Agriculture in California:
On the Brink of a New Millennium
1990—2010

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Preface

This volume contains a series of analytical reports by University of California staff on issues critical to the future of agriculture in this state. These studies were commissioned by the UC Agricultural Issues Center in response to a request from the California Department of Food and Agriculture to Vice President Kenneth Farrell, UC Division of Agriculture and Natural Resources. The goals of the papers were to anticipate—as accurately as possible, considering all the uncertainties—the agriculturally-related issues important to California’s people, economy, resource base, and environment during the last decade of this millennium and the beginning of the next; and to identify the most significant policy choices and research needed to deal with these issues. Almost 40 members of the staff of the UC Division of ANS accepted the challenge of authorship. The results are in the following chapters.

The interface of agriculture with California’s economy and its human and natural resource bases is examined here. The theme is the challenge of change—external changes that we can only adjust to and internal changes that we can make happen.

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Acknowledgements

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Introduction

California agriculture remains unique for its sheer size, its diversity, productivity and for its importance to the U.S. market and in world trade.

With only about 3 percent of the nation's total farmland, California accounts for nearly 10 percent of total U.S. agricultural cash receipts. That includes about one-half of all receipts for fruits and nuts and more than half for fresh market and processing vegetables. California produces over 250 different crop and livestock commodities, and leads the nation in output of 58 of them. More than 90 percent of the national output of 13 crops is grown in this state; more than half of 11 other farm products. (See Appendix.)

Assuming $3 of economic activity generated for every $1 of agricultural sales, agriculture contributes almost $52 billion of economic activity to the state's economy. And about one in six jobs in the state are related to the food and fiber sector.

New Challenges

Today, California agriculture is challenged by a set of basic problems. Some of them are relatively new, while others have been with us for some time but are rapidly approaching a critical phase. Three trends are particularly important. These are (1) increasingly scarce, lower quality and/or more expensive resources, (2) increased competition in world markets, and (3) changing public perceptions and attitudes about food and the environment.

In the following chapters, the authors consider these issues and others over a future time span of roughly two decades—until the year 2010.
Quantity and Quality of Resources

Scarcity of land, air and water—agriculture’s crucial natural resources—may be caused by physical shortages, by degradation in quality or by loss of the resource to other users. For example, as Chapter 4 points out, future shortages of irrigation water may result from drought or from loss, or sale, of agricultural water supplies to metropolitan areas.

Land as such, of course, does not become scarcer; but its availability for various uses is an open question. The “loss” of farmland to several forces (urbanization is only first on the list in Chapter 3) remains an issue crucial to future environmental quality in California as well as farm production. And, as Chapter 5 makes clear, scarcity of clean air—that is, degradation of air quality—is already causing millions of dollars of crop damage.

Besides scarcity of natural resources, California agriculture is experiencing pressure on other inputs and services such as the agricultural transport system (Chapter 6) and the farm labor market (Chapter 2). For example, much uncertainty has been aroused by changes in the immigration law.

Competition for Markets

Another reason that California agriculture faces fundamental challenges is intensified competition—in particular, for sales of food and fiber in worldwide specialized marketing. Changing markets in the U.S. and abroad, described in Chapter 7, are threatening California’s traditional role as low-cost, high-quality producer and shipper of many crops.

Public Perceptions and Attitudes

This leads to a third reason for California agriculture’s changing set of problems: shifting public perceptions and attitudes. In the next century as now, most citizens of this increasingly urbanized state will have little direct contact with croplands and corrals, food processing plants and agricultural marketing systems. Still, they will have to share this state with agriculture, and agriculture will have to share this state with them. Much depends on that relationship.

Consumers in the state and elsewhere are showing greater concern about food safety and quality. The environmental movement is active and growing. Clearly, these trends are changing agriculture’s options on pesticides and water use, for example.

Response to Pressures for Change

In response to these and other pressures, California’s farmers are experimenting with alternative production systems that are
more "sustainable"—that is, they are more aware of the balance needed between the use of resources in production and their replenishment in the system. Chapter 1 lays out various farming approaches being considered. Some combination of these will lead, sooner or later, to improved farming systems, largely built on current technologies but with reduced use of agricultural chemicals.

The notion of sustainability extends beyond the farm. It involves the entire food and fiber system—production, processing, marketing, and distribution. Changes in the total system may be required to satisfy shifting consumer demand and still be consistent with long-run food safety and environmental goals of society. Beyond the food and fiber system, there is need to sustain California's rural communities that grew up with its agriculture. (A report on rural development will be published later by the Center under separate cover.) And beyond the rural sector, it is society and the environment in which we all live that we want to sustain over time.

The agriculture of the future and its social and economic roles in California will be shaped by those within the food and fiber system, by government decision-makers and by the public. In the process, three areas will be of special importance:

• Information and public understanding of the issues. Changing needs in agricultural education, for citizen-consumers and for professionals within the system are discussed in Chapter 8.

• The ability of the University to respond to the challenges. Chapter 9 examines how UC's Division of Agriculture and Natural Resources identifies high priority areas that require new solutions, including those discussed in the other chapters of this book.

• The capacity of government to make well-informed decisions. Virtually all the policy recommendations in the following chapters assume that capacity at some level of government.

Policy Proposals
California agriculture is fundamentally influenced by decisions made in Washington DC (price support programs, for example); in Sacramento (pesticide regulations); and in hundreds of local governments (land-use decisions). Each of the following chapters contains recommendations that address such public policy decisions and their effects on agriculture, consumers, the economy and the environment.
Some of the recommendations are concerned with the public's crucial interest in protecting natural resources—for example, the enormous and potentially disastrous threats of salinization and air pollution in the Central Valley. (Resource-use issues affecting agriculture often cross local jurisdictional boundaries and thus are regional in nature—preservation of farmland, groundwater management, air pollution control.)

Other policy recommendations in this volume are aimed at more efficient and more equitable institutions that deal with people—for example, better job information for agricultural workers. Still others are intended to make public policies more effective by basing them on better information—about markets, for example.

Of course, the recommendations reflect the viewpoints of the university members who made them, and not the University of California.

Assumptions

Because of the inevitable uncertainties, certain assumptions are required for any broad-ranging look at the future such as this one. Some such assumptions are implied; others should be explicit. Previous analyses of the challenges facing California as a new century approaches have pointed out that much depends on what happens in three areas of change—the global marketplace, the state's population and developing technology (California Economic Development Corporation, 1988). Assumptions addressing those uncertainties have been adopted here, and others added. Whenever the authors deviate from these assumptions, as for example to consider the impact of a possible energy shortage, they explain this in the text.

California is part of a global marketplace.

Worldwide competition for markets, fueled by the spectacular growth of world trade and international financing, will continue to intensify. These markets are not just for goods, but for capital, ideas, services, management, and labor. Advances in telecommunications and transportation will continue to facilitate these trade flows. Faster-growing economies elsewhere will capture more of the benefits of trade; still, the potential markets for California's agricultural and nonagricultural products at home and abroad are enormous.

California's population is both growing and changing.

Although the rate of growth is slowing, 9 million more residents of this state are expected by 2010, for a total population of about 37 million—a 32 percent increase from 1988. Two significant trends within the overall population growth are under way: (1) Ethnic minorities are growing more rapidly than the total population
and in aggregate are expected to be a majority by 2010 and (2) the average age is increasing. This implies an increasing dichotomy between the elderly population who will be predominantly Caucasian and younger Californians who will increasingly be from ethnic minority groups.

\textit{It will be more difficult to capture the benefits of research and development.} California’s historic ability to lead the world in advanced technology—an advantage that is possibly even greater in agriculture than in other sectors—is under increasing pressure from the rapid, global spread of new knowledge and new techniques. Because of worldwide telecommunication networks, internationalization of research and education, and the global scope of enterprises themselves, it is becoming increasingly difficult to maintain effective possession of an idea or a technological innovation.

\textit{The climate will not change substantially.} Some scientific evidence points to the possibility of very severe, continued drought at some time in the future. However, an unqualified assumption that such a catastrophe actually will take place during the next decade or two appears difficult to justify. Therefore, except when authors specify otherwise, it is assumed that, at least until 2010, California’s temperature and precipitation patterns will remain within the range experienced during the past century—which, of course, includes floods and prolonged drought.

\textit{Energy resources will not change radically.} It is possible that another energy crisis similar to the mid-1970s will develop during the next two decades, but there is not enough evidence to simply assume that it will happen. Therefore, except when authors specify otherwise, it is assumed that (1) there will be no significant change in the availability of energy and (2) there will be a steady escalation in its price relative to other goods and services, leading to an approximate doubling of the real price of energy by 2010.
Changes in the Production System:

Chapter 1. Farming Systems in California: Diversity to Compete in a Changing World

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California Farming Systems: Diversity to Compete in a Changing World

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Introduction

Agricultural production is a highly extractive process. In fact, the object of the process is to convert soil resources to foodstuffs, and in doing so, nutrients are taken up. Thus, crop and animal production must continually replenish the resources used in order to maintain agricultural production. Societies rich in natural resources can initially use these reserves faster than they replenish them, to increase their return to capital. They then can turn this capital into technologies and knowledge used to manage resources for continued production. The degree to which societies use up resources before learning to manage them affects their future level of productivity. One of California’s greatest challenges is to maintain and enhance its agricultural productivity while sustaining its resource base and protecting the environment, both on and off the farm.

Agriculture developed, flourished and faltered in Mediterranean areas. In Europe, intensive agricultural production systems evolved where land was a limiting resource. Only in North America have the fruits of the technological revolution been coupled with land resources abundant enough to allow a high degree of mechanization on an extensive agriculture. In California, agriculture has

\(^1\)Assisted by D. Sound and L. Weigler.
come full circle. Here technology, efficient input use and extensive land areas have been combined with a Mediterranean-like ecosystem. While the state's robust farm economy is characterized by high productivity and great product diversity, the California experiment is still young and the future of irrigated agriculture in the state is facing major challenges.

In this chapter we bring together much of what is found separately in other parts of the book. We consider the most important forces affecting farming systems in this state. The key is to maintain flexibility and responsiveness. Because of its diversity, California agriculture has a better hold on that key than most other farming areas in the nation.

What are these forces effecting changes in the state's farming systems? California is "filling up." First, it is rapidly filling up with people. Because the western United States has had favorable climate, abundant natural resources and low population density, there has been limited direct feedback on resource use from one sector of society to another. This comfortable pattern is rapidly changing in California. Now, sectors compete over resources, contaminate resources essential to each other, and exert political force to develop policies to protect themselves against other sectors. Accordingly, urban populations that can outcompete agriculture for land and water will compel existing farming systems to adapt.

Second, California is filling up with by-products of its rapid development—degraded air, contaminated ground and surface water, solid waste, and transport congestion, to mention a few. Agriculture both contributes to and is affected by these side effects. Whenever and wherever agriculture adds to the problems, it will be coerced by more powerful constituencies to modify its farming practices.

Farming systems today, as in the past, have been responsive to external forces—reacting to the economy, the environment, and the society in which they function. Each farming system represents the reconciliation of an individual farmer to broad influences such as markets, policy and regulations, and weather, integrated with the unique characteristics of a particular farm site. Because they must respond to changing and complex economic, social and physical environments, the critical factor to success has always been the quality and flexibility of management that farmers employ to meet constraints imposed on them.

Today environmental constraints will be particularly binding on farming systems. In the future, agriculture will be required to be more cognizant of the balance needed between the use of resources and their replenishment. That is, it will have to internalize what in the past it has cast off. This will mean increased operating
costs, so, again, success will depend on improved management. Fortunately, California, because of its diverse agriculture and its potential for even greater diversity, holds a comparative advantage over other regions in the nation in that it enjoys more options in meeting the challenges ahead.

California by no means feeds itself. As input costs rise (especially water), California will continue to switch to higher-value crops, a good portion of which is exported. Meanwhile, in-shipments and imports of more basic supplies will continue to increase. The costs of this increased transport should also be counted in any overall view of the efficiency of the state’s agricultural system and in the overall food budget.

**California Present**

**Overview**

California is a unique site for agricultural production. The combination of developed supplies of irrigation water, fertile soils, and a Mediterranean climate provides nearly ideal growing conditions. Water, furnished by winter rain and snowfall, is captured in reservoirs and delivered by extensive irrigation systems during the warm dry growing season. Irrigation, mechanization, other technologies, and sophisticated management control the use of inputs critical to production. Most valley soils of California are alluvial in origin and are highly productive over time, when nitrogen is added. Moderate year-round temperatures in most of the state allow year-round crop production, when water supply is adequate, while diverse microclimates provide local niches for unique specialty crops.

In addition to 35 million acres of grazing land in the state, there are five basic types of cropping systems—irrigated field crops represent about 60 percent of California’s cropland; tree fruit, grapes, and nuts, about 18 percent; irrigated pasture, 11 percent; vegetable crops, 7 percent; and dryland cereal crops, 4 percent. Many farms mix two or more of these systems, and/or produce livestock or poultry. (For a more detailed description of the types of crops and livestock produced in California and their location of production, see Scheuring, 1983; also see the Appendix of this volume).

**Trends in Farming Systems**

Since World War II, the state’s farming systems have been characterized by increasing use of mechanized equipment, a vastly expanded irrigation system, a rapid rise in the use of nitrogen fertilizer and other nutrient inputs, development of new plant genotypes with more efficient partitioning for yield (that is, a greater proportion of plant production goes into useable product) and
disease resistance, increased use of chemical biocides, and improvement in information delivery to farmers. These innovations were embraced in a period when cheap energy allowed the expansion of activities that otherwise would have called for more expensive labor. Major emphasis was placed on the quantity and quality of yield with perhaps too little concern for the fate of applied inputs.

In the past two decades, acreage of fruit, nut, and vegetable crops has steadily increased in response to the development of markets, facilitated by expanded irrigation systems (Cassman and Rains, 1986). Irrigation has also allowed the proportion of the total land devoted to summer crops to increase markedly. From 1964 to 1968, annual winter crops that require relatively little irrigation (primarily barley) were grown on 55 percent of the irrigated acres of Kings County; but by 1984, only 22 percent were in winter crops (Table 1). These trends from winter- to summer-grown crops and the increased acreage of fruits, nuts and vegetables in the San Joaquin Valley have further escalated the demand for irrigation water. Also, many of these crops are “fragile,” requiring more management attention to pest control and soil fertility for successful production.

The dry summer climate provides high levels of sunlight that restrict the growth of fungal pathogens infecting insects. Also, the long, warm growing season increases the insect population by expanding the number of generations and allowing overlapping of hosts for the pests. For these reasons, California generally has more severe insect problems than elsewhere in the nation and uses more insecticides (but less fungicides).

In contrast to systems in the Midwest and South, field crop rotations in California are more variable with sequences composed of dominant and secondary crops. Dominant field crops (e.g., cotton, rice, processing tomatoes, and in some areas alfalfa, sugar beets, dry beans) are farmers’ main focus. Rotations are used to anticipate shifts in market demand, lower year-to-year risks, reduce pest problems, and improve soil conditions for dominant crops. Given the diversity of what can be grown in California, crop rotations offer a potential means to turn a competitive advantage in both domestic and foreign markets.

Although the level of input use is relatively high in California agriculture, yields do not approach levels that are theoretically possible (Loomis, 1984). Comparison of average state yields with state record-high yields for corn (9,000 vs. 18,000 lbs/acre), alfalfa (12,000 vs. 30,000 lbs/acre), and rice (6,500 vs. 12,000 lbs/acre) show that actual levels are well below peak potential. These differences stem from differing levels of input use and especially to intensity of field management, as well as soil and weather variations. Were the
Table 1. Average Annual Acreage of Winter and Summer Crops in Kings County, 1955-1984

Winter Crops, 1000 acres

<table>
<thead>
<tr>
<th>Period</th>
<th>Cereals</th>
<th>Saffl.</th>
<th>Misc.</th>
<th>Winter Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1955-59</td>
<td>209</td>
<td>-</td>
<td>7</td>
<td>216</td>
</tr>
<tr>
<td>1964-68</td>
<td>191</td>
<td>39</td>
<td>19</td>
<td>249</td>
</tr>
<tr>
<td>1970-74</td>
<td>162</td>
<td>33</td>
<td>19</td>
<td>214</td>
</tr>
<tr>
<td>1978-82</td>
<td>146</td>
<td>35</td>
<td>20</td>
<td>201</td>
</tr>
<tr>
<td>1984</td>
<td>71</td>
<td>22</td>
<td>11</td>
<td>104</td>
</tr>
</tbody>
</table>

Summer Crops, 1000 acres

<table>
<thead>
<tr>
<th>Period</th>
<th>Seed Crops</th>
<th>Alfalfa</th>
<th>Cotton</th>
<th>Fruit/Nuts</th>
<th>Misc.</th>
<th>Summer Total</th>
<th>Summer/Total percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1955-59</td>
<td>2</td>
<td>48</td>
<td>96</td>
<td>8</td>
<td>16</td>
<td>170</td>
<td>44</td>
</tr>
<tr>
<td>1964-68</td>
<td>7</td>
<td>62</td>
<td>88</td>
<td>9</td>
<td>35</td>
<td>201</td>
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<tr>
<td>1978-82</td>
<td>30</td>
<td>46</td>
<td>288</td>
<td>21</td>
<td>32</td>
<td>417</td>
<td>67</td>
</tr>
<tr>
<td>1984</td>
<td>25</td>
<td>27</td>
<td>267</td>
<td>23</td>
<td>25</td>
<td>367</td>
<td>78</td>
</tr>
</tbody>
</table>

Source: Cassman and Rains, 1986

Resource mix different (as it is in, say, Japan or the Netherlands where land is scarce), farmers' input emphasis would differ. In America, labor is one of the most costly inputs, so managers optimize production per unit of labor and capital rather than per unit of land. In California, where dominant crops are relatively high water users, increasing water costs may compel managers to improve efficiency of water use, optimizing yield per unit of water applied; to do so, might well mean increased use of complementary inputs.

Constraints on Production Agriculture

Availability of Water for Agriculture

During the last 50 years, California has enjoyed above-average precipitation, but historically, long periods of drought have not been uncommon. The record in tree rings indicates that the future is likely to produce droughts considerably longer than two years. Even the recent two-year droughts—1976-77 and 1987-88—fully tested the storage capacities of the state. By the end of 1977, there was virtually no surface water left, and ground water was overdrafted by 4 million acre-feet. During 1987-88, agricultural water deliveries were cut significantly.
With California’s rapidly expanding population comes increased competition with agriculture for available water. In the future, a prolonged drought coupled with increased population and other competing interests for water, could have a major long-term impact on the state’s agricultural base. Yet the development of new facilities to hold additional water is unlikely (see the chapter on water, Chapter 4). California agriculture, which uses approximately 85 percent of the water in the state, will come under increased scrutiny and pressure to use water more conservatively.

**Water Quality**

As California’s growing population spreads across the state, it also demands a clean water supply. The more wells drilled, the more water pumped, the more chemicals used in both agriculture and manufacturing industries, and the lower the detection limits achieved by sensing equipment, the greater the likelihood of discovering contamination. An increasingly concerned urban public will call for agriculture (and other industries) to adapt practices to protect the quality of available water. For example, agriculture has been identified by the U.S. Environmental Protection Agency as the largest nonpoint source of surface water pollution (National Research Council, NRC, 1989).

