reason to burn rice straw and stubble after harvest was to facilitate seedbed preparation for the following crop. However, some years ago scientific experiments confirmed what growers had long suspected—that burning also controls the fungus that causes stem rot, a widespread and potentially devastating disease of rice.

To demonstrate this, UC researchers compared the results of burning rice straw with plowing it into the soil. They measured development of stem rot over several years, both in fields that started out with small amounts of the fungus and those that were heavily infested. These tests showed that, compared to soil incorporation, open field burning prevents substantial damage from stem rot in heavily-infested fields—and even in rice fields that initially are almost disease-free, but in which stem rot would otherwise build up over a period of years.

Burning rice straw to dispose of it:

- Limits severity of plant diseases in subsequent rice crops, avoiding potential yield losses of 25% or more in sites that are heavily infested with stem rot.
- Efficiently disposes of straw at relatively low cost.
- Facilitates soil tillage and seedbed preparation.
- Returns various plant nutrients to the soil. (However, it interferes with recycling of organic matter, and more volatile nutrients such as nitrogen and sulfur.)
- Minimizes the formation of plant toxins and swamp gases in waterlogged soils.

Air Quality Impacts

The tradeoff, however, is air pollution. Rice straw burning emits many compounds into the atmosphere, including:

- “Criteria” pollutants, for which air pollution standards are set: particulates, carbon monoxide (CO), hydrocarbons, nitrogen oxides (NO_x) and sulfur dioxide (SO₂).
- Polynuclear aromatic hydrocarbons (PAH), which are emitted from virtually all combustion sources and

are everywhere in the atmosphere in both gas and particulate form. Many of these compounds are animal carcinogens.

- Silica fibers, small particles of straw ash with unknown health effects.

It is difficult to measure the amount of emissions from rice straw burning under field conditions. That amount depends on the moisture content of the straw, the manner in which the field is burned (heading fire, backing fire, strip-light fire), and the "emission factor"—the pollution emitted per weight unit of the particular fuel being burned.

For NO_x and hydrocarbons, rice has lower emission factors than the average field crop or average tree crop; for carbon monoxide, rice is substantially higher; and for particulates and sulfur dioxide, rice appears to be generally comparable although there is some uncertainty.

In California, how much of total yearly air pollution by the five "criteria" pollutants comes from agricultural burning? (Keep in mind that during burn days, agriculture's contributions are substantially higher.) Statewide, not counting forestry and range management burns, the annual figures for agriculture are only a tiny fraction of the total—1% or less. In the Sacramento Valley air basin, however, the situation is different. Slightly more than 1,000,000 tons of rice straw burned yearly in that region account for only 1.24 percent of particulate matter emissions; but they also contribute 10 percent of annual CO, 3.7 percent of hydrocarbons, 3.1 percent of NO_x, and as much as 17 percent of SO₂, although more recent studies suggest that this figure for sulfur may be five to 10 times too high.

Complaints about rice field burn emissions in the Sacramento Valley have been reduced in recent years by a program of "burn days," operated through Air Pollution Control Districts. Despite these gains, public concern over the problem led to passage of AB 1378 (1991) which is designed to eliminate most burning within this decade.

A central question for the industry, therefore, is: What are the alternatives to burning, and how will they affect the competitiveness of California rice? An economically viable alternative for disposing of all or most rice straw in California is badly needed.

Non-Burn Alternatives

The fine-textured soils that make the Sacramento Valley an ideal location for rice growing tend to remain soft and wet after harvest, particularly after fall rains. This makes it very difficult to dispose of straw by any method but burning. However, there are alternatives. They include: (1) rotation crops, (2) incorporating the residue into the soil and (3) hauling it out of the field.

1. In some areas, alternate crops can be grown on rice soils (See "Rice Land: A Limited Resource," page 34). One year's rotation away from rice reduces stem rot infestation; two or more years may substantially control it. The "half-life" of stem rot fungus populations is calculated at 1.9 years. The tradeoff here is economic, since the alternative crop may be less profitable and land preparation may be costly.

2. Incorporating rice straw into the soil is a potentially feasible method of disposal, although not every year and in all situations. It may affect yield by increasing algae infestation and production of methane and other swamp gases in water-logged soil. It clearly tends to build up the organisms that cause stem rot and other diseases. It also may build up beneficial organisms that help to stabilize the occurrence of disease over time. However, long term effects are not known with any certainty.

Soil incorporation, which involves chopping the straw, spreading it and turning it in, also:

- Increases costs of energy, equipment and labor.
- May result in less effective seedbed preparation and delayed planting.
- May reduce rice acreage in years of early or late rainfall because of the difficulty of managing straw in wet soil.

3. Another potential non-burn alternative is to haul the rice straw out of the field to be used for some purpose elsewhere.

To control stem rot with this procedure, the straw must be cut to within a few inches of the ground—"ground level harvest". Research shows that ground level harvest can control overwintering stem rot fungus as effectively as burning does, and that with short-stature rice varieties it may slow the

operation somewhat, but does not seriously reduce harvesting capacity. Another method is to harvest normally and follow with a swather—an extra and more costly (than burning) operation, but one that does not slow the harvest.

The underlying problem with removing straw from the field is cost. Regardless of the type of straw collection system (baling, chopping, cubing or pelleting), costs of between \$30 and \$50 per ton for straw delivered to a processing facility can be expected. One study of chopping, compressing and hauling up to 35 miles indicated a delivered cost of less than \$24 per ton, but this may be optimistic. ("Agricultural Waste to Energy Study," final report, R. M. Parsons Co., Pasadena, California, 1986). Another study showed a cost of about \$42 per ton for swathing, baling into large rectangular bales, hauling 35 miles, storing and grinding. ("Logistics and Economics of Biomass Utilization," B. M. Jenkins and others, *TRANS of the ASAE* 27(6): 1898-1904.)

What use might be made of rice straw if it is hauled from the field? So far there are no established commercial outlets for rice straw in California, but there are several possibilities—principally power generation, ethanol production and animal feed. In generating electricity from straw, the net energy balance is calculated as positive but technical problems are caused by the ash. Ethanol production from rice straw and other cellulosic materials has not been proven commercially, but is a major area of research and may be a viable future option. One proposal for a co-generation power/ethanol production plant near Sacramento claims to be a potential outlet for straw from 30,000 to 40,000 acres of rice land.

For animal feed, rice straw is a poor quality roughage, but it can be used in feed mixtures and its feed value can be improved by treatment with alkali or ammonia. Its value is calculated at about \$50 per ton as a maintenance feedstuff for dry pregnant cows and about \$30 per ton as feed for steers. However, not enough cattle are currently located close enough to rice fields to economically use much straw.

Rice straw also can be used to manufacture materials such as fiberboard or even fuel for wood-burning stoves. The problem is that under current conditions straw cannot economically compete for these uses. Limited amounts of straw can be used as a ground cover to control erosion on exposed slopes, such as highway cuts and burned-over hillsides. California highway officials have expressed interest in using more rice straw for this purpose.

A recent proposal with implications for rice straw disposal is to store water from winter flood flows on possibly 100,000 acres of harvested rice fields in the Sacramento Valley. Proponents point out that:

- The flooded fields would provide much-needed habitat for waterfowl.
- The additional storage in wet years would add to California's developed water supply.

Whether this plan would speed decomposition of rice straw, as the proponents also claim, is uncertain. Ordinarily, straw decomposes more rapidly under aerobic conditions.

Water: Quantity and Quality

The availability, quantity and quality of water are serious concerns for California rice growers. These concerns have increased in recent years as a result of environmental pressures and the drought. Historically, virtually all rice was irrigated with surface water from the Sacramento River, pumped directly or delivered through canals and drainage ditches—and often reused several times. During the current drought, pumped groundwater, although much more costly, has been used to supplement the surface supply.

Water Use by Rice

The total amount of water used to grow a crop of rice on any one field is the sum of (1) water used by the crop for evapotranspiration (ET), (2) water that percolates down through the soil and (3) water that runs off at the lower end of the field.

1. Evapotranspiration (ET). In the very early stages of a rice crop, ET is made up mostly of evaporation from the flooded field. However, by the time the crop grows a foot above the water, 90 percent of its water use is transpiration through the plants—a fundamental requirement for growth. Total crop ET is influenced by climate (sunlight, wind, temperature, humidity).

Currently, the average ET required to grow an acre of rice in the Sacramento Valley is 36 to 46 inches of water, or 3 to almost 4 acre-feet. This is roughly comparable to the ET needs of cotton, irrigated pasture, alfalfa and many other summer crops. (Crop water use is largely determined by length of the growing season. Before the mid-1970's, according to mathematical models, the average seasonal ET for rice was about 0.3 of an acre-foot more than it is today. It declined with widespread use of the new varieties, which mature in about 145 days rather than 170.)

2. Deep percolation. Another component of total water use is percolation below the root zone. Two opposing forces are at work here; rice soils generally have the lowest percolation rates but a rice field is continually flooded. On those soils that are virtually impervious, percolation is negligible. More commonly, rice percolation rates are between 5 and 24 inches of water yearly. Rice is rarely—and should not be—grown on soils with percolation rates above 48 inches. (Coarser, non-rice soils may have percolation rates as high as 120 to 240 inches yearly and are best suited for other crops.)

Although percolated water is lost to the crop, it is not lost to the hydrologic basin since it contributes to the groundwater resource. (Unless it goes to saline groundwater, which exists in some Sacramento Valley aquifers.)

3. Runoff. The third component of total water use is surface losses during irrigation (tailwater). Flow-through irrigation systems, originally dependent on abundant and inexpensive water and designed for easy management, are still the most common type used by rice growers. They require a constant inflow of enough water to meet the crop's peak daytime needs. They also require some outflow of tailwater to maintain water depths. The widespread adoption of laser-directed land leveling in the late 1970s greatly improved the farmer's ability to regulate water in these systems. However, flow-through systems typically spill 12 or more inches of water yearly, ranging from 9 to as much as 40 inches.

Currently, total water delivered yearly from irrigation districts to rice fields varies from 50 to as much as 100 inches (4.2 to 8.4 acre-feet). Of that amount, actual water needed to grow the crop is ET—possibly 42 inches. In addition, percolation losses, which are largely unavoidable, vary a good deal. Tailwater outflows range even more widely.

Of these major components of water use on individual rice farms, it is unlikely that ET can be reduced without losing yield. Improved water use efficiency, therefore, must come from reduced percolation or tailwater outflows.

As water becomes scarce and/or more expensive, soils with high percolation rates may well shift to other crops. Possibly more significant will be adoption of new and different irrigation systems that reduce water losses at the lower end of the field. Already in use by some growers, these systems also have important implications for downstream water quality. They are discussed later in this chapter.

Another potential incentive for increased water use efficiency involves changes in water district policies—unit pricing, water measurement, etc.

Water Quality

For the past 10 years, California's rice industry has been the focus of an intensive regulatory and educational program to reduce water pollution caused by pesticides. The goal is to

reduce toxic discharges until there are no adverse impacts to aquatic organisms in drainage canals or rivers.