**Increased Water Costs**

The low probability of developing new water sources and the competition for available water from a growing urban population will put upward pressure on the price of water. Prices for federal-supplied water will increase significantly as new water contracts are renegotiated. One estimate is that federal water will increase three- to fivefold on renewed contracts.²

Also, as energy costs increase, so will the cost of pumped ground water and the movement of surface water for irrigation purposes. Here we assume that the cost of energy will about double in real terms by the year 2010. Although production level agriculture is a relatively minor user of energy in the state, about 44 percent of the energy used in farming is associated with irrigation water (Chancellor and Johnston, 1986). Although in most cases water development for irrigation districts generates power so that an increase in the cost of energy may actually decrease the cost of surface irrigation water, higher energy costs will make ground water pumping more expensive. Lowered ground-water tables compound the problem, for the required lift is higher.

²Stackhouse, Bureau of Reclamation, personal communication, 1989.
Farming systems will have to adapt to these new conditions, but it is difficult to generalize about the impact of increased water costs on crop selection. For example, rice, a heavy water user, is grown mainly on heavy clay soils in the Sacramento Valley where water is relatively abundant. Even so, Adams, Johnston, and King (1978) found rice to be the crop most sensitive to energy price increases. Alfalfa is another high water-using crop, but its high evapotranspiration rate (ca 1200 mm annually) is spread over such a long growing season that its water-use efficiency is actually quite good. Because of its unique niche in the state’s important dairy industry, alfalfa is projected to be relatively insensitive to changes in energy and associated water costs. This insensitivity to price and the unique dependance of the dairy industry on this forage suggest that it will remain a major crop in the state despite increased production costs. Although cotton can be a heavy water user when cheap sources are available, it can be grown profitably with less water. Cotton’s hardiness and resilience provide growers with a buffer and, given the current government program for cotton, it will likely remain a major California crop despite higher water costs. Likewise, high-value crops such as perennial fruits, vines and nuts, as well as vegetables, are likely to maintain or increase in relative importance as water costs rise. Even so, ultimately, increased costs of production due to the higher cost of irrigation water could seriously threaten California’s competitive standing in the world market for many crops.

Salinization and Irrigated Agriculture

Although irrigation can provide precise control of water input, irrigation water always contains dissolved minerals and salts. Applied irrigation water in California’s Central Valley either evaporates, transpires, recharges ground water, or reenters the surface water system. The salt in this system has two fates: It is leached to a finite pool of ground water or it can be collected in drainage lines and removed from the system. The geographical arrangement of the

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3These soils allow little percolation of the water (i.e., loss to the ground water) and a large portion of the water entering the field is returned to surface water supplies, creating potential problems for Sacramento’s drinking water.

4Forage, especially alfalfa, maintains a balanced rumen fermentation essential for proper milk fat production. Alfalfa is unique in its ability to blend the attributes of forages with those of high energy feeds (usually grain) that allow high producing dairy cattle to maintain near maximal milk outputs. Seventy-five to 80 percent of California’s alfalfa is fed to the state’s dairy cattle.
valley, which is a relatively closed system, requires that in the long term there must be a balance between the inflow and outflow of salt on a regional basis for agriculture to survive.

This picture is complicated by naturally occurring toxicants, such as selenium, in the soils and water of the valley. Like other salts, selenium accumulates in drainage water and in evaporation ponds such as Kesterson Reservoir and can be concentrated biologically and by evaporation to levels that are toxic to wildlife.

The present system of evaporation ponds can, at best, solve the problem of salt balance in the valley only temporarily. If irrigated agriculture is to continue and ground water is not to be a sink for dissolved contaminants, inputs of salt into the valley must be balanced with outputs via drainage from the Central Valley. Note that water exports from the Sacramento Valley to the San Joaquin Valley mean that salts that once flowed to the ocean are now accumulating in the San Joaquin Valley.

Environmental Concerns

Changes in farming systems that have occurred since World War II were reactions to the major constraints on farming existing at that time. Given farmers' objective function to maximize profit from their operations, the response was to intensify nutrient input use, increase chemical control of pests, mechanize production, and improve germplasm. Meanwhile, agricultural researchers focused on factors that affected yield and were less concerned about various negative outputs from farming systems. They concentrated on the functioning of components within the system.

This largely economic perspective has not properly accounted for environmental costs associated with the production enterprise. From a broader perspective, the true costs of agriculture must include impacts on the environment. Costs that once were allowed to escape the farming system and (costlessly) contaminate other components of the ecosystem will have to be counted as integral parts of an operation. Already some of California agriculture's most pressing issues involve disposal—irrigation drainage water, ground water contaminated by fertilizers, dairy waste, crop residue burning, pesticide residues in feed and food.

This new major constraint will mean significant changes in the way California farmers produce food and fiber. The response will require a precise but integrated systems perspective of farming operations. Agricultural researchers will be called to integrate all components, understand their behavior in a systems context, and communicate their knowledge to farmers so that they can make production decisions in compliance with environmental concerns.
Other Pressures

Besides these concerns directly related to California’s irrigated agriculture are a number of other pressures on the state’s farming systems:

• Air pollution from the transportation demands and industrialization of a rapidly urbanizing state is already causing significant crop yield reduction in certain parts of the state. (See the air quality chapter, Chapter 5.)

• As urbanization occurs, farming systems must adapt by changing location of their production. The movement of apricots and prunes from the Santa Clara Valley to the Central Valley and, currently, dairy from the Clino Basin to the San Joaquin Valley are examples of such shifts. (The chapter on land, Chapter 3, discusses this and other forces affecting California’s farmland base.)

• New strategies are needed in response to changes in markets at home and abroad and to increased competition from other producing areas in those markets. Changes in marketing, in turn, impinge on the state’s farming systems—on what is grown, where, and when. (See the chapter on marketing, Chapter 7.)

• The growing communications gap between agriculture and other sectors is especially apparent with regard to food safety. (The food safety issue is also discussed in Chapter 7.) The agricultural community is currently debating about the appropriate level of chemical inputs to match profitable production with responsible land and environmental stewardship.

• Consumers also bear some responsibility for the influence they exert on production systems. Meeting public demands for cosmetically perfect produce at inexpensive prices grown with little or no pesticide inputs, for example, may be impossible. On the farmers’ part there are also tradeoffs and compromises in managing effective farming systems that meet all the constraints, including the environmental ones. Forced solutions will threaten the flexibility of California farming systems to remain competitive in world markets. (A discussion of the need for better public understanding about agriculture is found in Chapter 8.)

• Farm labor shortages were feared after the passage of the Immigration Reform and Control Act of 1986. However, special provisions made for agriculture have so far forestalled serious problems. If many of the newly legalized Special Agricultural Workers leave agriculture and are not replaced
or if border control becomes more effective, the state's most labor-intensive crops (e.g., lettuce, sun-dried raisins) could be forced to shift toward more mechanized operations. Some of California's farming systems that are most heavily dependent on the availability of a large seasonal labor pool would have to adjust should that pool dry up. (See Chapter 2.)

- Competitive relationships among individual commodities, among regions within the country and among countries in the international market place are distorted by federal commodity programs in place for over half a century. Restrictions on planted acreage and the desire to maintain historical acreage bases for program crops undoubtedly influences crop rotation decisions in ways consistent with neither optimal long-term land sustainability nor free-market price conditions. Furthermore, the benefits that derive from greater production per acre under existing programs lead to more intensive use of fertilizer, pesticides and other chemicals than might be the case, absent the programs. Should these farm programs ever be discontinued, California's crop mix could change dramatically. Even a 10 percent cutback in the state's cotton acreage would free up over 100,000 acres for other crops.

**Future Developments**

In response to these pressures, especially to anticipated environmental constraints, and to reduce input costs, farmers are exploring a wide range of methods ranging from "organic" production to highly technical computerized systems. The alternatives being explored offer an interesting corollary to the energy crisis of the 1970s. Then, the major dichotomy in the debate about strategies was between those favoring conservation methods and those advocating the development of new technologies. Conservation measures were surprisingly effective in the short term, perhaps to the detriment of the evaluation of longer term energy solutions.

A similar dichotomy has developed in the search for solutions to the current farming crisis. However, the alternatives being explored are not mutually exclusive; rather a combination of methods will emerge as a creative modification of existing production systems. The most likely result will, sooner or later, be a reduction in agricultural chemical use and an improved control over the fate of all

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5Because of increased costs of pesticides (as much as 20 percent of production costs for some specialty crops) and increased pest resistance, most farmers want to reduce their use of pesticides.
applied inputs. In any case, an increased management component will be required.

During the transitional phase, differing systems will operate alongside of present conventional management systems. Gradually, successes with new methods will promote change. Appropriate incentives in research, education, and government can hasten cultural changes in farming methods (Carter, 1990). However, sudden mandated change could impede progress.

One direction management may take is toward systems that rely on an increased understanding of the mechanisms and interactions that determine biochemical and physical processes. The NRC (1989) report, *Alternative Agriculture*, stresses that “alternative systems more deliberately integrate and take advantage of naturally occurring beneficial interactions.” Some of the alternative methods now being analyzed include: changes in irrigation, tillage, and sanitation practices; altered timing and density of planting; selection of resistant varieties; use of natural enemies or biological control agents; water-conserving irrigation technologies; and rotation schemes. Of course, attempts to substitute renewable sources of soil nutrients such as manures and legumes for chemical fertilizers are of long standing. In most solutions, the farmer is substituting land, labor, and especially management, for chemical inputs.

However, organic farming systems are not likely to dominate these regimes. Rather, the new farming systems that emerge will basically be a modification of present systems. And the source of an input will not matter nearly as much as how it is applied. For example, either an organic fertilizer (manure or compost) or a chemical one (anhydrous ammonia) may or may not contaminate ground water—depending on how it is applied and subsequent crop management.

Another possible direction is toward an increased use of computers as management aids. While mechanization and chemical use have given farmers power equivalent to about 1000 times that available from the human body alone, this gain has so far not been matched by an equivalent increase in decision-making capability. Computerization offers a start in such an increase. But, so far, the incorporation of computers in on-farm management has been slow. Computers and management programs require a considerable adjustment for a farmer in demands on their time and for information. Information required by most programs is quite structured and

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4 If brain had increased to match brawn in modern agriculture, each cropped acre of mechanized agriculture would receive the same meticulous attention as if it had 24 full-time gardeners caring for it (William J. Chancellor, Agricultural Engineering, University of California, Davis, personal communication).
not of the qualitative type most farmers use in decision making. Because of the relatively small market, few private software companies develop agricultural management software. Presently universities and the U.S. Department of Agriculture have provided most of the software for farm decision making and these programs have had limited distribution (Flint and Klonsky, 1989). Thus, it is not likely that this new technology will soon be an on-farm activity. Rather, aspects of farm management best solved by computers will be handled by consultants who will concentrate management software and computer skills in specialized companies. These secondary markets of information collectors and computer specialists will serve farmers in much the same way as the current pest control advisors.

Not only in the office but also in the field, the computer revolution will have an effect. The steadily decreasing cost of information processing, the promise of robotics, and the trend toward more intensive agriculture will lead to new technologies with the capacity to sense field conditions and apply inputs, both chemical and mechanical, without continuous human supervision. This new technology will be able to identify the state of some component and decide the appropriate action, eliminating the need to broadcast chemical applications. For example, the ability to detect the presence of a weed and apply herbicide only to that plant could reduce pesticide applications by approximately 40 percent (Reichard and Ladd, 1981). Targeted placement of 60 pounds of nitrogen per acre can produce yields equivalent to 100 pounds (Chancellor, 1981). This sensing capacity will also allow the optimal operation of field equipment by monitoring closely the performance of the equipment and being able to sense more quickly field conditions to speed up or slow down tasks. This technology offers a powerful opportunity for a farming system to be high yielding and profitable, but with greater control over the rate of chemical inputs.

Eventually, these information-processing systems may be coupled with robotics on broad span tractors. These “tractors” are arch-like structures with spans of 100 feet that move in a set track across the field with significant savings on trafficking damage and soil compaction. Different types of implements can be attached to the tractors to accomplish the typical tasks required in the field.

One such high-tech practice—laser technology—has allowed much more expansive land leveling. However, laser leveling that eliminates variability in elevation has greatly expanded land leveling which in turn creates a new heterogeneity by removing the surface horizon from the high spots and depositing it in lower areas, transforming the field to one with patches of no surface horizon and others at twice the original depth of topsoil. The cheapest, most practical, conventional approach in the face of such variability is to
Farming Systems

increase input use over the whole field with homogeneous applications of fertilizers, pesticides, and water. But then some areas do not get enough; others get too much. Therefore, one of the greatest potentials for information processing of field operations is sensing this variation and applying inputs according to site specific requirements.

Biotechnology may offer another means of adapting farming systems in response to pressures for change by increasing a farm's flexibility to meet the constraints faced. Because of the great diversity of biotechnology's possible applications, more responsibility than ever will be placed on the shoulders of management. The challenge will be to sort out the appropriate from the many potential applications and incorporate them into the farming system. The areas of biotechnology holding the most promise for farming systems include providing interspecific transfer of desirable traits, reducing reproduction time, enhancing the heritability of existing genetic resources through cloning, and reducing generation time for developing new crop varieties. For example, these strategies can be used to create crop plants resistant to certain chemicals or to tailor plants to thrive in lower input environments. However, most breakthroughs will be awhile in coming and will feed into more traditional breeding methodologies that will always be the mainstay of plant and animal improvement programs.

The future farming systems that evolve will most likely include some combination of the above directions. Integrated pest management (IPM) already provides an example that includes elements of several of these new systems. Programs have been developed for corn, cotton, alfalfa, grapes, apples, almonds, and walnuts, to mention a few. The goal of IPM is to help farmers maximize a profitable output while minimizing certain inputs and their environmental consequences. IPM uses a combination of biological, physical, and chemical controls; habitat modification techniques, and "whatever works" to economically reduce pest damage. In many cases, farmers adopting an IPM approach are able to reduce and sometimes eliminate pesticide applications that were routinely used in the past. And most important for widespread adoption, IPM practices are usually profitable, particularly on crops which normally require high rates of pesticide applications.

The crucial component of any of these systems solutions is improved management using more information. California is well suited to lead the development of new sustainable farming systems that are more environmentally sound.

But the world is shrinking. Technology and capital are expected to flow even more freely in the future than they do today. Information that is increasingly shared threatens to erode the
competitive advantage in agricultural technology once held by California. Technologies will continue to be transferred as in the past, but at a faster rate; the competitive edge will be maintained by the society that continues to produce new and more efficient solutions at the fastest pace. To do so, California's farming systems must maintain their flexibility to respond appropriately as challenges arise.

**Immediate Challenges**

1. **Disposal Systems Under Increasingly Crowded Conditions**
   Systems for agricultural and urban disposal must be worked out if California's Central Valley is to remain productive for agriculture and a quality home for people. Disposal systems must be found for solid waste, vehicle emissions, dairy waste, pesticide and fertilizer residue, to mention a few. Doing nothing means that the valley will continue to be a dump site for agricultural, industrial, and urban externalities of many kinds. As we said at the beginning of this chapter, California is "filling up." Actually, the coastal areas are almost filled. The valley is next.

   The irrigated systems of the Central Valley must also achieve a regional balance between inputs and outputs. Salt importation cannot continue without some export mechanism. Salts and other agricultural chemicals cannot continue to be leached into the groundwater, important both to agriculture and the urban sectors. Nor can these pools continue to be overdrafted. The state must seriously consider the development of ocean salt disposal. Without a drain the future productivity of the valley—even its survival—is tenuous.

2. **Research Focus**
   The discussion about the impact of these many forces on current farming systems and of farming systems on the environment is made difficult by (1) a lack of understanding about the fate of inputs used in agricultural systems, (2) an absence of data about costs of alternative production methods, (3) pressure and competing demands from an increasingly urbanized population, and (4) uncertainty about public risks of exposure to agricultural contaminants. Until now, agricultural research has not adequately focused on farming as a systems function. This fact, coupled with the introduction of a myriad of new farming methods, confounds the processes of sorting out appropriate responses to new constraints. A major target for agricultural research in the future must be to replace old (and new) dogma with carefully constructed knowledge about the impacts and efficiencies of agricultural practices. Knowledge on the part of all parties to the debate about the role of agriculture in the future is critical. There are problems, to be sure, but they need to be
addressed by clear identification of causal mechanisms, careful
identification of actual risks, and thorough evaluation of alternative
practices proposed.

Thus, a major focus for agricultural research in California
should be on increasing the efficiency of our production systems to
minimize their negative outputs and to insure the most effective use
of inputs. Included should be analysis of the factors controlling the
fate of applied inputs in agricultural systems, identification of
farming methods that increase efficiency of use and control of
inputs, and understanding the functioning of all the components of
farming systems in balance within the whole. This is precisely the
knowledge needed to evaluate the impact of various agricultural
practices on the environment. For example, such understanding
could lead to incorporating waste products into other production
systems to ease disposal problems in the state.

3. Policy Direction

Often policy treats symptoms, stifling innovation with rules
that exacerbate conditions, instead of setting standards that could
spur creativity to solve a problem. For example, in aiming to reduce
nitrate contamination of ground water, policy makers should
develop standards for nitrate levels within the soil profile, such as
just below the root zone, and directly enforce them. Because links
between contamination and specific farming practices are unclear
and vary from site to site, attempting to directly regulate input use
dangerously inhibits farmers’ flexibility. Because flexibility is so
critical to California’s farmers, its preservation is essential to a viable
and competitive agriculture in the state.

Meanwhile, benefits offered by long-established federal farm
programs are not sending appropriate stewardship signals to
farmers. If these programs are to be continued it would be desirable
to incorporate provisions that contribute to, rather than detract from,
long-term sustainability. This could include, for example, rules that
promote rather than effectively prohibit desirable rotations. Better
understanding of environmentally sound and economically feasible
rotations than currently exists in many California farm situations
would be needed.

4. Maintaining Flexibility in California Agriculture

Flexibility in adjusting to pressures and new constraints has
long been a strength of the state’s agriculture. Diversity of produc-
tion within and across heterogeneous regions is a key factor in
maintaining flexibility, as is the management input that is becoming
more crucial than ever before. Among the forces threatening
agriculture’s flexibility is rapid urbanization and competing de-
mands for land and water. Effective response must be well founded on an understanding of the entire systems involved. For example, any scheme to market water should be evaluated to determine the balance among the impacts on farmers' flexibility, production loss from water diverted from agriculture, and the efficiency of water use.

As long as California agriculture maintains its flexibility, the way will be kept open for making important choices. Flexibility will allow shifts that optimize profitable production subject to any new constraints encountered. In the face of an uncertain future, emphasis on enhancing flexibility may well be the essence of the best plan.