In the early 1980s, the herbicide molinate (Ordram) was implicated in fish kills and thiobencarb (Bolero) in creating a bitter taste in the city of Sacramento's water. Since then, increasingly strict conditions on pesticide use permits have vastly reduced the amounts of those herbicides discharged from rice fields into drains and the Sacramento River. These gains were accomplished primarily by holding water in the fields after treatment, thus providing more time for chemical compounds to dissipate. To do this, some innovative irrigation systems have been installed and many traditional flow-through systems have been adapted—primarily by re-using tailwater, by more intensive irrigation management and by ponding on "set-aside" land.

As a result, there has been no evidence of fish kills since 1984. By 1990, the annual molinate load in the river was down to 7,027 pounds (3,187 kg), compared to 40,667 (18,446 kg) eight years before. During 1991, when drought motivated rice growers to manage water with extra care, the estimated load was only 218 pounds (99 kg).

The control program for thiobencarb also keeps discharges of treated water within recirculation systems or elsewhere away from waterways. In this way, thiobencarb has been all but eliminated from the river—113 pounds (57 kg) in 1990 and zero (undetectable) in 1991, compared to 5,099 pounds (2,312 kg) in 1985. The taste problems have not recurred.

Meanwhile another herbicide, bentazon (Basagran), came under increasing control and was finally suspended in 1989 after a well survey detected it in ground water underlying rice-growing areas. Currently, regulations prohibit bentazon use on rice, but retain other (non-rice) uses.

Programs that brought about these improvements were designed and implemented by California Department of Pesticide Regulation. The Central Valley Regional Water Quality Control Board reviewed the programs to make sure that they were compatible with the water quality goals and objectives that the Board is required to enforce.

More recently, some insecticide use by rice growers also have created water pollution problems. In particular,

carbofuran, methyl parathion and malathion have been found in excess of state water goals; and malathion in violation of federal Environmental Protection Agency standards to protect aquatic invertebrates. Concentrations of these insecticides in Sacramento Valley waterways declined in 1991, but performance goals were still exceeded.

The regulatory pressure continues to increase. Before the end of 1993, the Regional Water Quality Control Board is scheduled to adopt numerical water quality objectives for five materials used on rice—carbofuran, malathion, methyl parathion, molinate and thiobencarb. Restrictions on pesticide use permits will ensure compliance with these objectives no later than 1995. These final adjustments also will have to take into consideration the cumulative impacts of several pesticides in drainage water at the same time.

In addition to these programs, Congress has put increased emphasis on control of nonpoint discharges such as irrigation return flows. There are indications that the federal EPA wants all sources of nonpoint discharges to follow management practices that reduce water pollution. There also are proposals to re-define individual farm drainage outlets as point sources. (See Section VI.)

Because management by rice growers has significantly reduced pesticide discharges, it appears that all current water quality objectives—for herbicides, at least—eventually will be met. But this may not end water quality problems for the rice industry. As regulatory programs are developed to deal with sediment, nutrients and other constituents of rice field drainage, more changes in production practices may be required in the future—particularly if farmland drains are re-defined as point sources.

Alternative Irrigation Systems

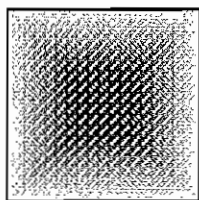
To meet water quality standards, rice growers must hold their irrigation water for a certain period of time after a pesticide is applied—in some cases for 30 days or more. This process allows pesticides to dissipate in the field and helps keep them out of public waterways. It also creates problems in irrigation management.

Although many growers are intensively managing existing systems to use water more efficiently, conventional flow-through irrigation is not designed for long holding periods. Recognizing this, some growers have shifted to new

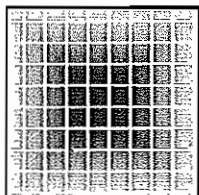
A "smart box" provides a way to automatically control water in an otherwise conventional irrigation system. It's a float connected to a valve mounted on the downstream end of a pipe where water flows from one basin to another. Once set to the desired depth of the downstream basin, the float opens and closes the valve to adjust water flow continuously. If water inflow is not limiting, all basins in a field can be completely self-regulating. Set properly, "smart boxes" can eliminate or reduce tailwater, conserve water and help control pesticide residues.

SACRAMENTO VALLEY RICE LAND

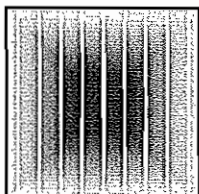
The patterned areas indicate generally where rice can be grown as an economic crop in the Sacramento Valley. Because soil capability is difficult to delineate, the borders are purposefully indistinct. Only part of this land is planted to rice in any one year. In fact, the total area marked with patterns is substantially bigger than the largest rice acreage yet recorded (600,000 acres).



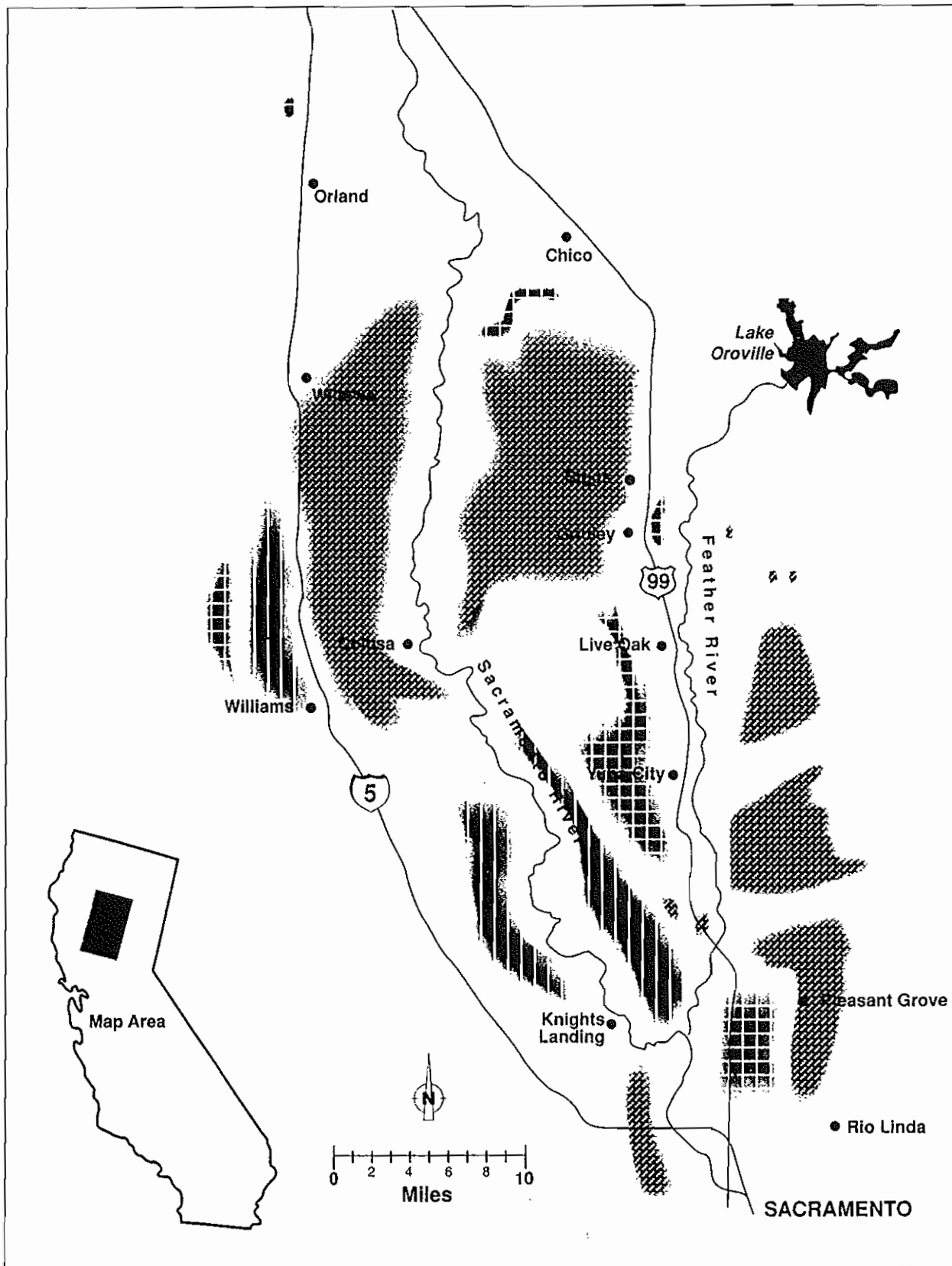
Rice is the main cash crop here. Because of poor drainage, possibilities for other crops are very limited.



This soil is suitable for rice and a few other crops, mostly grains.



Rice and many other crops can be successfully grown here.



Recent studies show another important advantage for recirculating systems—they appear to speed up the dissipation of pesticides. Preliminary results from one UC Cooperative Extension study show that, after 24 days, residues in a recirculating system were dramatically lower than in a conventional flow-through system. (90 percent less molinate; 83 percent less bensulfuron-methyl.)

types of irrigation systems in order to meet the water quality standards, use water more efficiently and gain more flexibility in irrigation management. There are three types of such systems—recirculating, gravity tailwater recapture, and static irrigation.

1. Recirculating systems use a sump or ditch to collect tailwater and pump it back for reuse. Many recirculating systems are on single farms, but some neighbors share one and some water agencies have an area-wide system. Smaller recirculating systems return water to the top of the field; larger ones, to a supply ditch. Costs depend largely on size, ranging from \$20 per acre for a 1,000-acre system to \$150 per acre for an 80-acre system. Recirculating systems also stretch water supplies, which is especially important in water-short areas. Preliminary results from a recent UC Cooperative Extension study show that a recirculating system can reduce tailwater losses by more than 35 percent compared to a conventional flow-through system. Several water agencies in the Sacramento Valley have reduced water losses by using recirculating systems. One agency along the Sacramento River recirculated over 50 percent of its water supply during the last three years.

2. Gravity tailwater recapture systems use pipes and gravity flow to divert tailwater from one field to another. They can serve a grower who has two or more adjacent fields, or cooperating neighbors. They can be converted to recirculating systems by installing pumps at the lower end of the system to keep tailwater and residues out of public waterways. These systems are relatively inexpensive. They provide some additional flexibility in irrigation management during the holding period, but also require more coordination of irrigation, pesticide application and other cultural practices.

3. Static irrigation systems, designed for use on individual fields, provide a special supply/drain ditch with pipes that regulate the flow and depth of water in each basin independently. There is no basin-to-basin flow as in conventional systems—and, of course, no tailwater. Besides keeping pesticides out of public waterways, static systems allow much more precise control of water in different basins. Also, water flow can be adjusted in hours rather than days as in flow-through systems. However, the fields cannot be flushed, which may be a problem in areas with salinity or sodicity problems. More research is needed to assess this potential limitation.

Rice Land: A Limited Resource

Rice growing is concentrated in the Sacramento Valley primarily because of its soils. Heavy clays or hardpan on about 600,000 acres (240,200 ha) in the Valley interfere with drainage and make it difficult to grow most crops. (See map, page 33.) However, because of its lack of drainage this land can be economically flooded for long period—thus making it suitable for aquatic plants such as rice. Most of it has been planted to rice at one time or another.

Slightly over half of this acreage is considered "rice only" soil, very poorly suited to rotation crops. There is no fixed boundary around "rice only" areas because the economics and technology of crop production change over time. However, on the most poorly drained part of the Valley's rice land—at least 300,000 acres (121,460 ha)—it would be very difficult under any circumstances to grow another crop, because these soils become waterlogged under winter rainfall and/or summer irrigation.