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Labor and Competitive Agricultural Technology in 2010

Howard R. Rosenberg, Roger E. Garrett, Ronald E. Voss, and David L. Mitchell

Introduction

An effective labor market is critical to the California agricultural industry and to all Californians. Can the market as currently structured sustain producers, workers, and our society in 2010?

The farm labor rules have changed, and they have uncertain implications for the near-term economics as well as long-term structure of California agriculture. Since passage of the Immigration Reform and Control Act of 1986 (IRCA), concern about the supply and management of agricultural labor has grown, but this critical factor of production has long been worthy of greater attention. Some 20-25 percent of overall farm production expense in California still goes to hired workers (California Department of Finance, 1988), who have a lot to do with how effectively the other 75-80 percent is used. Global market competition and other economic forces making production efficiency more essential may turn out to be much more influential than government regulations on labor markets and management.

People make the system run. Human labor is a most essential and complex factor of production at every level in California’s food and fiber system. The need for farm labor is derived both from

\footnote{The authors are specially indebted to Ray Coppock for invaluable editorial support in commencing this project.}
the demand for agricultural commodities and the technologies used to produce them. Since both commodity demand and production technologies continue to change, so do farm labor needs. Farm labor is dispersed around the state and draws on the myriad skills of people in such jobs as irrigator, picker, pruner, tractor or truck driver, herdsman, crew supervisor, biologist, bookkeeper, mechanic, manager, and attorney.

What farm workers and other personnel in the food chain do on the job has consequences for all of us, regardless of our stake in the system. Their performance affects the survival and profitability of food-related businesses, employee quality of life, and the availability, quality, and prices of products that everyone needs.

The Agricultural Labor Market

Need for Labor

Knowledge about agricultural labor is remarkably fragmented, perhaps because it has so many dimensions. Labor may be thought of in terms of numbers of jobs and people, costs of production, wage rates and earnings, employee working and living conditions, union-management relations, conflicts that disrupt workplaces and the flow of products to market, and government regulation of all the above.

How many people work in California agriculture? The answer depends on where the system boundaries are drawn as well as when and how the count is made. Because of measurement and reporting limitations, estimates of employment are less reliable than those of production tonnage. One estimate is that farm employment in California averages about 365,000 (California Employment Development Department, EDD, 1989). There are roughly five more jobs in agricultural input, processing, distribution, and retail industries for every one on the farm, so average overall employment in the California food and fiber system exceeds two million. No single day, however, is average. There is seasonal variation in both the total employment level and type of work performed in the system, particularly at the farm level.

Even at the farm level, extremes are more pronounced in some crops than others. In September 1988, for example, California grape growers employed an annual high of 77,036 workers but just one month later had their low of 21,855. But dairy farmers employed a monthly labor force of about 13,000 year round with very little month to month variation. The coefficient of variation for monthly employment in grapes was 92 percent greater than for dairy, reflecting the instability of vineyard jobs.

Although seasonal swings are most pronounced in fruit and vegetable crops, other crop sectors are also affected by farm employ-
ment variation. Seasonality of need poses problems for both buyers and sellers of agricultural labor. If all production work were spread evenly through the year, the annual demand for labor-hours or days would remain about the same, but the number of people needed to provide them would be dramatically reduced. There would be far fewer personnel transactions (hirings and layoffs), and it would be much easier to structure terms of employment attractive to workers.

Mechanization, the application of machines to task performance, has altered patterns of demand for labor. Labor-saving mechanization, along with biological advances, has eliminated many field jobs and further concentrated peak demands for post-harvest labor. These changes have occurred more in field crops and livestock than in the traditionally labor-intensive fruits and vegetables. Generally, mechanization has been applied to tasks that are strenuous or repetitive processes to which inputs are relatively uniform (e.g., plowing fields, threshing wheat, harvesting sugar beets). Operations on more variable or fragile inputs under less predictable conditions (e.g., picking strawberries, pruning grape vines, thinning peach trees) tend to require high levels of sensory perception, judgment, and manual dexterity, and so are performed mainly through labor-intensive methods.

While usually reducing the number of jobs to be filled, mechanization has also created new tasks to be performed by people. Furthermore, it has changed the nature of remaining manual jobs. Jobs in mechanized production systems tend to require a different set of skills, sometimes possessed by a broader segment of the workforce but also sometimes tending to exclude workers employed under the earlier technology. Operation, service, and repair of labor-saving equipment requires not only physical coordination but also technical understanding and skills in problem diagnosis, mechanics, mathematics, and communication. In addition, the administrative skills to structure such work and effectively manage the people who perform it are different from those commonly used in labor-intensive field work.

Technological advances that reduce or shift employment opportunities are controversial. In displacing individual workers they may also intensify social service needs and alter rural communities (Just, Schmitz, and Zilberman, 1979). While social ramifications of rapid technological change are particularly severe in areas without developed nonagricultural economies, lack of such change may merely forestall even greater impacts. Adoption of new production tools and techniques can contribute to maintaining the viability of commodity industries and thus any employment within them. Nevertheless, critics have taken issue with public institutions and employers for not projecting and mitigating problems related to
mechanization (Council for Agricultural Science and Technology, 1983).

Some technological changes run counter to the labor-saving trend. Increasing public concerns about environmental quality and pesticide residues in food have resulted in a movement toward production practices that decrease the use of synthetic chemicals (i.e., fertilizers and pesticides). Expanded use of “low input,” “organic,” or “sustainable” cultural practices could significantly affect the demand for labor. Cutting back the use of herbicides, for example, increases the need for “hand weeding.” Often complementing these alternative productions systems are alternative marketing activities, particularly direct selling through farmer’s markets and on-farm sales. The extent of additional labor that these methods require in field or marketplace may be an important factor in decisions about whether to adopt them.

From 1950 to 1983 total work hours devoted to farm production on the Pacific Coast were cut by half. Livestock led the way with a 76 percent reduction in hours, followed by field crops, in which total work time was trimmed 62 percent. In contrast, hours in fruits and nuts fell only 29 percent, and vegetable hours actually increased 19 percent (U.S. Department of Agriculture, 1983). By 1983, hours worked in fruits, nuts, and vegetables accounted for more than three-fifths of total farm production time on the Pacific Coast and more than four-fifths of all crop hours.

Although labor provided by farmers and unpaid family members—who perform most of the work on smaller livestock and field crop farms—has been decreasing in California, average agricultural employment of hired workers has risen steadily since the early 1970s. Aggregate employment effects of major labor-saving changes in fruit, nut, vegetable, and fiber production (e.g., mechanical harvesting of processing tomatoes, cotton, tree nuts and wine grapes, electronic sorting, and increased herbicide use) have been offset by expansion in acreage and yield of labor-intensive specialty crops (e.g., strawberries, avocados, nectarines). Some newly introduced labor-intensive crops (e.g., luffa, bok choy, bitter melon) meet market demands of fast growing ethnic and immigrant communities. Improved production efficiency at the farm level has helped maintain jobs in processing, packaging, and associated industries.

The inducements offered to workers in agriculture and the contributions required of them vary as widely between and within commodity sectors as do levels of employment. The nature of work to be done, local and industry customs, employer preferences, and regulatory constraints all shape the conditions to which individuals respond in their decisions to join, to stay, and to perform in different parts of the system.
Dual labor market theory recognizes a "primary market" of jobs in which relatively high wages, good working conditions, employment stability, and opportunities for advancement are common. The "secondary market" is associated with easy entry, low pay, undeveloped post-entry job allocation (promotion, transfer, open bidding) policies, and unstable product demand or production schedules, all of which tend to induce rapid turnover (Doeringer and Piore, 1971). While a gamut of characteristics is found in California agriculture, the primary market model tends to describe jobs in management, horticultural science, engineering, machine operation and maintenance. On the other hand, manual seasonal work, comprising a much larger share of all farm employment, more often fits the secondary market model. Pay, benefits, and the lack of stability of these farm jobs make the "average" terms of employment in agriculture markedly inferior to those in primary blue-collar nonfarm jobs. The typical compensation for strawberry picking, grape vine pruning, or peach thinning, for example, is less than for automobile assembly work, even though these jobs all require judgment, manual skills, and stamina.

Supply of Labor

Although the terms "labor supply" and "labor demand" are often used as though they represent fixed quantities, both vary as a function of other factors. Labor usage or employment during a period might be viewed as a measure of demand, but there is no such even arguable gauge of supply. Labor supply is elastic with respect to the "price" (wages and other aspects of attractiveness) offered for it. How many people would conceivably make how many days available for farm work? More than could be used, if the terms of employment were attractive enough. The catch, of course, is that increasing job attractiveness often raises employer costs, and the ability to pay costs is disciplined by the product market.

Three to four times as many people perform farm work in California at some time during the year as there are full-time equivalent farm jobs. In the nation as a whole, year-around and regular workers (those who work more than 249 and from 150-249 days per year, respectively) are estimated to make up less than one-fourth of the farm labor force, although they account for more than two-thirds of days worked. Seasonal workers (25-149 days) make up roughly one-third of the labor force and put in one-quarter of the days worked. Casual workers (less than 25 days), almost half the total number in the farm labor force, perform a very small portion of the work (Smith and Coltrane, 1981).

The different employment sectors tend to attract and admit workers with differing interests, abilities, and backgrounds. Eco-
onomic, social, and institutional factors keep secondary sector work-
ers from getting a foothold in primary employment. While some 
farm workers find compensating advantages in the secondary sector, 
most would prefer higher pay, less uncertainty, more employment, 
better housing, health care and child care for their families, and 
greater occupational dignity than their jobs afford.

Although farmers and their family members still perform 
many farm jobs in California, hired workers have gained in relative 
importance. As it has for the past century, California agriculture 
currently relies on inexpensive labor in strenuous, seasonal jobs of 
short duration for wages and under conditions that most U.S.
citizens shun. Manual field jobs that do not appeal to most settled 
U.S. residents have continued to attract people facing much poorer 
alternatives in other nations. With relatively little difficulty, farmers 
have been able to procure enough human effort at affordable cost to 
operate labor-intensive production technologies.

Meanwhile, changes in composition of the overall California 
workforce have been more pronounced than in agriculture. A most 
striking change is the 73 percent increase in female labor force 
participation and the 13 percent decrease in male participation from 
1950 to 1987 (U.S. Department of Labor, 1985). Women are projected 
to comprise 45 percent of all workers by 1990. The Hispanic popula-
tion, its share of the work force and its social-political influence in 
California continue to grow. A large recent influx of Asians has also 
notably augmented the work force. Aging of the baby boom genera-
tion, the 1960-1970s baby bust, and rising levels of education and 
living standards among more established U.S. residents leave fewer 
of them willing to take lower-level, secondary labor market jobs in 
agriculture. Immigration, however, has offset effects of these 
demographic trends.

Public policy in this nation and economic conditions in other 
nations have contributed to persistence of labor-intensive technolo-
gies in U.S. agriculture. Many farmers assert that only immigrants 
are willing, or even able, to do seasonal agricultural work. Union 
activists counter that plenty of legal resident workers are available 
but not effectively recruited by farm employers. Whatever the 
contributing factors, a succession of immigrant groups (Chinese, 
Japanese, Filipinos, "dust-bowl Oklahomans," Texas Chicanos, and 
Mexicans) has performed most of the work in California’s labor-
intensive specialty crops (Fuller, 1939). High turnover and the 
readiness of new immigrants to step in have been distinguishing 
features of the workforce in seasonal fruit and vegetable jobs.

The distressed Mexican economy and porous southern U.S. 
border are helping to maintain this tradition. Swelling population 
and economic despair in Mexico have dispatched a growing stream
of people northward to earn in an hour of farm, food service, and other secondary jobs what they might in a day of scarce employment back home. Farm employers in California have continued to depend heavily on immigrant workers, with or without legitimate papers, to more than meet the demand for agricultural labor.

In a survey of California agricultural employers, 85 percent reported hiring one or more aliens both in 1986 and 1987. Some 71 percent had employed at least one undocumented alien in 1986, and 55 percent in 1987 (Rosenberg and Perloff, 1988). The U.S. General Accounting Office (1989) obtained similar findings for 1987 from a study of growers in Washington, Oregon, and California. One result of illegal immigration has been bounteous agricultural production, undoubtedly achieved at lower cost than if only legal residents did the work. Another result is that millions of illegals have lived in fear of discovery and deportation, at the fringe of social institutions. Many who have not been able to qualify for legal status have stayed in the United States, and others are still coming (Cornelius, 1988).

Legality of presence in the United States is an important but by no means the only significant basis for distinguishing among persons in the immigrant labor force. Mexican farm workers are no more a mass of undifferentiated laborers than are jobs, skills, and terms of employment the same in all of agricultural production. Among the differences that relate to their roles in the labor market are extent of dependence on agricultural employment, commitment to a particular crop or type of farm work, education, total income, age, family size, skills, generation in the United States, usage of the English language, and cultural assimilation. A classification of Mexican and Mexican-American farm workers that considers all these attributes describes, in ascending order of legitimacy, several worker categories of illegals ("border jumpers," "adventurers," "innovators," and "climbers") and legal residents ("commuters," "opportunists," "loyalists," "naturalized," and "native born") (Gonzales, 1985). Individuals with less legitimacy (and poorer employment opportunities) commonly aspire to and work toward the types with more.

From June 1987 through November 1988, many farm workers accelerated their progress through these "ranks" by pursuing legal resident status in the United States under the Special Agricultural Worker (SAW) program of the 1986 immigration reform law. Some 1.3 million SAW applications were made nationwide, of which about 760,000 (58 percent) were in the western region, mostly in California. Approval rates through late autumn 1989 were very high, but some 55 percent were yet to be adjudicated.2 Despite

2Personal communication with Aaron Bodin, Deputy Assistant Commissioner for SAW Programs, Immigration and Naturalization Service, 1989.
having suspected fraud in about half of the pending applications earlier in 1989, at the end of the year Immigration and Naturalization Service officials were projecting a final composite denial rate of only 15 percent (Ramos, 1989). If that estimate holds true, about 500,000 SAWs will have been legalized in California by the time all decisions are made.

Problems in the Current Market

Agricultural labor market dynamics have worked well enough to make available at relatively low prices a tremendous amount and variety of food and fiber. California agriculture provides needed goods for domestic consumption and export; it also generates great wealth. On the other hand, the labor system is not free of dysfunctions.

Many farm employers face:

- uncertainty about labor availability at critical times,
- a bewildering array of legal mandates and prohibitions affecting their labor management practices,
- indirect costs of seasonal worker migrancy,
- barriers to communication with their own employees,
- personnel performance and accountability problems,
- loss of human capital with each employee turnover,
- the burden of finding it necessary to operate in violation of law, and
- higher costs and lower product quality than could be achieved under other conditions.

Meanwhile, a large proportion of the seasonal workforce faces:

- uncertainty about finding jobs and earning sufficient income,
- the brunt of migration costs,
- expense and dangers of illegal immigration,
- family disruptions,
- tenuous recognition and compensation for outstanding work,
- limited advancement opportunity within agriculture as well as mobility outward,
- inadequate personal respect, and
- relatively high exposure to occupational injury and disease.

Agricultural jobs are associated with low incomes. A 1983 survey of California farm workers found an average hourly wage of $5.10 for agricultural services, just 54 percent of the average rate for manufacturing jobs and less than 37 percent of the average for jobs in construction, mining, or transportation (Mines and Martin, 1986).
On a per-week basis, average weekly earnings of $182 for farm laborers was only 48 percent of average weekly earnings in manufacturing and less than 35 percent of earnings in construction and mining. More than two-thirds of the survey respondents in four-member households had incomes below the U.S. poverty level of $10,178 (1983 dollars), compared to 10.3 percent in the overall national economy. Average hourly wages in July 1989 were $6.07 for all hired farm workers in the Pacific Region (California, Oregon, and Washington) and $5.64 for field and livestock workers (U.S. Department of Agriculture, 1989). Associated with relatively low wages to farmworkers is the percentage of California rural Hispanic families in poverty which has climbed from a low of 20.3 percent in 1981 to a high of 50.6 percent in 1986, dipping slightly in 1987 (Gwynn et al., 1988).

Seasonality of agricultural production and the concomitant variation in labor demand translates to high job turnover and frequent unemployment for farm workers. The 1983 survey reported that 45 percent of all farm jobs lasted four weeks or less; only 7 percent of all respondents reported working for the same employer for 30 weeks or more. The majority of farm workers pieced together several jobs, farm or nonfarm, throughout the year to earn their livings. Most reported frequent spells of involuntary unemployment totalling an average of nearly one-half year. By contrast, in 1983, a recession year, the U.S. labor force experienced a 9.6 percent unemployment rate, and half of all job losers were unemployed for 10 weeks or less (U.S. Department of Labor, 1985).

Low education level among California farm workers impedes their ability to secure off-farm employment. In 1987 less than 20 percent of Hispanic farm workers over age 25 had completed high school and less than 1 percent went on to college (Oliveira and Cox, 1989). Nearly half had completed five years or less of formal schooling. The migrancy that often accompanies agricultural employment reinforces and perpetuates the low level of education among the California farm worker population. The 1983 farm worker survey found that one-third of all children of Mexican farm workers themselves travelled with their parents in “follow-the-crop” circuits.

While a theory of “compensating differentials” would suggest that better working conditions make up for lower pay, interindustry evidence supports the dual-market notion that job hazards, insecurity, and lack of advancement generally go together with low pay in secondary sector jobs (Robinson, 1988). And so it is in agriculture. Farm laborers contend not only with poverty but also with dangers of the work itself. Farm work is the nation’s most hazardous occupation in terms of work-related mortality, with an accidental death rate five times that of the national average. Almost 20
percent of the farm workers surveyed in 1983 reported musculoskeletal problems. Six percent had suffered chemical poisoning from pesticides and herbicides (and many cases of pesticide illness are mistaken for the flu). Another 6 percent reported skin diseases originating at work. In total, some 50 percent of the respondents reported having some type of work-related health problem within the previous two years.

These farm labor patterns yield conflicts within California's social and political fabric. There is discomfort with the dissonance between stated values and the reality of employment, an erosion of respect for law, a strain on social services, and an uncertainty about the sustainability of the system as product market competition intensifies.

IRCA as a Stimulus for Labor Market Change

The Immigration Reform and Control Act of 1986 (IRCA) offers both new and old kinds of alternatives to widespread employment of workers who are here illegally. Its designers acknowledged the patterns molded by historical and current forces but clearly envisioned something different. The logical goal of the new direction is a legal resident workforce and a labor market much less isolated from the rest of our economy. The old direction points to an institutionalized reliance on guestworkers employed under more heavily regulated conditions (Rosenberg, 1988).