The remaining rice acreage varies in its suitability for rotation crops. For much of this land, there are relatively few choices, the most common being wheat or safflower every third or fourth year. High value rotation crops are not grown on this intermediate soil. In a few areas of more versatile soils, such as the Sutter Basin and District 108 in Colusa and Yolo Counties, rice is routinely rotated with various other crops, including wheat, safflower, tomatoes, cucurbits, beans and sugarbeets. Here, rice may be as useful for its benefit in breaking pest cycles of higher value crops as it is for a cash crop.

Competition for Crop Acreage

A farmer's decision to grow rice in the Sacramento Valley is influenced by the suitability of climate and soil, the value of rice and alternative crops, government programs, the availability of water and equipment, and his own interest and skill. Changes in any of these will not only affect total rice acreage but will have different consequences in the different rice soil groups.

Farmers on "rice only" land, for example, will be least affected by changes in total rice plantings. If total acreage drops, these lands tend to stay in rice as more valuable crops are planted on the better land. If total acreage increases, they continue in rice because they produce it economically. However, under circumstances that make it more difficult to grow rice—higher water costs or limited water supply, for example—these farmers

New Cities Planned on South Sutter Rice Land

In the South Sutter area, about 25,000 acres (10,120 ha) of farmland are under consideration for rezoning to accommodate four new communities with potentially more than 140,000 people. The area includes 10,442 acres (4,228 ha) of Class I and II land ("prime" farmland), and 15,083 acres (6,106 ha) of Class III and IV land.

Rice is grown on all classes of soil in the area—about 13,000 acres (5,263 ha) in 1990. Plans for three of the new towns call for them to be built entirely on rice land; the fourth would extend into it.

An early consequence of this proposed development is that, even before rezoning, the market value of land rose to well above its ability to produce income from farming; also, the cost of leasing farmland has increased. This makes it even more difficult to keep land in agriculture. It also reduces the incentive of landowners to maintain and improve land for farming.

As development proceeds, the farming infrastructure can be expected to erode. Aerial application will be more difficult because of nearby houses; new construction will interfere with transportation of rice; there will be new

competition for the water supply; noise, dust and mosquitoes from rice fields will aggravate urban neighbors. There will be growing pressure for more regulation of rice farming.

Project planners suggest mitigation methods: use open space as transition from farmland to urban areas, phase development by using setbacks and buffer zones, concentrate agriculture and grow high value crops on the remaining land (although suitable soils are scarce). However, when the project is complete, there will be no large, contiguous farmland parcels; agriculture would be restricted to narrow bands.

will be hard hit because their only alternative crops, such as pasture, range or dryland winter cereals, are lower in value.

Farmers with limited rotation crop capability share some of the problems of the "rice only" land. Their alternate crop choices, grains and safflower, are frequently lower in value than rice and usually yield less than the same crops on better land. If rice acreage declines, these growers must increase yield or reduce costs of the rotation field crop—or try other crops if possible. Since rice fields are virtually flat, they also may need to re-level and re-construct levees to get better surface drainage for the rotation crop.

For the small number of farmers with the flexibility to grow several crops, the choice of rice is more economically determined than on poorer soils where there is little if any alternative. In addition, their per-unit costs of production are lower because crop rotation helps to control pests, improves soil fertility and may increase yield. Also, straw management is easier when the field does not have to go back into rice. If conditions dictate less total acreage, rice in these limited areas will become a secondary crop. If total acreage increases, the decision to grow rice will depend on potential returns and on the water supply.

Competition from Urbanization

Population in the Central Valley is increasing faster than in the state as a whole; one projection is for a 50 percent increase by the year 2010. Most growth pressure is in the Sacramento area and San Joaquin Valley, but rice acreage is threatened both directly and indirectly. Most immediately, development directly north of Sacramento will either reduce the total available supply of rice land or cause relocation of acreage as displaced growers move to less pressured areas. In addition to conversion of farmland to urban uses, there is increasing potential for conflicts at the farm/urban interface.

Rice land also can be lost by conversion to wetlands through government acquisition or easements. Both the U.S. Fish and Wildlife Service and the California Department of Fish and Game were involved in recent land purchases in the Butte Sink. This area is a major flyway for waterfowl where sanctuaries are already well established. Much of the land there is also farmed to rice. These shifts in land use will increase the size of the sanctuaries at the expense of some rice acreage.

VI

FUTURE COMPETITIVENESS OF CALIFORNIA RICE

Because California rice growers are located in an increasingly crowded and urbanizing state, they must cope with resource and environmental constraints that increase costs and could limit the industry's competitiveness. Also, the future of rice in California depends in large measure on political and economic factors that are outside the industry's control.

These pressures, and the industry's reaction to them, will largely determine the future of California rice during the next decade or two.

Pressure on Natural Resources

The chief resource constraints on the rice industry are air and water quality regulations and the availability of an adequate water supply. Over the longer run, significant amounts of rice land could be lost to urbanization or restricted by urban influences. The most immediate challenge comes from the newly-mandated controls on air pollution. The industry's responses to this change will include (1) progressively more soil incorporation of rice straw and (2) more innovation, as the cost effectiveness of potential straw uses is explored (energy production, construction material, livestock feed, etc.) Both alternatives will be more costly than field burning, unless and until rice straw develops more market value.

On virtually all acreage where straw is incorporated and the land is replanted to rice, yields can be expected to drop somewhat. Losses probably will be in the 5 to 10 percent range during the first two or three years, and could increase substan-

tially beyond that in fields that are heavily infested with stem rot. However, there is some evidence that where straw is regularly incorporated, soil microorganisms develop different population patterns after the first few years. This might tend to stabilize losses to stem rot disease.