Like most laws, IRCA is designed to serve its purpose at the level of society by influencing decisions at the level of the individual. The complex set of inducements and penalties that constitute its mechanism are at once horrendous to administer and ingenious for what they disclose about the contradictory values that need to be reconciled. Diverse interests based this watershed public policy on five dubiously compatible aims:

- To control unauthorized immigration to the United States.
- To not cause undue economic disruptions in economic sectors that have grown dependent on labor provided by people who are here illegally.
- To recognize the stake in and contributions to the U.S. of many people who have lived or worked here illegally in the past.
- To protect the legal resident workforce from unchecked foreign competition for jobs.
- To reduce the relative isolation of the farm labor market, and thereby to improve conditions of employment in agriculture.
Although not an agricultural law, IRCA treats agriculture specially in ways designed to help the industry adjust to a changed labor market. It deferred the application of sanctions for either hiring ineligible workers or not documenting eligibility of workers until December 1988. It also provided means for specifically expanding the farm labor supply with legal immigrants or guestworkers. The Special Agricultural Worker (SAW) program is granting legal resident status to a large number of people who worked on farms between May 1985 and May 1986. The Replenishment Agricultural Worker (RAW) program may replenish the agricultural workforce by legalizing additional aliens if needed in fiscal years 1990-93. A third labor supply provision, the H-2A program, enables farm employers to legally recruit and hire temporary guestworkers from abroad if (1) they can show that insufficient labor is available for a specific type of job during a given period in a defined market and (2) they offer terms of employment that meet prescribed standards.

IRCA hiring sanctions encourage those employers who have depended on undocumented workers to alter their recruitment and selection practices. The SAW and RAW programs, together with the deferral of sanctions against producers of perishable commodities, help farmers who want to make an orderly transition to legal, resident workers. By no means, however, will these measures alone be sufficient to attract and retain the eligible, qualified employees needed for a “soft landing” from the elimination of illegals. Personnel management policies of individual employers will weigh heavily in capable workers’ choices to join, stay, and perform effectively in farm operations.

Of considerable near-term interest is the extent to which SAWs will stay in agricultural work. Initial surveys indicate that most are still working in agriculture, but their occupational choices are not legally constrained, and departure of many to jobs in other industries is anticipated. Their rate of exit will depend on terms of employment in various agricultural sectors, existence of and perception of alternative opportunities, vocational abilities, language skills, and self-concept. Economic activity in other industries could exacerbate competition for legal agricultural workers. Recession could make more workers available to agriculture.

IRCA’s effect on the farm labor market in California during the next few years will also depend much on (1) law enforcement by the Immigration and Naturalization Service and the U.S. Department of Labor, (2) administrative rules and calculations determining the number of RAWs to be legalized, and (3) general economic activity. Immigration reform has the potential to change the farm labor market significantly in the longer run—with consequences in terms of:
• farm workforce composition,
• mobility and occupational choice of legalized farm workers
• worker exercise of employee protections under the law,
• union organizing activity,
• pay and other terms of employment
• use of farm labor contractors, and
• technological change substituting machinery for labor.

This law alone could ultimately affect basic structure, crop mix, and viability of labor-intensive agriculture in California and the nation as a whole. More likely, it will interact with other factors stimulating business adjustments. In fact, the importation of products may greatly overshadow the immigration of workers as an influence on California agriculture.

Business Trends and the Dilemma of Cheap Labor

The new immigration law joins other regulatory, technological, social, and market forces that have put pressure on the traditional agricultural labor market and are building the need for adjustments in farm production. Labor management decisions are influenced by several factors, on and off the farm: tradition, technology, managerial values and assumptions about workers, product as well as labor markets, financial situation of the firm, laws and regulations, and union contracts. These factors weigh in differently at different times, and they often have conflicting management implications. Those formerly most significant (tradition, management preferences, union contracts) have not remained so. Laws and regulations have become increasingly influential on labor management decisions.

Complicating the impact of all this, and of mounting significance, is globalization of product markets. Managers have had to shift attention from the pursuit of efficiency in a rather stable context to more strategic planning under conditions of flux and heightened competition. Fundamental choices about business line and location, market outlets, and investment strategies have come open for reconsideration. All have consequences for labor management.

National and state legislation during the past two decades has narrowed gaps between employee protections in the agricultural and nonfarm sectors. Developments applying to all industries have given employees more legal rights within their jobs, providing some of the benefits for which unions have traditionally bargained.3 For

3Such laws and regulations pertain to collective bargaining, recruitment and pay stub information, minimum wages and overtime premiums, unemployment insurance, workers compensation insurance, occupational safety and health.
employers these protections and accompanying paperwork have raised costs and risks of maintaining a directly hired workforce. Where competitive product markets give employers extra impetus to realize cost savings, a common adjustment has been to downsize and contract with outside providers for services that were once integrated within the organization (Belous, 1989).

The increased use this decade of farm labor contractors (FLCs) and management service companies is an expression of this trend in California agriculture. In 1988 the California EDD reported an 11 percent increase over 1987 in the number of agricultural laborers employed by farm labor contractors, citing this as the year's most significant change in the agricultural labor market. EDD data suggest that FLCs and management service companies were responsible for a majority of all fruit and vegetable work in the San Joaquin Valley during the third quarter (July-September) of 1987 (Villarejo, 1989).

One advantage growers commonly derive from contracting for labor is reduced cost—both from not having to carry underutilized human or physical assets and from sharing in any savings realized by FLC lowering of labor standards (e.g., offering less health insurance and other voluntary fringe benefits, or failing to cover employees with mandatory workers compensation and unemployment insurances) (Mines and Anzaldua, 1982). Wages paid by FLCs in 1983 were the lowest among all classifications of agricultural employers in California, averaging slightly less than 58 percent of the mean agricultural wage (Vandeman, 1988).

Although cost reduction and removal of legal employer obligations motivate grower patronage of FLCs, so do broader business strategies. Advantages from contracting out for agricultural services, as in other industries, may take the forms of organizational flexibility to pursue new ventures or markets, ability to access a wider variety of specialized skills and equipment needed for a limited time, and concentration of core personnel on valuable functions that they perform best (Miles, 1989).

In nonfarm industries, recent years have brought departures from union-management arrangements that had been relatively stable since the mid-1950s. While the legal framework for union organizing and collective bargaining in California agriculture was not erected until some 40 years after the National Labor Relations Act (which specifically excluded farm employment), both farm and nonfarm unions have experienced loss of influence in the 1980s. In neither the primary nor secondary sectors do firms routinely accept pattern bargaining within an industry of long-term contracts with wage raises, automatic cost-of-living wage adjustments, bilaterally formulated work rules, extensive fringe benefits, and quasi-legal
adjudication of workplace disputes as the price of stability, labor peace, and predictable costs.

The California Agricultural Labor Relations Act was enacted in 1975 to "... ensure peace in the agricultural fields by guaranteeing justice for all agricultural workers and stability in labor relations" (Agricultural Labor Relations Board, ALRB, 1978). In the first six years under the act, from 1976 through 1981, 889 representation elections (average 148 per year) supervised by the ALRB resulted in 749 (84 percent) union certifications, and 14 decertification elections resulted in seven (50 percent) union losses. In 1983-88, the most recent six for which complete data are available, unions were certified in 74 (53 percent) of 140 representation elections (average 23 per year) and decertified by workers in 27 (61 percent) of 44 votes held. As the numbers of union certifications and contracts have declined, so have indirect benefits derived by nonunionized workers from the threat of unionization.

Expansion of labor contracting, decertifications of unions, and closures of companies with union-influenced terms of employment may be traced to competition in the product and labor markets. In product markets, abundant domestic supply and increased production abroad have kept prices down and made cost control more critical to financial success. In labor markets, abundant supply has given farmers the opportunity—that many need—to hire people who will work for less.

However, cheap labor has a troublesome companion—belated innovation in production systems. Although extensive illegal immigration from Mexico has given California farmers a plentiful source of seasonal labor, it has also slowed progress in development of new machines, methods, and management practices that are needed for competitiveness in world markets (Martin and Olmstead, 1985). While fruit, vegetable, and horticultural specialty producers have been concerned about the availability of alien farm workers, other nations with even less expensive labor have been building farm sectors destined to increase their market share. The cost of broccoli production in Mexico during the 1986-87 season was but 40 percent of the California cost, in substantial part due to the typical Mexican farm wage of about $3 per day (Cook and Amon, 1983). Thus, near term labor market conditions obscure a plausible scenario of California labor-intensive crop sectors languishing for not having lowered or at least controlled costs through technological change.

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*Personal communication with Robert Dresser, Board Counsel, Office of the Executive Secretary, ALRB, Sacramento, November 1989.*
Labor and Technology

The dilemma is that the same inexpensive labor that enables businesses to prosper today cannot over the long run be a competitive asset for California agriculture. Since other nations—and even other states—have lower labor standards, the California farmer would be better off with labor cost as small a factor as possible in the production equation. The longer we depend on cheap labor for agricultural production, the more vulnerable we are to foreign competition. Technologies that more fully leverage human work can reduce the labor cost disadvantage.

Conceiving the Future

A viable California agriculture in 2010 will need an adequate supply of employable, competent farm workers, located where and when work is to be performed. Costs in the production system should permit growers to remain competitive in world product markets. Wages and working conditions should enable more workers to live closer to the American mainstream in terms of income, social status, access to public institutions, and opportunities for occupation growth. Is this possible? Can we have both a better lot for farm workers and tolerable costs for farm operators? Not unless new technology and labor management practices increase productivity and reduce waste enough to preserve workable economic margins.

It is not certain that streams of immigrants and other disadvantaged workers will continue to offer ample labor for secondary farm jobs. Even if they do, patterns of demand for labor will likely have changed by 2010. Related developments in production technology and the organization of work will shape tomorrow's patterns of aggregate need for workdays in agriculture and people to supply them. While some production systems may retain their basic processes, the context if not content of virtually every agricultural job will change during the next 20 years. Much of the workforce will have to be prepared to operate technologies different from today's.

Mechanization may be designed primarily to achieve private and social benefits other than reduction of labor requirements. It can help conserve soil, water, and energy; improve fertilizer placement; more efficiently apply pesticides; reduce damage to crops; and reduce worker exposure to hazards. Almost always, however, one of the important impacts of agricultural mechanization is to increase labor productivity. Farm production per work-hour in the United States increased nearly 800 percent—much more than in nonfarm industry—from 1944 to 1978 (Council for Agricultural Science and Technology, 1983).

Changes in the nature of jobs have accompanied reductions in labor intensiveness. Adoption of the mechanical cotton harvester,
for example, nearly halved the labor bill in that commodity while saving producers 15 percent of their total operating costs from 1950 to 1970. Concurrent with a sharp reduction in total employment, the average wage for remaining cotton production jobs increased along with the levels of reliability and skill required. Agricultural mechanization in the future, supported by biotechnological developments, can be expected to similarly alter job numbers, types, and conditions. Replacement of strenuous harvest, cultivation, and carrying jobs with machine operation, sorting, and maintenance work should, while reducing total employment, increase the proportion of the workforce who sustain longer careers in agriculture.

Machines can enhance the work of human minds as well as relieving hands and backs. Microelectronics in information processing adds new dimensions to the potential for technological and organizational change. Engineers and manufacturers are developing a new generation of tools applicable to agriculture (Agricultural Engineering, 1989). Some of these devices provide assistance to an operator in monitoring machine functions to which adjustments must be made (e.g., seed drop sensors on planting machines that transmit information on seeding rate, acreage sown, and planter malfunctions; sensors that monitor speeds of fans and threshing cylinder shafts on combine harvesters). Some relieve the operator of routine decisions. Still others are capable of sensing product or environmental attributes that humans cannot and translating such information directly into continuous automatic adjustment of machines (e.g., the "laser plane" that precisely controls the cutting blade position on a soil scraper; tractor speed and load monitors that directly set gear and throttle for optimal fuel efficiency).

Developments in industrial robotic mechanisms are also being explored for possible adaptation to agriculture. Finer sensors and models, more versatile mechanisms, and smarter control systems could enable machines to take on more tasks that have heretofore required human observation, analysis, decision-making, and dexterity (e.g., harvesting oranges; gathering, sizing, inspecting for internal blood spots, and packing eggs; culling dried prunes for various defects). Near-term opportunities for such technological changes are probably greatest in post-harvest operations.

Partnerships among farmer-inventors, university engineers and extension staff, and manufacturers must be strengthened and exploited to turn such mechanical advances into competitive advantage for California agriculture. Economic benefits from technological change typically accrue to early adopters, until a new method becomes standard practice and producer competition passes the benefit on to consumers. If California producers lack the means or motivation to rapidly adopt new technology, they lose the opportu-
nity to capture, even temporarily, any advantage from it. Moreover, innovations developed in California can even work against the industry here if applied more promptly elsewhere.

Microelectronics are also invaluable, of course, in the form of computers for handling administrative and management information. Substantial productivity gains may begin with better quality and reporting of data on such subjects as inventory, herd health, chemical applications, personnel skills and task preferences, crew performance, prior yields, costs, customers and so on. Access to such information enables the people whose hands are on plants, animals, or machines to make more and better decisions, thereby also reducing supervisory cost.

With or without technological change, organizational management can yield cost reduction and employment stability by either increasing productivity per worker or spreading the work over a longer time. Mutual employer-worker benefits are achievable through restructuring of work, clarification of job duties, systematic pre-employment screening for job-related knowledge and skill, investment in orientation and training, adroit supervision, rationalization of pay systems, and employee participation in decision making.

Employers are challenged to build organizations that facilitate the productive interaction of workers who have different languages and cultural frames of reference. Many rely on bilingual supervisors, such as foremen and FLCs who have long been key in seasonal farm labor markets. The selection, training, and performance appraisal of these cultural and hierarchical boundary-spanners merit more managerial attention than ever.

While laws of the state prescribe penalties for employer violations, less well codified laws of human and organizational behavior penalize careless labor managers with operational inefficiency. Casual patterns of personnel management in agriculture have provided fertile ground for the growth of real and perceived inequities. Conflicts result from such practices as hiring without clearly specifying job duties or presumed qualifications, setting wage rates through an uncoordinated series of individual negotiations, and allowing foremen or FLCs full discretion to recruit, assign work, discipline, discharge, and cope with problems. Workplace disagreements have escalated to wasteful litigation and physical violence. Farm managers can do better in managing labor. They will have to as advances in mechanization, automation, and biotechnology render each worker’s performance more consequential and mistakes more costly.

While much technological change is anticipated, there will still be short-term, seasonal jobs in the agriculture of 2010. FLCs
serve the economic function of reducing personnel transactions for growers. For some workers they also provide more continuous earning opportunity by stringing together a series of short-term jobs, although for others they provide but temporary employment in secondary jobs under miserable conditions. Such contingent employment, offered by FLCs or growers, while increasing flexibility, tends to reduce employer investment in human capital development. It also makes workers more economically insecure, especially with respect to benefits for which eligibility is a function of continuous employment. Employers with diversified operations, employer associations (especially those including multiple commodity growers), and the state job service may be able to facilitate labor market processes that supplement or substitute for the FLC function.

Agriculture should operate under laws that are comprehensible, internally consistent, and fairly applied. The legal environment could be better grounded in consensus principles about the value of domestic agriculture, the need for entrepreneurial risk and skillful management, and the essential contributions and dignity of those who work in the system. Much state and federal legislation has already been put on the books to address labor market dysfunctions and farm employment inequities, but it promises much more than it delivers.

In agriculture the employment of thousands of people not truly eligible to work in the United States is only one type of incongruity between public policy myth and field-level reality. After years of being excluded, most of California agriculture is now covered by wage and hour standards, child labor, social security, unemployment tax, health and safety, workers compensation, disability, and labor contractor regulation. Nevertheless, for example, some field workers still handle pesticides without wearing protective clothing; injuries go unreported despite their compensability under the workers compensation system; piece rate (and even hourly) earnings sometimes fall below the minimum wage standard; labor camps do not uniformly meet local health and safety codes; and FLCs, unregistered or registered, overcharge for transportation, drinks in the field, or other services.

Uneven compliance by employers may stem from either ignorance or willful disregard of applicable laws. The volume and complexity of legal mandates and prohibitions contribute to the former. Partly responsible for the latter are regulatory differences between states (e.g., in union organizing protections, minimum wage, unemployment insurance) that are competitively disadvantageous to growers in California. Agricultural employers in this state, as well as workers in others, would benefit from federal legislation that makes the legal environment less of a national patchwork.
Compliance with public policy on farm employment is undermined when economic incentives to disregard the law are not neutralized by strong enforcement. Responsible watchdog agencies simply do not have adequate resources to cover their domains through routine inspection, especially given the wide dispersion in location, type of setting, and stability of agricultural workplaces. Effectiveness of most labor laws depends on the expectation of agency follow-through on employee complaints. Workers have an important role in enforcement, but their limited knowledge of applicable legal protections and whistle-blowing mechanisms restricts the effectiveness of the overall process. Regulatory and educational institutions could help reduce violations by getting more information about employment laws to sellers as well as buyers of labor (workers as well as employers).

Adjustments and Investments

It behooves public policy makers and their constituents to recognize the external forces necessitating adjustment within the agricultural labor system and to work toward adaptive changes. The types of public and private investment prescribed in the California Economic Development Corporation's 1988 report for the state in general are certainly appropriate for the agricultural community. Attention to infrastructure, human resources, and the legal environment is needed. Highest priorities include:

Infrastructure

- Development of mechanical and biotechnical advances that increase overall production efficiency, provide greater leverage for human effort, and reduce hazards and seasonal shifts in agricultural employment. Incorporation of worker as well as grower knowledge and perspectives in design of new equipment.

- Support for timely trial and rapid adoption of new technologies, including applied research, extension education, and tax incentives. Vocational and social services to cushion technological displacement of workers.

- Improved facilitation of labor market processes that match supply and demand, especially for short-term jobs. Extensive use of computerized and other electronic (e.g., FAX) systems for giving workers and employers convenient access to real-time job information. Public collection and distribution of reference information on prevailing wages and benefits.
- Housing for workers who perform jobs that still necessitate migration from home. Public facilities, if policies to encourage private operation of worker housing are not effective.

- Portable fringe benefit programs that enable workers to accumulate and carry eligibility credits from seasonal job to job within a given agricultural sector. Incentives for employer groups to provide continuous benefits within a region.

**Human Resources**

- Management education for farm operators and labor contractors, to enable more of them to structure and lead organizations that attract, retain, and elicit a high standard of performance from well qualified employees. Special attention to selection and development of first-line supervisors and other boundary spanners within agricultural businesses.

- Research on design of jobs that better utilize employee intelligence and knowledge and that bring a fuller range of employee assets into work process adjustments and other management decisions.

- Better public education at the primary and secondary levels, providing more of our population with the fundamental cognitive and communication skills required by jobs in a more technologically sophisticated agriculture. Integration of second language instruction and intercultural awareness material into curricula.

- Continuing education and on-the-job training for agricultural workers who can extend their skills to fit higher level or newly emerging jobs; training and out-placement counseling services for those who cannot.

**Legal Environment**

- Increased public analysis and discourse on agricultural labor issues, particularly including criteria for weighing the benefits and costs of labor-intensive technologies. Attempts to develop consensus on how to distribute costs of reducing labor market dysfunctions.

- Promotion of federal legislation establishing more uniform labor regulation and standards across states.
Strengthened efforts to clarify, publicize, and enforce existing laws that either directly regulate terms of employment or affect aggregate labor supply and demand.