One possibility for dealing with stem rot is to rotate newly incorporated fields into land idled by government programs or drought, thereby providing more time for the incorporated material to decompose. However, if California growers plant more rice as a result of increased domestic and foreign demand, the amount of government program-idled acreage could shrink, thus reducing this source of flexibility. (This occurred during 1991 and 1992.)

Another way to combat stem rot is to rotate to other crops. This option, of course, is not readily available on "rice only" soils, which make up half or more of the acreage. However, some soils now thought to be "rice only" may, with management and new technology, prove to be more adaptable.

As non-burned acreage increases and more straw is incorporated into the soil, more field operations will be required—more machinery, more times over the field and possibly more delay in preparing seedbeds, all of which increase production costs.

Soil incorporation is an important area of applied research, which must be continued and expanded where appropriate. Meanwhile, impacts of the field burning phase-down on the rice industry should be carefully monitored.

Water Availability

During the next few years, scarcity of irrigation water may limit the output of California rice. Whether that actually happens depends on: (1) severity and persistence of possible drought, and (2) the amount of increase in competing demands for quantity and quality of water both for urban and for instream use. (As well as economic conditions in the industry.) In any sustained future statewide water crisis, the rice irrigation supply clearly would be reduced at some point.

Meanwhile, the endangered species issue—specifically, the dispute over salmon kills in the Sacramento River—threatens the Sacramento Valley's agricultural water deliveries. Also, environmental and urban needs for better water quality in the Delta create ongoing competition for the limited surface supply.

These problems, made worse by the drought, suggest that rice growers need to develop groundwater where feasible.

In years of normal or close to normal runoff, however, competing demands of a water market such as the State Water Bank will not substantially reduce the surface irrigation supply for rice. Because of high investments in their fields, landlord-tenant relationships, expected crop income, farm program requirements and the undesirability of disrupting established domestic markets, rice growers are less likely to voluntarily transfer water than growers of many other crops. For example, rice acreage in the 1991 State Water Bank was relatively small compared to corn. Of course, the price offered in future years for water transfers will be a factor. In 1991, it was \$125 per acre-foot.

In any case, the existing pressure for improved water use efficiency on rice farms will increase, particularly if severe drought conditions continue. Several approaches are available to individual rice growers:

1. Field selection. Especially during a severe water shortage, rice should be planted only on fields with little deep percolation—hardpan soils.
2. More efficient irrigation system design.
3. Better in-field water management.

At the water district level, policy changes also could increase efficiency. For example, unit water pricing and/or higher charges would encourage more efficient use. With changes in water law, districts also might give priority in water deliveries to areas of tighter soil.

A less tangible but important consideration for the rice industry's water supply is the widespread public belief that rice uses a disproportionately large amount of irrigation water. More public understanding is needed of the facts that: (1) even though they grow in standing water, rice plants use no more for ET than many other irrigated crops (2) water that runs off the lower end of a rice field has value for downstream use, and (3) because of tight clay soils, most rice fields lose relatively little water to deep percolation.

A compensating factor in the public mind is the value of rice fields as wildlife habitat. There is little doubt that Sacramento Valley waterfowl populations depend heavily on

rice fields for both food and living space. Some environmentalists, at least, can be expected to resist proposals to dry up large acreages of rice land in order to make more water available for use elsewhere.

Water Quality

It appears that the effects of herbicide residues in rice field drainage—problems of fish kills and foul tastes in drinking water a decade ago—are substantially resolved. Residue levels have been greatly reduced. Most significant, the problems have not recurred for several years.

This has been accomplished primarily by holding irrigation water in the field for mandated periods after herbicide application. Also, growers are tending to use more biologically specific pesticides and lower rates of application.

A point of vulnerability is the fact that growers commonly have ponded their treated water on government program-idled acreage. This procedure has worked well in the past. However, if planted acreage increases substantially or the program allowance continues to be relatively small as in 1991 and 1992, this option would be less available and water quality problems could reoccur. For this reason as well as water use efficiency in general, rice growers need to consider permanent irrigation improvements—tailwater return systems or static systems—so there is less water from treated fields to pond or discharge.

What about other aspects of water quality? Controls on insecticide residues are being tightened and growers can be expected to comply by, among other actions, ponding treated water as they do with herbicides. Again, this emphasizes the need for improved irrigation systems.

One open question with potential impact is whether individual rice field outlets might, or feasibly could, be treated as "point sources." Both environmentalists and regulators have, on occasion, suggested such a change. The cost to chemically analyze water from individual farms would be enormous, and might not protect downstream users any better than the present method of requiring specific holding periods, and then analyzing water in major drains and rivers to check for compliance with water quality goals and objectives. On the other hand, such a system might pin-point individual violators,

to the rice industry's ultimate benefit. Research on quicker, cheaper monitoring methods is under way and should continue.

In any case, the degree of pressure to re-define farm drains as point sources may well depend on the success of current agricultural water quality control programs. In the case of rice field drainage, those programs appear to be working.

It can be argued that, despite progress in pollution control, scarcity of resources may well limit the future output of California's rice industry. The mandated phase-down of field burning, competition for the water supply, ever-tighter water quality regulations, conversion of rice land to sub-divisions or permanent wetland habitat—all these and other prices to be paid for agriculture's co-existence in an urbanizing environment will have a cumulative impact.

On the other hand, the ability of rice growers to adjust is a demonstrated asset. That is indicated not only by success of the pesticide residue control program but by the willingness of many growers to experiment with soil incorporation and new irrigation systems.