Conclusion

Agricultural producers have a history of achieving increased output quantity and better quality from the same human effort or input dollar. Innovations in technology, work organization, job design, recruitment, selection, supervision, training, compensation, dispute handling, and employee involvement in decision making have contributed to these results, though not as much as they might have and not without contention. In the coming decades California farmers will need to innovate more.

Policy on labor-related issues will help to mold future behavior of farm employers and workers, and ultimately the structure of California agriculture. Public and private choices will determine how separate the primary and secondary labor markets remain, how the costs of technological and structural change are distributed, and how effectively the state's food and fiber system can produce. Although public policy will have to accommodate some divergent goals of competing interests, its efficacy will be demonstrated more by the welfare of the agricultural community as whole than the success of any of its parts.

It is neither accurate nor helpful to construe labor issues simply in terms of conflict between owners of capital and providers of labor. While some absolute differences of interest between employee, employer, and public groups require "distributive" resolution, many issues present opportunities for "integrative" decision making. Competitive pressures and narrowed margins have brought growing numbers of managers and workers to realize a shared interest in business efficiency. The squandering of materials, market opportunities, technological advances, human skills and spirits can only harm profits, jobs, and consumer budgets in the long run. Whether unilaterally designed or bilaterally negotiated, organizational structure and processes can render labor—and the entire system—more effective. Intelligent theories of business and worker behavior are needed to guide decisions that will work for the many.

The general public has a natural stake in the welfare of the food system as a whole, the businesses that comprise it, and the workers who make it run. The prevailing mix of public values, however, holds somewhat inconsistent implications for policy. Many consumers who enjoy their access to reasonably priced food and who favor unregulated markets for products and labor also want better incomes and working conditions for farm workers.
Achievement of the latter may compromise the former, unless productivity is improved.

Viability of California agricultural industry and of the units within it is ever more sensitive to technology, workforce performance, and the management of human resources. The common challenge for public and management policy is to build socio-technical systems that are both highly productive and personally rewarding.

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Changes in the Resource Base and in the Environment:

Chapter 3. Farmland in California: A Changing Resource

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Chapter 4. California’s Water Resource: The Current Status and Future Challenges

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Farmland in California: A Changing Resource
Michael J. Singer, William W. Wood, Jr., and Curtis D. Lynn

Introduction
Soil, unlike water, cannot be moved from place to place as needed. Some soil types are deep, well drained and naturally fertile while others are shallow, poorly drained, and chemically unsuitable for crops. Thus, soils vary significantly not only with location but in productive capacity depending on physical, chemical, mineralogical and morphological characteristics, as well as availability of companion resources, especially water.

California contains just over 100 million acres. (To be precise, 100,069,000.) The state’s farmland resource base—those soils that are used to produce crops and livestock—covers less than one-third of the total land area. Much of this is pasture and rangeland; less than one-tenth of the state’s total acreage is irrigated, intensively-cropped land.

This chapter considers the state’s present farmland resource base and some of the factors that will determine its role during the next 20 years. There are direct forces for expansion or contraction of the base, e.g., availability of irrigation water, conversion of farmland to urban uses. There are also indirect forces. For example, an increased demand for California agricultural exports may increase the demand for land to farm; a cutback in federal farm commodity income supports may decrease it.

Although the farmland base is defined here in terms of acres, its economic output within the agricultural system is determined by
two basic factors—total acreage and per-acre productivity. Forces operating on the land base may act in either, or both, of these dimensions. For example, loss of farmland to urbanization reduces agricultural acreage, whereas air pollution lowers yields. Another example: If markets are good, additional land may be brought into production (increasing the base) and/or some land may be double cropped (increasing its productivity in dollars per acre).

There is a complex relationship between per-acre productivity and expansion or contraction of the land base. When yields are reduced by, for example, salinization, there may be economic pressure to increase the land base elsewhere in order to compensate for that loss of production. The increase, however, may be in the form of either newly cropped land or more intensive production on existing acreage. Meanwhile, the original farmer may shift to another, more salt-tolerant crop. Thus, the forces interact.

**California’s Agricultural Land Base**

The state’s agricultural land resource is generally categorized into four broad use groups—irrigated cropland, nonirrigated cropland, rangeland, and timberland. Although limited by climate, soil, topography, water, and other resources, there is some flexibility for land to shift from one use to another. In addition, it is possible to add to the total of agricultural land, since some acreage in the state that is not now used for production, even as livestock range, could be farmed if irrigation water were available.

Shifts in agricultural land use within California, as reported by the last two agricultural censuses, are shown in Table 1. The figures show reduction in all farmland categories between 1982 and

<table>
<thead>
<tr>
<th>Category</th>
<th>1987 Acreage</th>
<th>1982 Acreage</th>
<th>% Reduction</th>
</tr>
</thead>
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<tr>
<td>Land in farms</td>
<td>30,598,178</td>
<td>32,156,894</td>
<td>4.8</td>
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<tr>
<td>Cropland</td>
<td>10,894,503</td>
<td>11,257,374</td>
<td>3.2</td>
</tr>
<tr>
<td>Harvested cropland</td>
<td>7,676,287</td>
<td>8,764,808</td>
<td>12.4</td>
</tr>
<tr>
<td>Irrigated land</td>
<td>7,596,091</td>
<td>8,840,508</td>
<td>10.2</td>
</tr>
</tbody>
</table>


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1Wildlands that are not grazed as range are excluded. However, more intensive use of these lands is possible—biomass production, for example. Timberland also is not discussed here because much of it is in public ownership. However, it may be subject to the same forces that affect the other land use categories.
1987. These census figures generally agree with other sources as to amounts of land in various categories. For example, in 1986 the American Farmland Trust (AFT) estimated that there were about 31 million acres of agricultural land in California, of which 9.5 million were irrigated cropland, 1.5 million were dryfarmed cropland, and 19.7 million were pasture and grazing land.

Another way of looking at the farmland base is contained in a report by the Governor's Office of Planning and Research (OPR) report (1974), which concluded that California had 12.6 million acres of "prime" agricultural land and an additional 7.9 million acres of potentially prime land.

**Forces on the Agricultural Land Base**

Within the land base—the total number of acres used in production agriculture—the amount used for any one purpose changes. For example, land can be irrigated or withdrawn from irrigation. This is seen in the history of California agriculture. Many areas of the San Joaquin Valley that were sheep ranches or vast grain farms at the turn of the century are now producing tree fruits, grapes, and nuts because of the availability of irrigation water and an increased demand for California specialty crops.

Changes in productivity may indirectly influence the size of the agricultural land base; for example, when additional acres are cropped to compensate for a yield loss. Thus, while one may think in terms of a fixed land base of a specified number of acres, it is more useful for policy considerations to examine the various factors that influence availability and suitability of land for agricultural production. Because the many direct and indirect forces and the responses to them are so interwoven, it is difficult to sort them out. For purposes of the discussion, therefore, we consider them in terms of whether they expand or contract the base and/or increase or decrease its productivity.

**Irrigation Water Availability**

One direct factor determining the amount of land in production agriculture in California is the availability of water for irrigation. Were "affordable" water to be delivered to the "potential prime agricultural land" in the state—land not now farmed but USDA Class I and II soils that have the physical and chemical properties of high productivity (Reganold and Singer, 1978)—some 4 million additional acres could be brought into production.³

² Also see the chapter on water, Chapter 4.
³The fact that the USDA's estimate of "potential prime" acreage is so much less than that of the 1974 state OPR report shows how much perceptions and classifications of land capability can vary.
What is the likelihood of new irrigation projects bringing additional irrigated acres into production? The answer depends on future political and economic conditions in the state. Any new water storage system will require planning, funding and then construction. The history of such large projects suggests that at least 10 to 15 years are required to develop new sources of water. Also, any new source development will need to meet the strict environmental controls imposed by our society. It is unlikely, we believe, that any new major supply systems will meet the environmental and economic constraints in the next 20 years. And even if new sources were developed, top priorities almost certainly would go to urban uses and correction of ground water overdraft.

Meanwhile, both drought and expansion of urban demand for water have the potential for substantially decreasing demand for agricultural land as water becomes less available and more costly. Currently available developed water supplies are likely to gradually shift from agriculture to urban use during the next 20 years. Also, there is about a 2 million acre-foot yearly groundwater overdraft in the San Joaquin Valley alone. Unless additional supplies of water are developed to offset it, as much as 500,000 acres of irrigated cropland eventually could go out of production there.4

Although reduced availability of surface and ground water will tend to decrease the demand for land, especially lower-quality irrigated land, water will continue to be available and economical for higher-valued crops that can afford to pay more for irrigation—even though those crops may be high water users. With less and more costly water, some farmland may shift to crops which can be dry farmed; some will convert back to native pasture or weeds. Regional changes of this sort are apt to be much more severe than aggregate state trends would reveal. The reduction will be greatest in parts of Southern California, Imperial County, the western San Joaquin Valley, and the Central Coast.

Urbanization Pressures on the Land Base

Urbanization removes land from commercial agricultural production by direct development on it, by breaking it up into smaller parcels, and by nearby residents' complaints about production practices.5 Direct development is probably the most noticeable force reducing the number of acres in production agriculture in

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4 Because of the overall high basin-wide efficiency in the San Joaquin Valley, conservation through improved irrigation efficiency cannot help this situation much.

5 For example, urban residents object to the smell or dust caused by some farming operations, and are sensitive to the use of agricultural chemicals that may drift onto their properties.
California. However, large-lot and ranchette housing in agricultural areas will convert more acreage than will high density urban development.

Conversion of land to urban uses is permanent; once urbanized, it is very difficult to return land to agriculture. Also, the land removed tends to be the most productive. (Relatively flat prime farmland is also “prime” for development because it offers lower construction costs.) And some of the land being removed from production is in unique climatic zones, making it difficult to find other areas to grow particular crops. (Artichoke production near the Monterey Peninsula is one example.)

Estimates vary about how much farmland is being lost directly to urbanization and indirectly to other forces associated with urbanizing pressures. One estimate is that California currently loses about 30,000 acres of irrigated cropland and 30,000 acres of nonirrigated farmland to development each year. (Since even nonirrigated farmland needs water after development, agriculture may be additionally impacted by loss of water diverted to urban use.)

The California Department of Conservation, Office of Land Conservation (1988) documented changes in land use on 66.8 million acres of California land, which is about two-thirds of the total land area. It reported that “important” farmlands in California increased from 7.2 million acres to 7.3 million acres between 1984 and 1986. Urbanized land also increased, from 2.09 to 2.18 million acres.

Does this mean there is no net conversion of agricultural land to nonagricultural uses? Not according to the AFT 1986 report, which estimated that 44,000 acres of cropland, including 36,000 acres of irrigated land, are converted to urban uses each year in California. AFT states that most of California’s urban growth has taken place in the 11 coastal counties from San Diego to Alameda where, between 1955 and 1982, the urban area increased by 471,000 acres and agricultural land decreased by 125,000 acres. The largest losses of agricultural land were in Santa Clara and Orange counties.

Since these reports, urban growth in the Central Valley has accelerated. If trends of the past decade or so continue, the AFT 1989 report predicts, an additional 300,000 acres or more of the Central Valley will be urbanized by the year 2010. High housing prices and congestion in Los Angeles-Orange County and the Bay Area may well create even greater demand to live in the Central Valley. Meanwhile, new urban areas in the Valley compete for water and their ability to outbid agriculture may force additional acreage out of production.

Assuming that population projections for the state are reasonably accurate, demand for land for housing, commercial and industrial development, for roads and streets, and for other urban
purposes will continue at least at present rates. At these rates, it is quite likely that another 500,000 acres of agricultural land in California will be converted to urban uses during the next 20 years. In fact, the rate of development may be even more rapid, at least for a while. Eventually the rate of urban expansion could be slowed by the associated externalities of long commute distances, traffic congestion, air pollution and the like.

Meanwhile, some land within urban areas is actually being farmed. Utility rights of way and other vacant urban land can and are being utilized for high valued crops, particularly those with high labor requirements—for example, strawberries, vegetables, and Christmas trees.

**Salinity, Sodicity and Drainage**

Salinity and sodicity are soil conditions that limit plant growth and choice of crops due to both chemical and physical soil effects. (Salinity is an accumulation of soluble salts in the soil root zone and sodicity an accumulation of sodium.)

It is not uncommon for both problems to occur together. In any case, both occur naturally in arid and semi-arid climates where evaporation exceeds precipitation. In regions such as the San Joaquin Valley, Mojave desert, Coachella and Imperial valleys, and some interior coast range valleys, precipitation is often insufficient to wet the entire soil profile and so there is little natural leaching of salts and sodium. Meanwhile, mineral weathering releases soluble salts and sodium that accumulate in the soil profile.

High or “perched” water tables result in soil salinity when shallow ground water slowly moves upward. As this water evaporates or is transpired, it deposits salts and sodium in the crop root zone. Also, both surface and pumped irrigation water, even the highest quality runoff from the Sierra Nevada snow melt, carries some dissolved salt. Thus, use of irrigation water to grow crops inevitably brings salt into the soil profile.

Regardless of its source, if the salt is not leached from the profile with additional water (excess to the crop’s needs) and removed from the field by artificial drainage, salts and sodium build up in the soil root zone until salt sensitive crops can no longer be grown. This results in either complete removal of the land from agriculture or change in the type of crops being grown.

According to the U.S. Soil Conservation Service (SCS) County Resources Inventory, about 3 million acres of irrigated cropland in California are affected by saline soils (Figure 1). High

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6 This issue is also discussed in the farming systems chapter, Chapter 1, and the water chapter, Chapter 4.

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Figure 1. Salinity Problem Areas

- Areas with saline/sodic soils which affect crop yields

water tables contribute to much of this salinity. In addition, 1.6 million acres of nonsaline soils are affected by the salts in irrigation water. In short, soil salinity reduces crop yields—a trend that eventually could reduce the land resource base. Some crops, such as cotton and barley, are more tolerant but as the salt content of soil and soil moisture increases, they too produce less. In Kings County, for example, the SCS predicts that even barley and cotton cropland will be entirely lost within a decade or two unless a solution to the drainage problem is found.

The future area impacted by salinity will depend very much on the politics of water in the state. If a San Joaquin Valley drain is completed, the valley will be protected from additional salinization, and reclamation of saline and sodic soils can continue. Without the drain or some alternative technique for removing salts and sodium—as well as toxic trace elements, to be discussed later—from the soil and water, many thousands of additional acres will be lost from production and yields can be expected to further decrease. Some of this acreage, however, might be usable for urban development, and thus reduce development pressure on more productive farmland in the Valley.

Since up to 50 percent of the irrigated acreage in California is susceptible to loss of production by increased salinity and sodicity, this is a major determinant of future land use in California. Precisely how much land will be removed from productive agriculture cannot be predicted. However, this is one problem for which there are technological—though costly—solutions; and upon which policy can have a major impact.

Erosion

Water, wind and gravity produce soil erosion. According to the SCS County Resources Inventory, in 1984 water erosion affected over 13 million acres of grazed land, timber land, and dry and irrigated cropland in California. The SCS inventory considered on-site erosion problems, such as loss of productivity due to soil removal and plant damage by wind abrasion.7

Water erosion is not a major concern in the level lands of the San Joaquin, Sacramento, or desert valleys. It is a serious problem on some of the sloping lands that are traditionally used for grazing and forestry. Water erosion also becomes more of a problem as vineyards and orchards expand into the foothills from the valley floors. Without careful conservation practices to control erosion

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7 Off site problems also exist. Soil erosion causes sedimentation of streams and navigable waterways, and water quality may be impaired by pesticides carried on the sediment. Wind erosion, of course, decreases air quality over large areas.
damage on hillsides, the thin soil there ultimately limits crop production.

Wind erosion is a problem in flat valley lands. It is not likely to reduce the land base available for agriculture because of on-site damage—but if urban populations perceive agriculture as a major contributor to air pollution, they may demand either additional conservation practices or the removal of some land from agricultural production. A case in point is reduced production of white asparagus in the Delta area because of severe wind erosion that carried peat dust into Stockton.

In addition, landslides can cause serious damage. Acreage losses from landslides are likely to be small, but where they do occur in agricultural operations they can be financially devastating. The Coast Range is the most susceptible landslide area in California.

Compaction

The soil’s physical condition contributes importantly to production. Compaction by farm equipment, off road vehicles, or any other weight on the soil surface increases soil density. Increased density inhibits the growth of plant roots, reduces rooting depth, decreases the rate at which water penetrates the soil surface, and inhibits the free movement of water through the soil. Increased subsoil density has been shown to reduce the growth of both forest and orchard trees. Most of the cultivated land in California is compacted to some degree, and it is common practice to “rip” the compacted zone by an additional tillage operation to prepare soils for crops.

Increased density can be managed, but only with increased costs. In some cases the costs associated with amelioration of compacted soils might be sufficient to remove land from agriculture, but it is not likely that compaction will significantly decrease the amount of land in commercial agriculture in California. However, the physical management of soils is important in the overall care and conservation of California’s land base.

Soil Pollution

The extent of soil pollution is largely unknown but it has the potential to remove land from production. Whether this occurs or not depends largely on public policies and regulations. Our ability to detect ever smaller concentrations of naturally occurring elements as well as manufactured compounds has changed the definitions of “pollution.” In the western San Joaquin Valley, the discovery of damaging levels of selenium in soil and water is a recent key policy issue that already has restricted irrigation. However, selenium is only one of a number of naturally occurring toxic elements. (For
example, boron, although more of a threat to plants than animals, is
much more widespread than selenium.) If more such issues, involv-
ing natural or man-made substances, arise, what will be the impact
on the agricultural land base? Much will depend on society’s
aversion to risk. Meanwhile, those in agriculture have control over
what is added to soils, and limited control over what is dissolved out
of soils, such as selenium; but no control over what is in the soil
naturally.

In any case, there is both need for care in using additives and
need for better public information as to the benefits and risks of
added and natural chemicals. The public’s concern for zero risk in
the food supply could reduce—through market forces, if not regula-
tion—the amount of chemicals used in agriculture so much that
more acres would be needed to produce the same amount. (Mean-
while, reduced use of chemicals without lowering yields is the goal
of integrated pest management.) Also, agriculture could be forced
off land that is deemed “polluted.” However, reclamation measures
presumably would be available.

Another concern is the effect of urban and industrial waste
disposal on land pollution. Chemical waste dumps, other kinds of
land fills, and similar land uses that pollute the soil may remove
small acreages of land from the “available for agriculture” category.

Delta Flooding

California’s Sacramento/San Joaquin Delta is made up of
levee-protected islands that lie below sea level and are steadily
subsiding due to the oxidation of organic soils. Some of the levees
are old and in danger of collapsing, which would flood the islands.
Once levees are lost, replacement is difficult and costly. Should
some levees fail, land going out of production potentially could
amount to hundreds of thousands of acres. An associated problem is
that the evaporation from flooded islands is about twice as great as
the evapotranspiration from crops previously grown there; and
agricultural users presumably would have to make up for most of
the additional evaporative losses.

Air Pollution

Deteriorating air quality in certain air basins is reducing
both cropping alternatives and crop yields, and therefore has become
a significant negative influence on the agricultural land resource
base. Air pollution is a particularly serious agricultural problem in
the San Joaquin Valley, and is currently estimated to reduce yields of
some crops there by 10 to 15 percent or more.

Since air pollution reduces crop productivity rather than
directly eliminating acreage, its impacts on the land base are indirect
and complex. For example, demand for farmland elsewhere may increase in order to compensate for lost production. (See the chapter on air quality, Chapter 5.)

Technology

A direct force with potential to increase the productivity of existing acreage is the development of new technology. On the one hand, such development could mean that less land would be needed to produce the same amount; on the other, it could allow cultivation where crops were not previously grown.

For example, low volume irrigation systems and modified cultural and harvesting practices allow steeper slopes to be utilized for certain specialty crops. Also, genetic engineering and other biotechnological developments have potential to substantially increase per acre yields. Such technology might also open new lands for agriculture as new drought-tolerant varieties are developed. If kenaf, an experimental fiber crop grown in dry conditions, becomes a major paper pulp source, a new agricultural industry would open in the desert—provided, of course, that water was available. Another biotechnology impact could be the development of salt-tolerant crops that could be grown with poorer quality water. This would allow land currently producing certain crops to stay in production if water quality decreases. It also would allow the expansion of cultivation onto soils of higher salinity.

Government Policies

Federal farm policies are an important influence on the amount of land used for production agriculture. Attractive price and income supports encourage production of certain commodities. Certainly, more land is being used for production nationwide than if there were no farm subsidies. The situation is somewhat different in California where there are so many alternative crops from which to choose. This means that there are indirect as well as direct impacts of changes in federal programs. Should price and income support programs be reduced sharply or eliminated, land use patterns in the state would surely change. For example, some of the San Joaquin Valley’s 1.1 million acres of cotton would likely be used for other crops, with associated price effects on those crops. However, much of the Sacramento Valley’s rice land has few alternative uses and might be fallowed in absence of the program.

8 Acreage set aside for federal production control programs is still farmland and counts statistically as part of the base. Acreage in the Conservation Reserve also continues to be counted.
Another government (state and/or federal) policy with considerable potential to affect the land base would be a legally mandated withdrawal of certain widely used agricultural chemicals. Unless adequate substitutes are found, such a ban would reduce productivity. Then, assuming the same production, more acres would be needed. There also might be voluntary shifts in cultural practices that have the effect of reducing yields per acre. The trend to sustainable agriculture—defined as an agriculture that is both economically viable and environmentally sensitive—could require additional land to maintain the same level of production. Unfortunately, because of restricted water supplies, opportunities for expanding California's agricultural land base in response to either mandatory or voluntary changes in production practices appear to be very limited.

**Markets**

An indirect force determining the expansion of the land base or its intensity of use is demand for the products being grown. Although demand is partially a function of population growth, an important aspect for California products, and particularly for its specialty crops, is increased economic affluence at home and in developed countries abroad. California is well situated to benefit from important markets along the Pacific Rim. (See the chapter on marketing, Chapter 7.)

As commodity demand and prices increase, idle land tends to be brought into production. Another response to favorable market demand is to crop the existing land base more intensively. As soil and climate permit, more than one crop per year is grown on the same parcel of land. This is especially so for irrigated vegetable and field crop acreage—for example, winter cereal and summer dry beans or corn. Another way of intensifying production is to shift from lower-valued to higher-valued crops, e.g., from barley to grapes. Again soil quality would be a crucial ingredient of success.

Besides shifts in domestic and international demand, there are changes in competing supplies from other production areas. All the complex forces discussed in this chapter that affect the state's agricultural land base also help determine California's success at competing in domestic and world markets against products from elsewhere. Should any of these forces adversely affect the state's competitive marketing position, the demand for land in agricultural production could fall—in addition to other economic repercussions. However, the probability is that longer term demand will continue to exert at least some pressure toward expanding production of many specialty crops in California and, indirectly, the demand for land on which to grow these crops.
Farmland in California

Policy Options

Land uses in California are constantly changing under many forces, some of which have been discussed here. In general, few forces are adding new land to the agricultural land base; many are reducing it. Most of these forces also change the productivity of the land base.

The magnitude of potential impacts and the probability of occurrence differ for each of these forces. In order of probable significance, the most important are (1) conversion to nonagricultural uses, (2) constraints on water supply, (3) salinity/drainage, and (4) markets. (Biotechnology and shifts in cultural practices also may be important, although not determining factors.)

Of these potentially most important forces, conversion to other uses and salinity/drainage will continue to directly reduce the land base. Meanwhile, constraints on water could reduce the land base, while markets have the potential for increasing it.

If Californians desire to alter current trends threatening the land resource base, policy attention to these forces has the most potential. The number of possible policy options available is large. Many, however, will be highly controversial, if not generally unacceptable; others will have little or no measurable impact. The actual choices will be made largely in the political arena, reflecting economic, legal, and societal pressures. Therefore, the possible options discussed here are stated in very general terms and are intended as illustrations only.

Conversion to nonagricultural uses. Among the relevant policy options are to:

—Increase the state's interest in preserving/conserving/retaining all or specified prime agricultural land in its nonurbanized condition through strong mandate over local government. Prime land is suggested since it tends to provide more cropping alternatives and thus maintains flexibility.

—Increase financial incentives to local government to deny development on agricultural land and to shift development either to nonagricultural land or to much higher population densities.

—Provide significantly more attractive economic incentives than now exist to land owners to retain their land in agricultural production. This could include purchase of development rights or public financial underwriting of land trust institutions.
—Require agricultural elements in county general plans to address such issues as economic critical mass in farm input supplies, marketing facilities, and transportation.

—Further change the property tax system in order to discourage development and encourage continued agricultural usage of nonurbanized land.

**Constraints on water.** Among the relevant policy options are to:

—Change California water law to better facilitate water transfers and/or direct water to those prime lands most important to the state.

—Adjust water prices, as well as property taxes, in order to contribute to the continued feasibility of irrigated agriculture, particularly in urbanizing areas.

—Reclassify priority water uses to distinguish among residential, landscape, and classes of industrial use as well as location or crop for agricultural use. While some municipal and industrial water uses may be highest priority, others may not be as high as certain agricultural uses.

**Salinity, sodicity and drainage.** Among the relevant policy options are to:

—Complete a master drain for the San Joaquin Valley and develop an effective drainage and salt balance for the Imperial Valley.

—Publicly finance and/or underwrite the installation of on-farm drainage systems for agricultural land.

—Through regulation, encourage more efficient cropping patterns and/or water application.

**Markets.** Among the relevant policy options are to:

—Consider implications for the land resource when attempting to influence California’s access to international markets. This could lead to setting commodity criteria based upon type and location of land required for production.
In addressing these and other policy options regarding agricultural land, certain underlying issues must be considered. These include (1) the balance of power and responsibility between local and state government, (2) the balance between private and public interests in privately “owned” natural resources, and (3) the magnitude and, particularly, the distribution of costs and benefits—both monetary and nonmonetary. Since public policy by its nature is a redistributive process, the underlying issues are concerned with whether the potential gains exceed losses and who participates in those gains and losses.

References
California’s Water Resource: The Current Status and Future Challenges

H. J. Vaux, Jr., and Rex J. Woods

California has become the most populous and prosperous state in the nation in part because it has had access to ample quantities of high quality water. California’s earlier economic growth was led by agriculture, and agriculture remains a mainstay of the state’s economy today, with gross receipts of about $17 billion annually. The preeminence of agriculture can be partly attributed to the state’s climate and soils which favor the culture of most food and fiber crops, including some which are not grown elsewhere in the nation. Yet, without an ample supply of good quality irrigation water, the scarcity and variability of rainfall in most regions of the state would have severely constrained its agriculture. Developed water supplies now irrigate over 9 million acres in the state.

California has always had abundant supplies of surface water within its borders. Average annual precipitation statewide is an estimated 193 million acre feet (MAF), producing an annual average run-off of approximately 71 MAF. While this is more than twice the current net demand for water of (34.2 MAF), the variability of surface supplies from season to season, from year to year and from place to place has always posed problems in meeting the state’s demands for water.

Much of California has a two-season climate. The months from November through March, when water demands are relatively small, are typically the wettest; the period from June to September, when demands peak, are typically the driest. Although a significant
portion of the water supply falls as snow at high elevations and snowmelt contributes to the flow of many streams into mid-summer, sustained and uniform rates of streamflow are rare. The variability of supplies from year to year is also substantial. In recent years, precipitation has ranged from 65 percent below normal to 50 percent above normal and run-off has varied from a low of 16 MAF in 1976-77 to a high of 133 MAF in 1982-83. Furthermore, approximately 70 percent of the state's annual precipitation occurs in the northern one-third of the state, while over 70 percent of the demand is found in the southern two-thirds of the state.

Californians have, in many instances, overcome these annual, seasonal and locational imbalances between water supply and demand by developing an extensive system of impoundment and conveyance facilities. Approximately 1,300 dams have been constructed to capture and store wet season and wet year flows. An impressive system of canals and pipelines has been built to transfer water. Traditionally, these new supplies have been developed well ahead of projected demands to ensure that growth was not constrained by lack of water. Today, surface water supplies account for about 76 percent of total net demand statewide (26 MAF of the 34.2 MAF).

The variability of surface water supplies also has been offset in many areas by ground water resources. Current storage in California's ground water basins is estimated to be about 857 MAF. Of this, some 500 MAF may ultimately be usable. The largest ground water reservoir in the state, in the San Joaquin Valley, is estimated to contain 200 MAF within 500 feet of the surface. Although these ground water resources are vast, their use may be limited in some areas by high pumping costs. In some places, the substantial depth to ground water has been caused by overdrafting.

Currently, ground water withdrawals provide for approximately 23 percent (8 MAF) of net use. In average years the rate of total withdrawals exceeds the rate of recharge by about 2.0 MAF. This "ground water mining" is greater in dry years such as 1976-77 when the overdraft is estimated to have exceeded 5 MAF. While ground water mining may often be justified economically (especially in dry years), it cannot be sustained indefinitely. In areas where mining occurs, water users must anticipate the ultimate exhaustion of their ground water supplies and plan either for a transition to a less water dependent economy or development of substitute surface supplies. Historically, ground water overdraft has been countered in many regions of California by developing supplemental sources of surface water.

Trends during the last 20 years suggest that California's historical water past may not be a good guide to its future, since
there are likely to be significant constraints on the development of additional firm ground and surface water supplies. There also are disturbing trends in water quality deterioration which threaten to reduce useable supplies. Traditional efforts to manage potable water quality have focused successfully on removal of biological organisms and dissolved minerals from water supplies. However, vastly improved detection techniques have heightened public concern over the threat posed by toxic chemicals, both natural and synthetic.

It is now widely recognized that the quality of virtually any water source can be degraded more readily than was previously thought. Increasing numbers of spills and leaks have been discovered which, along with improper toxic waste disposal practices, have diminished the quality of the state’s ground waters. Watershed lands have often been managed in ways that lead to water quality deterioration from nutrients and sediments carried in run-off. Since World War II, the intensive and widespread use of fertilizers and pesticides in irrigated agriculture has resulted in increasing levels of residues in irrigation drain water and ground water.

The potential for further degradation of both ground and surface water supplies is substantial as California’s highly technical and industrial economy continues to grow. Once in the ground, toxic wastes are expensive and difficult if not impossible to contain or remove completely. As a result, stringent new regulations governing water use and waste disposal are being called for, despite the fact that regulations have not always worked to prevent or mitigate water pollution in the past. Compliance with new regulations will undoubtedly impose new financial costs on both producers and consumers.

Most economic and demographic studies conclude that California will continue to grow through the year 2010 at rates which will sustain its position as the nation’s leader in both population and gross economic product. This continued population and economic growth is likely to be influenced by the availability of adequate supplies of high quality water. However, as the past two decades have shown, growth itself can adversely affect both the availability and quality of water supplies. Although the agricultural sector is projected to retain its leading position in California’s economy, intensifying water scarcity statewide coupled with deterioration of water quality may have significant impacts on the quantities of water available to agriculture as well as on the ways in which the agricultural sector uses water.

**Challenges—Present and Future**

The emerging issues suggest that in the future, agriculture may have to view its water supply problems in new and innovative
ways. Some of the challenges related to water quantity and quality face all California water users. Others are peculiar to the agricultural industry itself. Categories of issues discussed here include (1) adequacy of existing supplies, (2) the threat from deteriorating water quality, (3) the nature of competing uses, and (4) proposed actions.

**Adequacy of Existing Supplies**

It is not clear how California will meet the projected growth in water demand while preserving current patterns of water use. The California Department of Water Resources (DWR) has estimated probable changes in net water use between 1985 and 2010. These projections, shown in Table 1, are based on the same assumptions about population growth, climate, and energy prices which underlie the analyses in this volume. DWR estimates that net water use statewide will increase by 4.2 percent between 1985 and 2010. Virtually all of this growth is projected to occur in the municipal and industrial sectors, largely as a consequence of the growth in population. In contrast, net water use in the agricultural sector is projected to decline very slightly, reflecting the fact that California agriculture may become somewhat less competitive in national and international markets. Net water use in the sectors other than urban and agriculture is projected to grow very modestly.

<table>
<thead>
<tr>
<th>Table 1. Net Water Use in California, 1985-2010</th>
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Source: Department of Water Resources

Arrayed against this prospect for net use is a somewhat tenuous supply situation which is summarized in Table 2. For 1985, supplies totaled 34.2 MAF, exactly equivalent to net use. However, 2 MAF of this supply is attributable to ground water overdraft, almost all of which is in the agricultural sector. For the year 2010, DWR's figures show that, in the absence of additional development, supplies will grow by only about 0.2 MAF. This increase is attributable to the provision of approximately 0.8 MAF of unallocated supplies from the Central Valley Project plus very modest increases in safe ground water yields, local imports, and reclaimed waste water (about 0.2 MAF). Offsetting these increases is the loss of approximately 0.8 MAF in Colorado River supplies which reflects the
reduction in California’s historical level of use as Arizona begins to use the full entitlement granted to it by the Supreme Court. The loss of Colorado River water will have direct effects only on urban users in Southern California. However, it is likely to reverberate through the California water industry and will be indirectly felt in many agricultural sectors as southern California’s urban dwellers seek additional water to support the burgeoning economic and population growth projected for their region.

Table 2. California Water Supply by Source

<table>
<thead>
<tr>
<th>Source</th>
<th>1985</th>
<th>2010</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local Surface Water</td>
<td>10.2</td>
<td>10.2</td>
<td>0.00</td>
</tr>
<tr>
<td>Ground Water (Safe Yield)</td>
<td>6.0</td>
<td>6.1</td>
<td>+ 1.67</td>
</tr>
<tr>
<td>State Water Project</td>
<td>2.4</td>
<td>2.4</td>
<td>0.00</td>
</tr>
<tr>
<td>Federal Projects</td>
<td>8.3</td>
<td>9.1</td>
<td>+ 9.60</td>
</tr>
<tr>
<td>Colorado River</td>
<td>5.0</td>
<td>4.2</td>
<td>-16.00</td>
</tr>
<tr>
<td>Reclaimed Wastewater</td>
<td>0.3</td>
<td>0.5</td>
<td>+66.67</td>
</tr>
<tr>
<td>Subtotals</td>
<td>32.2</td>
<td>32.5</td>
<td>+ 1.00</td>
</tr>
<tr>
<td>Ground Water Overdraft</td>
<td>2.0</td>
<td>2</td>
<td>0.00</td>
</tr>
<tr>
<td>Totals</td>
<td>34.2</td>
<td>34.5</td>
<td>+1.00</td>
</tr>
</tbody>
</table>

Source: Department of Water Resources

For the year 2010, a comparison of the total dependable supply figure in Table 2 with the total net use figure in Table 1 reveals a projected water supply shortfall of 1.2 MAF. DWR indicates that perhaps two-thirds of this shortfall could be made up through the addition of some facilities to the state water project and ground water banking programs. The remaining one-third (0.4 MAF) would have to be made up from sources as yet unidentified or from changes in institutional arrangements which would reduce the growth in demand.

The 1.2 MAF shortfall may be understated, however. DWR has assumed that approximately 0.4 MAF of ground water overdraft will be offset by construction of a mid-valley canal to bring supplemental Central Valley Project supplies to part of the eastern San Joaquin Valley where overdrafting is currently substantial. Should this conveyance facility not be built, overdrafting would be 0.4 MAF higher than reported in Table 2.

Increased ground water pumping is one obvious alternative to additional surface supplies. However, the possibilities for increasing ground water extractions without substantially worsening existing levels of overdraft are limited. Studies by DWR indicate that of the 200 inventoried ground water basins in California, 40 are being overdrafted with 11 characterized as critically overdrafted.
The vast majority of these ground water basins are in agricultural regions.

Critical overdraft poses the threat of significant environmental, social and economic consequences resulting indirectly from economic exhaustion of the aquifer or directly from land subsidence, seawater intrusion, and degraded ground water quality. All this implies the ultimate need for as much as 2.0 MAF of additional surface supply or equivalent reductions in net use to forestall the otherwise inevitable consequences of ground water overdrafting.

California’s aquifers have a usable storage capacity of over 150 MAF, which is approximately twice the surface reservoir capacity. The use of this underground storage is becoming increasingly attractive. This means that ground water banking and storage schemes are likely to make a significant contribution toward solving future water supply problems. This, in turn, points to the need to manage basins with more care. Uneconomical overdraft is a particularly obvious target for regulation. Managing ground water supplies solely with recharge and other supply augmentation strategies is not likely to be sufficient because of the high costs and other problems associated with the development of new surface supplies. The need to avoid or minimize further ground water quality degradation also will be very important.

Deteriorating Water Quality

Salinity and Drainage

Virtually all naturally occurring waters contain some dissolved mineral salts. When water in the root zone is evaporated from the soil surface or transpired by plants, most of the salts are left behind. In the absence of mitigating measures, these salts build up causing a loss of soil productivity and declines in crop yields. The process may take centuries. However, irrigated lands can become salinized quite quickly when irrigation water has high salt content and soils are not well drained.

The conventional means of dealing with salinity is to apply water in excess of the crop’s demands in order to flush salts from the root zone. This process, called leaching, works well only when drainage is adequate. In many areas, including some in California, leaching produces increasingly shallow and saline water tables. In the long run, adequate drainage is required to complement leaching if soil productivity and crop yields are to be maintained.

Although salinity and drainage problems have existed almost from the time that irrigation was introduced in California, they have been largely confined to specific areas and managed in a reasonably successful fashion. Currently, however, about one-half million acres in the central and western San Joaquin Valley have
shallow ground water tables that have risen to within 5 feet or less of the soil surface and the affected acreage is increasing. Furthermore, approximately 7 million tons of salt are introduced annually into the San Joaquin Valley and are not being removed. Imported water from the Delta brings in about half that amount; chemical weathering of minerals in rocks and soils accounts for the remainder.