Markets, Prices and Free Trade

Other major forces in determining the rice industry's future in California will be (1) demand for japonica-type rice in the U.S. and in world markets and (2) impacts of potential changes in farm programs. At least some sustained expansion in this state's domestic rice market appears likely—particularly in the West, in groups of japonica-preferring consumers elsewhere in the nation, and in the processing industry.

In addition, some within the industry argue that an important domestic market niche is available for high-quality, California-grown, brand-identified rice—whether long-grain, specialty medium-grain (M401) or even short-grain. These products represent relatively small segments of total U.S. demand, but are seen as an opportunity to exploit higher-priced domestic markets if increased consumer awareness of California quality and taste is developed.

Foreign sales will continue to be important. Because California's rice output is tiny compared to consumption in the Far East, a small increase in market availability there would have a dramatic effect on demand for japonica rice from this state.

In May, 1991, U.S. Department of Agriculture economists forecasting the effects of agreement under the Uruguay Round of GATT negotiations had this to say about impacts on the rice market by the mid-1990s: "In the U.S., only japonica-like rice produced in California would meet the quality standards required by Eastern Asia consumers. Consequently, California rice production would rise in response to higher prices and export demand. However, the increase in California rice production would not be as large as the increase in its exports. This would leave a larger domestic market for producers in the Southern States." As a result, the economists added, the Delta States would grow both more indica and more medium-grain rice and "Delta producers would receive a higher price for medium-grain rice than for indica, but not the premium paid by Asian importers for japonica-like rice." ("Economic Implications of the Uruguay Round for U.S. Agriculture", Office of Economics, U.S.D.A., May 1991.)

Political trends in Japan indicate a possibility that barriers to rice imports there will soon be lowered by at least a token amount and possibly more—unless U.S.-Japan disputes over industrial trade policies become even more contentious. The current GATT negotiations are important, but bilateral trade agreements are probable in any case. Any Japanese movement toward freer trade in rice almost certainly would result in (1) an increase in the world price of japonica rice, possibly offset to some extent by reduced price supports in the U.S. and elsewhere (see page 46), and (2) significant shipments of California rice to Japan, at least in the short run.

It is important to distinguish between possible overseas rice market situations during the next few years and in the more distant future. In the shorter run, California's potential competition exists almost entirely in those few japonica-growing regions of the temperate latitudes where rice is produced for export.

(A central question for the entire global rice market, as well as California, is whether high-quality, japonica-type rice can be grown outside the temperate zones. Or, conversely, whether high-quality indica rice can be grown outside the tropics or sub-tropics. Plant breeders are at work on both problems.)

Initially, California's obvious competitor in the newly available portion of the Japanese rice market—if and when it materializes—would be Australia. Thailand also can deliver rice to Japan at well below the Japanese cost of production; but Thailand grows primarily indica rice. (It is possible that the Japanese would accept indica rice for certain processing uses.) In the Mediterranean region, possible competitors for the japonica-type market would be Italy, France and Spain.

In the U.S., medium-grain rice can be grown in Arkansas, Texas and Louisiana. However, California has a competitive advantage in international trade due to this state's ease in achieving U.S. No.1 grade; the South's standard export grade is U.S. No. 2. Compared to the Southern states, California has a transportation cost advantage to Japan of possibly \$5 per ton (\$5.51/metric ton). However, the South has a similar advantage in shipments to the Mediterranean and European markets. In any event, California would appear to be in an advantageous position in any early move toward trade liberalization by the Japanese. To gain long-term benefits, it will be important for California's rice industry to maintain a reputation for quality and dependability of its rice exports. Special cooking quality

and flavor characteristics will be required for specific market niches, in Japan and elsewhere.

The longer run international outlook for the California rice industry is less predictable. If a substantial price difference between japonica and indica rice in the global rice market persisted, japonica producers in other temperate-zone growing regions (North Korea, China and Brazil, for example) might attempt to exploit it. This could create significant competition for U.S. growers. (See box on this page.)

During the coming decades, population will be an extremely important determinant of demand in traditional rice-consuming countries of Asia. Pressure of population growth in countries such as China and India probably will limit their capacity to participate in export markets. However, it is conceivable that a major increase in the world price of japonica—as might result from opening of the Japanese market—could lead China to export large quantities of rice and import wheat, if wheat prices remain relatively lower. In most of the rest of Asia, it is likely that the diet shifts away from rice found in almost all middle and high income Asian countries will partially offset the impact of population growth on total demand.

In Western Europe and the Middle East, rising incomes probably will lead to more demand for rice in order to increase variety in their diets. Newly-developed markets for California rice in the Middle East probably will continue, barring extreme political instability. In most of these countries, however, market preferences between indica and japonica varieties are not so marked and relative prices are likely to have much more impact.

In summary, changes in international demand for rice in the short run will depend largely on political developments such as those under discussion in the Uruguay Round of GATT negotiations. Of supreme importance are actions by Japan which has the potential to become the world's largest rice importer and which, because of its strong preference for high-quality japonica rice, is crucially important to the California rice industry.

In the longer run—assuming the Japanese market opens to some extent—international demand for California rice will depend on:

- The trend of japonica production in other temperate zone growing regions and, possibly, in sub-tropical and tropical areas.

A 1991 study by the University of Arkansas projected worldwide demand and supply for japonica rice if a more open market is created under GATT. The study was based on assumptions that (1) Japan would allow imports of 1,102,000 tons (1 million metric tons) yearly and (2) trade with other japonica-consuming nations would be completely liberalized. In this projected scenario, total world trade in japonica increased by 288 percent over the 1986-87 base year and the weighted average world import price increased 96 percent. Rice imports by Japan, South Korea, Taiwan and the EC-10 increased; imports by other countries remained the same or decreased. The exporting nation with the largest increase in japonica exports in this scenario was China, followed by North Korea and Australia. U.S. japonica exports increased by 187,000 tons (0.17 mmt).