In some areas of the San Joaquin Valley, drains have been constructed to lower subsurface water sufficiently to permit effective leaching. Although the immediate problem of managing salinity can be solved in this way, the long term problem of providing for adequate disposal of the drainage waters remains. Proposals to dispose of drain waters through master drains emptying to the Sacramento-San Joaquin Delta have foundered because of relatively high costs and because of increasing public concern about possible environmental damages to receiving waters. Yet, unless saline drainage waters can be exported from the San Joaquin Valley, salt balances cannot be maintained. The resulting salt build-up has been estimated to threaten as much as a million acres of crop land in the valley.

The drainage and salinity problem has been substantially complicated by the discovery of selenium in irrigation drain waters. Selenium, a naturally occurring element, is required by animals in trace amounts as an essential nutrient but may be toxic in larger amounts. Soil-borne selenium, mobilized by irrigation water, has been identified as the cause of deformities and deaths among water fowl at Kesterson Reservoir which until recently was the receptacle for saline agricultural drainage water from a portion of the western San Joaquin Valley. The discovery of selenium as well as other potentially toxic elements such as arsenic, boron, chromium, mercury and molybdenum in irrigation drain waters has raised additional concerns about the impacts of drainage water on the quality of receiving waters. This has further confounded efforts to design an effective salt management plan for the San Joaquin Valley.

If the salinity problem is to be managed successfully, a number of actions will be required. To minimize drain water flows, irrigation water will have to be managed more intensively to reduce the amount of drainage percolating below the root zone. Also, development of techniques for reusing drain waters of low or moderate salinity will clearly be important. In regions that lack opportunities for discharging drain waters, facilities will have to be improved and expanded either at the farm level or on a regional basis to retain and evaporate drain water—while preventing salts and other residuals from entering water supplies or harming wildlife. It is important to recognize that these facilities will only buy time. Ultimately, the problems of how and where to export salt will
have to be addressed if the removal of some lands from production is to be avoided. The search for a solution to this problem is likely to continue through the next several decades.

**The Use of Chemicals**

Salts and trace elements in irrigation drain waters are not the only water quality problems faced by agriculture. Excess nitrate levels in ground water, a potential human health problem, have been recorded in many parts of the state (Figures 1a and 1b). The primary sources are nitrogen fertilizers and livestock manure. In addition, residues from pesticides and other chemicals in irrigation tailwater, run-off and sub-surface drainage have been detected in both ground and surface waters. Although the concentrations detected are usually not above trace levels, the mere appearance of such chemicals in the water supply fuels the pressure for more stringent controls over the use of agricultural chemicals. Ground water pollution from industrial sources adds to public concern.

"Alternative agriculture," also known as low input or sustainable agriculture, is being advanced, in part, as a means of minimizing or eliminating the use of agricultural chemicals in crop culture. Alternative agriculture, still in its infancy, is unlikely to be widely adopted until it is shown to be acceptably competitive with traditional agriculture in terms of yields and profits. However, various techniques of alternative agriculture may become viable more quickly both because of research advances and because new regulations on the use of agricultural chemicals may make conventional farming practices more costly and difficult. As the turn of the century approaches, agriculture will need to be open to the use of new and innovative techniques which will contribute to the resolution of major water quality problems associated with irrigated agriculture.

**Competition for Available Water Supplies**

*Urban Uses*

Superficially, it might appear that the shortfall in water supplies anticipated for the year 2010 would not affect agriculture since virtually all growth in water consumption is projected for the municipal and industrial sectors. But, if augmenting supplies proves to be as difficult in the next 20 years as in the last, efforts are likely to secure a reallocation of some water away from agriculture to serve the expanding demands of urban sectors as well as for environmental purposes. As the users of four-fifths of California's water supply, agriculture will be under increasing public scrutiny and should expect intensifying pressure to defend both its water entitlements and management practices.
Figure 1a. Well locations where nitrate levels have been recorded at 45 mg/liter or greater during the period 1975 through 1987.

Source: Water Resources Control Board
Figure 1b. Well locations where nitrate levels have been recorded with the range of 20 through 44 mg/liter during the period 1975 through 1987.

Source: Water Resources Control Board
The pressure for reallocation of some of agriculture's current supply to support the growth in domestic use arises from the observations that (1) urban users are willing to pay more for water than agricultural users and (2) water is more productive and valuable at the margin when devoted to urban uses. It is sometimes argued that the willingness of urban consumers to pay more is evidence that expensive new water supply technologies, such as brackish and seawater desalinization and sophisticated wastewater reclamation processes, could be used to meet new urban demands. However, water produced by these technologies costs anywhere from five to ten times the current prices paid by urban users. Reallocated agricultural water may, in many instances, be even less expensive than current urban water supplies. It is also evident to many urban water users that only relatively small amounts of water currently used by agriculture would have to be reallocated to meet all foreseeable new urban demands for water. Ironically, economic and political pressures to reallocate some agricultural water to urban uses may arise in traditional agricultural areas in the Central Valley which are now subject to rapid urban expansion as well as in southern California.

Environmental and Recreational Uses

State and federal laws now require that the environmental consequences of proposed water developments be considered before such developments are approved. Moreover, the enunciation of the "public trust doctrine" by the California Supreme Court has further strengthened environmental claims to water uses such as the protection of fisheries, wildlife, and recreation. In the future, the public trust doctrine will likely strengthen efforts to reallocate water from historic uses to instream uses.

The controversy surrounding the City of Los Angeles' diversions from the Mono Lake basin is illustrative. As this case makes clear, the state is not bound by past decisions and has the power to mandate reallocations of water away from consumptive uses to support environmental and recreational uses. The ultimate impact of the public trust doctrine on current patterns of agricultural water use is highly uncertain. It seems clear, however, that some current agricultural uses could be challenged.

Uses in Areas of Origin

California has strong laws designed to protect water supplies in basins of origin for use within those basins. As a consequence, there is an absolute upper limit on the quantities of remote supplies which can be exported to the agricultural and urban regions of the state. Water demands in basins of origin are projected to
increase somewhat over the next two decades which will mean that the amount of water available for export will continue to diminish. This will further constrain California’s capacity to develop new water supplies.

**Proposed Actions**

*Water Conservation and Improved Efficiency of Use*

As a consequence of the increasing competition for a fixed or shrinking water resource base, agriculture can expect strong public pressure to conserve on water use. The issues surrounding agricultural water conservation are extremely complex, partly because the concept of “water conservation” is defined in different ways. It is obvious that conservation entails some reduction in water use, but some definitions include only part of the reduction as actual conservation, while others include it all. Similarly, irrigation efficiency, which is considered a crucial element in conservation, has different meanings for different people. In addition, some observers equate high irrigation efficiencies with effective farm management, overlooking the fact that efficient water use may be achieved at the expense of crop yield. Much of the debate about the need for agricultural water conservation has been unproductive and unnecessarily controversial because of these ambiguities of definition and interpretation.

Nevertheless, some savings in agricultural water use could be obtained with more intensive irrigation water management. However, it is important to recognize that growers currently have little or no incentive to do so. Water management practices are influenced by the price of water, by cropping patterns, and by water delivery schedules, among other things. Improved water management activities may be costly, so as long as there is no offsetting benefit to be gained from economizing on water use, growers are understandably reluctant to invest large sums in conservation efforts.

The role of agricultural water conservation in alleviating statewide competition for water is also clouded by the complex laws and regulations that govern water allocations and entitlements in California. In some instances, prevailing contracts give users within the same district or service area the right of first refusal of water that is surplus to the demands of other users within the same jurisdiction. Only in exceptional instances has the orderly transfer of water which is surplus to the needs of agriculture become routine. Thus, even though irrigation water might be saved, it is not always clear that it could be made readily available to users outside the agricultural sector.

Public policies that mandate water use practices often lack
incentives and thus can be both difficult and costly to implement effectively. On the other hand, sharp increases in water prices or reductions in commodity prices would undoubtedly lead to water economizing behavior by many growers. In that case, surplus water might become available in some agricultural areas, but there still are questions about how easily that water could be transferred to other sectors.

Despite these difficulties, public pressure on agriculture to conserve water is likely to continue. In responding, the agricultural industry faces a dilemma. There are real hindrances to water conservation and the transfer of conserved water to other agricultural sectors as well as nonagricultural sectors, but these problems are not widely appreciated by people outside agriculture. As a consequence, agriculture gives the appearance of being intransigent. Dealing with this dilemma would appear to require (1) an effective educational program and (2) collaborative efforts to devise new legal and institutional arrangements.

*Water Pricing and Water Marketing*

Over the last decade, water transfers have emerged as an increasingly visible option for dealing with problems of water scarcity. Such transfers can take many forms such as water exchanges, water sales, water leases, water ranching/farming, water salvaging or water sharing. "Water marketing" refers to the voluntary transfer of developed water from a lower- to a higher-valued use. These transfers are attractive both to sellers, who can make more by selling or leasing the water than by using it themselves, and to buyers, who can acquire water more cheaply through the market process than from any alternative source.

Virtually all studies of the potential of water marketing in California conclude that the establishment of markets would result in the transfer of water from the agricultural sector to municipal and industrial uses, but that the quantities of water would be relatively small. One study suggests that over the next three decades only about 10 percent of the water used by California agriculture in 1985 would move out of agriculture as a consequence of voluntary sales and leases—and most of this amount could be transferred without taking farm land out of production.

There are a number of advantages to water markets. Both buyer and seller gain, and all transactions are voluntary rather than mandated. Market pricing is preferable to administrative or court-ordered pricing which is cumbersome, costly and frequently results in pricing distortions. A less obvious advantage stems from the fact that markets impose an opportunity cost on water that more nearly reflects its true value. This is in contrast to current practices which
base water prices only on the average cost of impounding and delivering the water—and which almost always understate the true economic value of water. By imposing the opportunity cost of water on users, water markets would allow buyers and sellers to capture the economic gains from trade which have been estimated to amount to over $100 million annually for California.

If water markets are to play an important role in resolving California’s water problems, a number of troublesome issues will need to be resolved. First, low cost ways must be found to protect the interests of third parties. Current cumbersome and expensive procedures can be costly enough to completely offset any gains from trade. Second, there is much concern about the broader economic consequences of water marketing on areas of origin. Where existing local or regional economies depend on water, its sale or lease could damage those economies, erode tax bases and ultimately jeopardize the fiscal viability of local governments. Some protection will probably have to be given to areas of origin but it should be given with great care. There is persuasive evidence showing that although the absence of water may constrain economic growth, the presence of water does not guarantee growth. Moreover, the quantities of water involved in market-like transfers are likely to build up slowly over time, giving regional and local economies the opportunity to adapt and minimize the costs of transition.

Third, there is the threat of adverse impacts on environmental amenities and recreational and wildlife resources. Methods must be found whereby water supplies for public uses can be formally allocated through markets. The present environmental impact statement process is costly and time consuming, and serves only to protect existing public uses.

Water marketing is in its infancy. The administrative and legal procedures that govern water exchanges are likely to evolve on a case by case basis as more exchanges are proposed. Thus, the actual benefits of water marketing will accrue incrementally. Market development also will be hindered to some extent by the fact that governmental oversight of the market process is not effectively coordinated. As with water policy in general, responsibility for overseeing water transfers is fragmented among levels of government and among agencies at the same level. While this situation is unlikely to change in the near term, some restructuring of water institutions may ultimately be necessary if marketing is to contribute significantly to solving California’s water problems.

Conjunctive Use and Water Banking

Conjunctive use is coordinated management of ground and surface water in order to optimize the available water supply. Water
banking, a form of conjunctive use, entails storing surplus surface water in underground basins for withdrawal during periods of shortage. DWR estimates that there may be as much as 143 MAF of available storage capacity in the state's ground water basins. The difficulties of constructing new surface storage facilities makes water banking a highly attractive alternative for augmenting the state's water supplies.

The fact that extractions are unregulated in most ground water basins poses a problem that will have to be resolved if the full promise of ground water banking is to be realized. There is a clear need to develop appropriate legal and institutional rules to govern the use of ground water storage. Although many of the direct benefits of ground water banking will go to non-agricultural sectors, water users who farm lands overlying aquifers used for banking will benefit from higher water tables in all but very dry periods—even if they are not the recipients of the additional water. This means that agriculture has a stake in the development of effective ground water management programs. To be effective, however, such programs will have to include measures for managing ground water extractions.

**Construction of New Facilities**

The tradition of developing new impoundment and conveyance facilities to firm up supplies in anticipation of growing demand (and to alleviate ground water overdraft) appears less and less viable. Most of the presently undeveloped reservoir sites are remote or relatively costly to develop. In addition, the costs of construction have risen faster than the rate of inflation during the past two decades. Meanwhile, the competition for public funds has become increasingly intense and the willingness of citizens to bear new tax burdens has declined sharply. Furthermore, the adverse environmental and aesthetic consequences of water development are now better understood.

All of these factors have contributed to public skepticism about new construction to solve California's water problems. Differing value systems espoused by participants in water development controversies show little sign of change. A wide array of interest groups and constituencies now participate in public decision-making through legislative initiatives and other processes. This has both broadened and sharpened controversies over the development of water supplies. As a result, no major new water facility has been built in California for 20 years and the immediate prospects for construction of new facilities are cloudy at best.

Even if agreement were readily attainable, early development of significant new supplies of water for irrigation use is un-
likely, given the time lags between authorization, funding and construction and the fact that the costs of new supplies exceed the willingness and ability of most users to pay. Although facilities to complete the State Water Project, including an improved Delta transfer facility, may ultimately be completed, additional projects may be very difficult to secure.

Furthermore, even if new facilities could be constructed at reasonable environmental and economic cost, it is unlikely that the additional water would go directly to agriculture. Apart from economic considerations, public concern over salinity and drainage problems and additional crop surpluses will be difficult to assuage. Additionally, there is a strong argument that new supplies should go to correct the ground water overdraft and to mitigate past environmental damages. This could, of course, benefit agriculture by indirectly reducing pressure for the reallocation of irrigation water.

Water Reuse

There are a number of ways to reuse irrigation water that could both increase the amount of water available for irrigated agriculture and help manage problems of salt build-up. Not all forms of reuse require the same level of water quality. For example, water with high nitrate levels can be used beneficially by most crops but would cause public health concerns if used for domestic consumption. The capacity of agriculture to use saline and brackish waters is limited, but improvements in plant breeding and irrigation strategies may permit the use of moderately saline waters on some crops.

At present, such strategies have little appeal to most farmers because of the lack of incentives to adopt the special management practices required. The ability and willingness of California growers to adjust to changing water conditions will depend heavily on the extent to which policies are developed to maintain water quality, to make fuller use of lower quality water, and to provide incentives to make the desired changes.

Conclusions and Recommendations

The ability of California’s agricultural sector to compete effectively in the national and international markets of the future will depend, in part, on its capacity to adapt to changing water supply conditions. The past growth and development of California agriculture was supported by abundant water supplies in most areas. These were available largely because of the ability of local, state and national governments, as well as the growers themselves, to develop relatively low-cost sources of surface and ground water.

The era of abundant water supplies now appears to be over.
New surface supplies are vastly more difficult to develop for economic, environmental, and political reasons. The quality of much of the existing supply is being degraded as a consequence of growth and indiscriminate waste disposal. Urban sectors of the state are growing rapidly. The demand for instream uses of water continues to intensify. Taken together, these factors imply that increasing water demands will have to be met from a resource base that will be difficult to expand and may actually shrink if water quality deterioration cannot be reversed.

Many signs point to the need to manage water more intensively if California’s economic and population growth is to be sustained into the 21st century. In an era of intensive management, past methods of agricultural water use will be vulnerable. This is because agriculture is an extensive water user, accounting for approximately 80 percent of net water use statewide; because some of the marginal uses of agricultural water are low-valued uses; and because agriculture is perceived to be a significant contributor to the degradation of water quality.

Adapting to an era of intensive water management will require changes in agricultural water use and management. If the agricultural sector is unwilling or unable to adapt, change may well be imposed from outside by urban dwellers who now control most of the state’s political machinery. Agriculture is likely to fare better if it takes control of its own destiny than if it allows others to dictate its response.

In some instances, effective change will require more scientific facts and an understanding of how to apply them. Here, additional research can help to minimize the inevitable costs. In other instances, what is required is the recognition that change is costly but self-imposed change is usually less so.

There are a number of areas in which water policies relating to agriculture will undoubtedly have to change. These are enumerated below.

Policies Related to the Management of Ground Water

The prospects for continuing to augment water supplies by developing additional sources of surface water are decidedly dim. However, ground water banking offers significant potential for storing surplus water that is not now used. Agriculture is unlikely to benefit directly from ground water banking, but it may well capture indirect benefits in the form of supply augmentations and reduced pumping lifts in all but dry and critically dry years.

The substantial promise of ground water banking is attenuated somewhat by two factors: (1) the continuing threat of toxic contamination of ground waters and (2) the absence of institutions to
manage ground water extractions in most agricultural areas. New policies and practices of waste disposal will be essential to preserve ground water quality. This will require better information on the fate of contaminants in soils and water, better techniques for reducing the production of toxic wastes, and better techniques for long-term storage and immobilization of toxic wastes. Clearly, a substantial research effort will be needed.

Proposals to regulate ground water extractions have always been enormously controversial in California. This state remains one of only two in the nation that are without effective means to manage extractions. The promise of ground water banking is not likely to be realized without such management which will require, at a minimum, an effective system of ground water extraction rights. Virtually every aquifer in California has different physical and economic characteristics. Local management of aquifers is better suited to deal with these differing characteristics than is state or federal management. While research will be helpful in identifying the least costly means of developing more intensive ground water management, research alone cannot solve the problem. If local management is to work, local citizens must develop and support it. Otherwise, state or federal management of ground water appears inevitable.

Policies for Improving Water Quality

As the turn of the century approaches, the need to reverse the trend of water quality deterioration in California is receiving more attention than any other water issue. The problem of managing salt balances in irrigated agriculture is particularly vexing. While research on salt tolerant crops will help, strategies for minimizing the impact of salts and for disposing of salts will be required if irrigated agriculture is to remain viable over the long run. These strategies and others will also be needed to deal with the problems of salt-associated toxics, such as selenium.

Reuse of irrigation drainage water helps to minimize the impact of salinity on receiving waters. Irrigation management techniques that reduce the volume of water percolating below the root zone also help, though only temporarily in many instances. The substantial research effort devoted to development of such regimes should continue. More importantly, perhaps, research is needed to develop incentives for growers to use water-conserving management techniques even before they experience the consequences of salt build-up. Policies that mandate the use of certain water management practices are likely to be very costly to implement, given the enormous diversity of soil, water qualities, crops and climate in California.

Research is also needed to help control the discharge of
California's Water Resources

agricultural chemicals and their residues from irrigated agriculture. Regulations to ban or control the use of agricultural chemicals, while probably unavoidable, are not the ultimate answer because they are costly to implement and because they create substantial uncertainties for agricultural production which is already surrounded by much unavoidable uncertainty. More research is needed to develop effective techniques for growing crops with minimal or no use of chemicals. Such techniques, however, must allow the grower to compete effectively in world and national markets. Policies that simply mandate the use of low-input practices are also likely to be costly and difficult to enforce.