- The response of Japanese rice growers to lower producer prices.
- The response of consumers throughout the world to a higher price difference between japonica and indica rice varieties.

Role of Support Programs

If the GATT negotiations lead not only to liberalized global rice markets but to a phase-down of government supports for U.S. rice growers, economic adjustments would be inevitable. Of course, under any prospective GATT arrangement, growing regions elsewhere in the world also would lose price/income protection—some substantially more than the U.S.

Since loss of government price support programs through international agreement would result both in lower effective prices to California rice growers and similar economic pressure on their competitors, the result would be a move toward an open, commercial market.

In the resulting test of competitiveness, California would have the advantages of high yields, quality and location on the Pacific Coast, and the disadvantages of relatively high costs and more restrictive water supply and environmental controls. (It appears that increased environmental awareness in the Southern U.S. will place similar pressures on growers there in the future.)

What would be the effect on the California rice industry—specifically, on rice acreage in the Sacramento Valley? That would depend on the actual price level during and following the adjustment period. One immediate result of significantly lower prices could be to concentrate the crop on “rice only” soils, with other crops moving onto land capable of growing them. Some soils might well be returned to dry range, dryland grain or, possibly, safflower.

Even if the economic adjustment were less severe, it is unlikely that in the near future California rice acreage will return to its historic high of 600,000 acres. In addition to economic pressures, limited water supplies and restrictions on chemical use and field burning probably will tend to reduce the planted acreage. Normal-year plantings could settle out at 400,000 acres or less, possibly going as high as 450,000 in years of strong demand and plentiful water.

That situation could change over the longer run as production efficiency improves and demand for imported rice rises in such markets as Japan, Korea and Taiwan. Economists for the International Rice Research Institute (IRRI) predict substantial increases in total global demand for rice in the coming decades. ("IRRI Toward 2000 and Beyond," International Rice Research Institute, Manila, Philippines, 1989.) Support programs or not, California very probably will be in position to supply the more affluent part of that expanding market.

Strategies to Improve Competitiveness

In the face of higher costs, limited natural resources and probable shifts in the market environment, what lines of action are available to California rice growers, to the industry and to associated institutions such as UC? Which problems are researchable? Which call for industry action?

One basic issue is production and processing costs. Most growers already are highly cost-conscious, but some additional reduction in production costs may be possible. Economic choices will be required; for example, some growers may forego even higher yields in order to keep per-unit costs down.

Potential processing cost reductions could well focus on the problem of mill out-turn, which is a source of competitive weakness vis-a-vis the South. One specific need is for a small-scale research processing facility so that experimental new varieties could be more quickly evaluated for this aspect of quality.

Another research need is for facilities to conduct long-range studies on crop sequencing and other production practices. The Rice Research Station is largely devoted to plant breeding and pest control research. Meanwhile, the use of commercial farms for test plots is difficult with long-term trials of, for example, fertility changes resulting from straw incorporation. A similar need is for long-term research on systems to utilize rice biomass.

Another important issue for California rice growers is the apparent reluctance of agricultural chemical manufacturers to register new compounds in this state because of California's stringent regulatory requirements. Weed control is a particular area of concern. Current chemical materials, particularly

molinate (Ordram), are under regulatory pressure. The consequences would be serious if molinate were withdrawn, since other currently available chemicals may be worse pollutants and the alternative of weed control through crop rotation means less production. Under California conditions, it appears almost impossible to grow high yields of rice continuously in the same field without chemical weed control.

Variety improvement for better yields, quality, pest resistance and other adaptive characteristics is another continuing challenge. How much additional yield is available from plant breeding? In China, a 15 to 30% increase has been reported through the introduction of hybrid varieties. However, yields in California already are so high that there is less potential for dramatic gains from hybrid vigor. Thus, in the foreseeable future, a sudden jump in yields comparable to the introduction of short-stature varieties in the late 1970s is not likely. However, some future increases in yield—possibly as much as 20%—can be expected in small increments.

Thus, somewhat higher yields, a result of both improved genetic capability of the rice plant and improved management to exploit it, will tend to increase California's future rice supply. On the other hand, forces tending to decrease it will include (1) environmental regulations, (2) possible constraints on the water supply and (3) relative costs.

These are important research areas, involving a more integrated examination of both farm management and marketing—for example, a systems approach to harvesting, drying and processing.

The Broader View

It is increasingly apparent that production and processing of California rice is one component within a global network that is becoming more complex and also, thanks to the advent of communications technology, somewhat more manageable. Other components of the system include such forces as population growth in California, the environmental movement, agronomic conditions in Arkansas, consumer tastes in New York, politics in Japan, government policies in Thailand, and—not least—technological development throughout the world.

For California rice growers and marketers, there will be increasing need to deal with uncertainty. Possible changes in the farm program and possible changing dynamics of the input

supply (for example, the option to market water rather than using it) will require growers to make new kinds of decisions. Extreme uncertainty of demand/supply responses to political decisions (for example, the current GATT negotiations) will require more flexibility in marketing.

Within the global network, the California rice industry's competitive edge depends on:

- Continually improved crop and pest management that is compatible with the aquatic environment.
- Maintaining higher yields than competing regions.
- Maintaining a market reputation for quality and dependability.

These are the industry's potential strengths. Its challenge, in the face of increasing scarcity and regulatory pressure on natural resources, is to maintain production and processing costs that are reasonably competitive with other rice-growing regions.

Despite resource constraints and market uncertainties, the California rice industry can be expected to survive, and very probably to prosper, for as long as can be reasonably forecast. But that outcome will depend on the industry's ability to adapt to changing market conditions, regulatory circumstances and political realities.

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