Policies Related to the Reallocation of Water

Some shifting of agricultural water to other sectors is probably inevitable as California responds to the demands of its own growth and to the national and world economies of which it is a part. Water markets are probably the least painful way to accomplish this reallocation because they are decentralized, voluntary and benefit both parties to an exchange. There are however, substantial legal and institutional barriers to market-like exchanges of water. If these barriers cannot be lowered, other—but more costly—ways to reallocate water include litigation, administrative reallocation, and legislation.

Therefore, new policies are needed to facilitate the development of water markets. These policies need to address the problems posed by potential third-party effects of water transfers. Specifically, ways need to be found of accounting for third-party effects while minimizing the transaction costs associated with market exchanges. Additional research is needed on the magnitude of third-party effects as well as on institutional means of accommodating such effects.

Policies Related to Water Management, Use, and Reuse

Regardless of how water markets ultimately develop, new policies are needed to promote more efficient management of agricultural water and to provide incentives for adopting innovative water management practices, including reuse. Changes in water pricing policies are one obvious possibility. They could result in water prices which more accurately reflect the true value of water statewide. In addition, they would permit growers and users to adapt to increasing water scarcity in ways best suited to their own individual circumstances.

Further research on water management techniques and water reuse schemes is clearly needed. Research to identify appropriate incentives and indicate how they could become institutional-
ized at minimum cost is also required. The overall research goal should be to minimize the costs of adapting to increasing scarcity of water which the agricultural sector is likely to face.

References


Air Quality Impacts on California Agriculture, 1990-2010:
Arthur M. Winer, David M. Olszyk, and Richard E. Howitt

Introduction
The atmosphere is a dynamic system which affects every aspect of the earth’s plant life as well as its human population. Currently there is great concern over inadvertent modification of the global atmosphere due to human activity, including increased emissions of carbon dioxide (CO₂) and other “greenhouse” gases (e.g., methane, nitrous oxide, and chlorofluorocarbons). Increasing concentrations of these and other gases in the troposphere and stratosphere could lead to higher air temperature, enhanced short wavelength ultraviolet radiation at the earth’s surface, and an array of secondary impacts on vegetation resulting from global warming. Most, if not all, of the consequences of such global air pollution phenomena would impact California’s agriculture but are not quantifiable for the foreseeable future and therefore are treated only briefly in this paper.

1The authors acknowledge the efforts of the California Air Resources Board staff in providing updated forecasts of ROG and NOₓ emissions inventories. We particularly thank Terry McGuire, Ed Yotter, Barbara Brown, Gary Agid and William Lockett. We also thank Tony van Curen and John Holmes of the ARB staff for helpful suggestions concerning the methodologies employed in the air quality and economic analysis and Minn Poe of the Statewide Air Pollution Research Center staff at UC Riverside for assistance in the computer analyses.
However, on a regional and statewide basis, air pollutants, especially photochemical oxidants, have been adversely affecting California crops for decades. In fact, California continues to have the most serious photochemical air pollution problem in the United States, including the highest ozone levels. In addition to human health effects, one of the most critical impacts of these adverse pollutant levels is the reduction in yields of many of the state's important crops (Air Resources Board [ARB] 1987; Olszyk, Thompson, and Poe, 1988; Olszyk, Cabrera, and Thompson, 1988). At the present time, the economic losses resulting from these reduced yields in California are estimated to range up to several hundred million dollars (Howitt, Gossard, and Adams, 1984; ARB, 1987). Additional losses may occur due to wet and dry deposition of acidic materials in some of California's airsheds, but such effects cannot be presently assessed with precision.

Crop productivity, particularly for specialty crops, will continue to be seriously affected by adverse air quality in California's urban airsheds, especially in the South Coast Air Basin (SoCAB) and the San Diego Air Basin. However, the most serious economic impacts are expected to occur in the Central Valley, which not only has the highest concentration of agricultural production in the state, but also exhibits the topographical and meteorological characteristics conducive to photochemical air pollution. Indeed, the California Air Resources Board (ARB) estimates that if emission densities similar to those in the SoCAB were placed in the Central Valley, air quality could become worse than in the Los Angeles Basin (ARB, 1988). Moreover, by measures such as the number of days above the federal ozone standard (12 parts per hundred million, ppb), portions of the Central Valley (e.g., Fresno and Kern counties) already experience worse air quality than such major cities as New York, Houston, Philadelphia, and Chicago (ARB, 1988).

At the present time, the economy of the Central Valley is growing rapidly, at a rate greater than for the state as a whole. Unless appropriate policies concerning urbanization and air quality are pursued, in the coming two decades air pollution will threaten the continued productivity of agriculture in the Central Valley, particularly in the San Joaquin Valley Air Basin. For these reasons, the primary focus of this paper will be on California's Central Valley.

At the start of the final decade of the 20th Century, California is at a watershed in its efforts to control air pollution. Many of the readily-implemented and cost-effective emission control strategies have been adopted. One of these, the use of three-way catalytic convertors in light-duty motor vehicles, has been largely responsible for a significant improvement in air quality over the past decade in certain of the state's airsheds, most notably the South Coast and Bay
Area Air Basins. This improvement has occurred despite substantial
growth in vehicle miles travelled and in numbers of stationary

Unfortunately, with the exception of carbon monoxide
levels, the Central Valley has largely failed to participate in such
improvements. Specifically, over the past 10 years, ozone levels in the
central portion of the San Joaquin Valley Air Basin (Figure 1a) have
remained essentially constant despite significant reductions in
hydrocarbon emissions (Figure 1b). In addition, particulate matter
and visibility have actually worsened in the central and southern
portion of the Basin (ARB, 1988). Indeed, the fine particulate (PM-
10) problem in the Central Valley is among the most complex and
difficult in California (ARB, 1988). These trends reflect the complex
relationship between secondary air pollutant levels and primary
emissions of hydrocarbon and oxides of nitrogen precursors (Fin-
layson-Pitts and Pitts, 1986) and suggest that achieving improve-
ments in air quality in the Central Valley over the next two decades
will be a challenging task.

This challenge will be made more difficult by the robust
growth in population and industrial activity predicted to occur in the
Central Valley over the next two decades, and the resulting increase
in primary pollutant emissions which will occur if no further control
programs are adopted. (See Figure 2.) For example, since 1980 an
entirely new emission class has been created in the Central Valley
with the construction of approximately 50 alternative energy facili-
ties. At the present time, over 100 such facilities either have permits
to build or are being planned, and many of these are small projects
for which emission offsets are not required (ARB, 1988). As noted
earlier, growth of these and other emission sources in the Central
Valley will take place within an airshed which has both the topogra-
phical and meteorological characteristics favorable for the produc-
tion of elevated levels of photochemical air pollution, including
ozone, peroxyacetyl nitrate (a powerful phytotoxicant), and visibil-
ity-reducing fine particulate (PM-10).

An additional complication is the extent to which hydrocar-
bon emissions from agricultural crops themselves contribute to pho-
tochemical air pollution in the Central Valley. Previous (Winer, Fitz,
and Miller, 1983; Lamb et al., 1986, Chameides et al., 1988) and more
recent (Winer et al., 1989) research continues to provide evidence
that such emissions may have significant implications for design of
air pollution control strategies in certain regions of California and
the nation, including the Central Valley.

Finally, as discussed in more detail below, the overall effects
of global warming and stratosphere ozone depletion are in the direc-
tion of exacerbating regional air quality problems in California, in-
cluding those in the Central Valley.
Figure 1a. Ozone Concentrations for the Central Portion of the San Joaquin Valley, 1975-1987

Based on data from Fresno and Visalia air monitoring stations

Figure 1b. ROG and NOx Emissions for the Central Portion of the San Joaquin Valley, 1975-1987

This paper uses specially forecasted emission inventories, current knowledge of atmospheric chemistry, and crop loss and economic modeling to estimate the present impact of ozone on crops in the Central Valley, as well as future impacts in 1995 and 2010. Two scenarios representing "best" and "worst" bounding conditions for the future are evaluated. The worst case projects increases in ozone concentrations based on ARB calculations which assumed no further emission controls on ozone precursors beyond those presently mandated by law. The best-case scenario assumes decreases in ozone concentrations due to aggressive emission control programs to be adopted in the future. The decreases were assumed to permit each air monitoring site in the Central Valley to meet the current
California ambient air quality standard for ozone of 9 parts per hundred million (pphm).

Crop yield losses were then estimated based on the alternative ozone projections. Using an appropriate economic model, dollar benefits or losses to crop producers were calculated corresponding to the estimated yield differences between the worst case air quality scenario and the scenario which assumes attainment of the California air quality standard for ozone. In addition, brief discussions are provided concerning (1) the potential for agricultural crops themselves to contribute reactive organic gases (ROG) precursors in the Central Valley and (2) possible effects of global atmospheric modification. Finally, policy implications for California agriculture are identified and discussed. They are based, in part, on the projected effects of ozone on crops in the Central Valley.

Due to the availability of reliable and extensive ozone air monitoring data, and of suitable crop yield loss and economic models, we have concentrated here on a quantitative estimate of the range of impacts of ozone on agriculture in the Central Valley. We emphasize that ozone is only one of a broad spectrum of gaseous and particulate air pollutants, including acidic materials, which may impact California’s agriculture. Thus, even our so-called worst-case estimates must be viewed strictly as lower limits to the actual reduction in yields and other damage to agriculture which are presently occurring and may occur in the future. Moreover, we emphasize that we have limited our analysis to a treatment of yield reduction, which is amenable to quantitative assessment; but air pollution can cause important impacts on produce quality including visible injury which may reduce market value.

In any case, this analysis of impacts on agriculture takes place within the larger context of air pollution’s effects on human health. Regulatory standards for ozone are, and almost certainly will continue to be, based on human health effects. These health-based standards will be the chief forces driving air quality regulatory programs—including those in the Central Valley, where the economic stakes for agriculture are high.

Analysis

Future Air Quality

As indicated by Figures 1 and 2, data are available which document trends over the past decade in both precursor emissions and ambient air pollutant concentrations in the Central Valley, particularly for the San Joaquin Valley Air Basin. (For the purposes of this paper the Central Valley is defined as including the San Joaquin and Sacramento Valley Air Basins). Updated projections of future ozone precursor emissions [reactive organic gases (ROG) and oxides
Table 1. Baseline and Forecasted Emissions (Mobile and Stationary) of Reactive Organic Gases (ROG) and Oxides of Nitrogen (NO\textsubscript{X})

<table>
<thead>
<tr>
<th>Air Basin</th>
<th>1986 ROG</th>
<th>1995 ROG</th>
<th>2010 ROG</th>
<th>1986 NO\textsubscript{X}</th>
<th>1995 NO\textsubscript{X}</th>
<th>2010 NO\textsubscript{X}</th>
</tr>
</thead>
<tbody>
<tr>
<td>San Joaquin Valley</td>
<td>687.4</td>
<td>518.8</td>
<td>579.0</td>
<td>511.7</td>
<td>655.9</td>
<td>605.2</td>
</tr>
<tr>
<td>Sacramento Valley</td>
<td>254.8</td>
<td>208.4</td>
<td>232.6</td>
<td>209.3</td>
<td>264.7</td>
<td>255.7</td>
</tr>
<tr>
<td>Central Valley</td>
<td>942.2</td>
<td>727.2</td>
<td>811.6</td>
<td>721.0</td>
<td>920.6</td>
<td>860.9</td>
</tr>
</tbody>
</table>

Source: Air Resources Board, 1989.

of nitrogen (NO\textsubscript{X} = NO + NO\textsubscript{2}) over the next 20 years were generously provided for the purposes of this analysis by the ARB staff. They are based on plausible scenarios for the growth of mobile and stationary sources in the Central Valley (ARB, 1989). Specifically, using 1985 emissions data as a baseline, forecasts were made for ROG and NO\textsubscript{X} emissions for 1986 (adopted as the “basecase” year for the present analysis) and for 1995 and 2010. The resulting projections are shown in Table 1. While it is recognized that there are significant uncertainties in projecting ROG and NO\textsubscript{X} emissions 20 years into the future, the ARB-furnished estimates represent the best data currently available.

At the present time, a major experimental study of air pollution formation and transport in the Central Valley is being initiated under the sponsorship of the ARB and a diverse group of other agencies and private sector participants. Results from this research are expected to provide an experimental data base with which the next generation of airshed models applicable to the Central Valley can be developed and tested. Unfortunately, neither the results from this important study nor an appropriately validated airshed model are yet available; therefore we take an empirical approach to predicting future ozone levels in the Central Valley.

Adoption of an empirical approach to predicting future ozone levels requires a choice in weighting the dependence of ozone formation on either ROG or NO\textsubscript{X} emissions, or both. Due to the complexities of atmospheric chemistry and the critical role of both ROG and NO\textsubscript{X} ambient concentrations in producing photochemical air pollution, the issue of the relative importance of the two classes of ozone precursors remains a source of controversy. However, in recent years there has been a growing recognition based on airshed modeling studies (Russell and Cass, 1986; McCrae, 1987; Chameides et al., 1988) and air pollution and emissions trend analyses (Pitts et al., 1982; ARB, 1985) that in many airsheds, and also in large regional
areas such as the southeastern United States, peak ozone levels may be largely determined by the availability of oxides of nitrogen. This is consistent with present knowledge that photolysis of NO\textsubscript{2} is the only significant source of ozone formation in the troposphere.

There is also recent evidence (Ingalls, Smith, and Kirksey, 1989) that in California, ROG emission inventories may have been significantly underestimated due to higher than expected vehicle "running" ROG emissions and due to the potential for significant contributions of ROG emissions from vegetation (Winer et al., 1989). These two factors reinforce the view that ozone formation in many receptor areas in California will be NO\textsubscript{x}-limited rather than ROG-limited. Finally, a decade of ROG and NO\textsubscript{x} emissions data compared to ambient ozone concentration trend data, like those in Figure 1, are consistent with NO\textsubscript{x} emissions being the primary determinant of ozone levels in many, if not most, portions of the Central Valley.

Based on the above considerations, for the purposes of this analysis hourly ozone concentrations in 1995 and 2010 were assumed to change solely in proportion to the ARB-projected changes in NO\textsubscript{x} emissions for each of these years, relative to the 1986 "basecase" emissions. As shown in Table 1, in the Central Valley as a whole, NO\textsubscript{x} emissions are projected to be little changed in 1995 compared to 1986, reflecting a balance between implementation of presently-mandated control measures and growth in total numbers of sources. However, by 2010, if no additional control programs are adopted, total NO\textsubscript{x} emissions in the Central Valley are projected to increase over 1986 by more than 130 tons per day, or approximately 18 percent, due to substantial growth in mobile and stationary emission sources associated with further urbanization and development in the Central Valley.

Assuming future year ozone concentrations are directly proportional to NO\textsubscript{x} emissions, 1986 ozone values in the Central Valley were increased by 18 percent to obtain predicted 2010 levels. To allow for the naturally occurring background level of ozone in the troposphere of approximately 3.5 pphm, only the portion of hourly ozone values greater than 4 pphm was multiplied by the projected change in NO\textsubscript{x} emissions at each air monitoring site in the Sacramento or San Joaquin Valley. As noted earlier, the hourly ozone data for 1986 served as the base case for the future ozone concentration projections.

For the best-case scenario, corresponding to attainment of the California ozone air quality standard, ozone concentrations were rolled back for each hour at each site in proportion to the decrease in the highest one-hour average for that site needed to bring it down to 9 pphm. However, as for the worst-case scenario, only the proportion of ozone hour values > 4 pphm was decreased.
Agricultural Impacts on Air Quality

Concerns over the possible role of reactive hydrocarbon emissions from vegetation in complicating air pollution control strategies date from more than a decade ago (Westberg, 1977; Dimitriadis, 1981; Bufalini and Arnts, 1981). A recent paper by Chamiedes et al. (1988) has rekindled interest in this topic and presently an ARB-sponsored study is being conducted to determine the magnitude of such emissions in the Central Valley (Winer et al., 1989). Preliminary results from that study suggest that emission of isoprene and monoterpenes, as well as other reactive organic gases, may be significant from a number of major crops. While it is premature to speculate about the relative importance of ROG emissions from anthropogenic sources compared to vegetation in the Central Valley, this remains a potentially complicating factor in developing cost-effective emission control strategies for photochemical oxidants in the Central Valley. At a minimum, these results suggest that additional emphasis be given to control NO\textsubscript{x} emissions.

Possible Effects of Global Atmospheric Modification

Over the next 20 years, regional impacts of the kind discussed above are expected to dominate air pollution effects on California’s agriculture. However, toward the end of that period, and certainly on into the early decades of the 21st Century, additional and potentially serious impacts could occur due to the accumulation of CO\textsubscript{2} and various trace gases in the global atmosphere. Among these potential effects is a substantial increase in short wavelength, ultra-violet (UV) radiation due to a decrease in stratospheric ozone caused by emissions of perhalogenated compounds such as the chlorofluorocarbons. Although recent international policy initiatives such as the Montreal protocol may be effective in terminating use of the most harmful halogenated compounds by industrialized nations, it should be recognized that because compounds such as CFC-11 and CFC-12 have atmospheric lifetimes as long as 100 years, the chlorine mixing ratio in the stratosphere is not expected to return to pre-1960 levels for at least two centuries (Rowland, 1989). Thus, direct damage to vegetation from energetic UV radiation may be significant during the next century, and this could in principle affect much of California’s agriculture to varying degrees.\textsuperscript{2}

A secondary effect of enhanced UV radiation is the more rapid and, in some cases, greater production of photochemical oxidants due to higher photolysis rates of key free radical sources such as nitrous acid, formaldehyde and ozone (Winer et al. 1979; 1989).

\textsuperscript{2}To date only soybeans have shown statistically significant yield-depressing effects from UV-B radiation (Adams and Rowe, 1990).
Finlayson-Pitts and Pitts, 1986). Similarly, increased global temperatures could result in greater levels of ozone and other photochemical oxidants due to both the temperature dependence of a number of important elementary atmospheric reactions and enhanced rates of emission of reactive hydrocarbons from vegetation. In addition, drier autumn periods would have the effect of extending summer smog seasons and increasing chronic exposures of vegetation to ozone. Although it is not possible to make reliable quantitative predictions of the magnitude of such effects in the case of tropospheric ozone increases, preliminary estimates suggest that they could be of the same order or larger than those calculated for our 2010 scenario involving increased NO\textsubscript{x} precursor levels (California Energy Commission, 1989; Knox, 1989). Thus, global air pollution impacts on vegetation may offset or overwhelm any benefit from enhanced photosynthesis due to increasing CO\textsubscript{2} levels. When this is considered, our so-called worst-case calculation of ozone effects in the Central Valley may underestimate possible total impacts by as much as factor of two.

Finally, it should be recognized that if increasing atmospheric levels of carbon monoxide, methane, and long-lived organic compounds cause suppression of the average atmospheric concentration of hydroxyl (OH), the principal radical scavenger in both the troposphere and stratosphere, then all emitted species whose atmospheric lifetimes are determined by reaction with OH radicals, including airborne toxic chemicals, will be longer lived. This implies that even if emission sources remain constant, atmospheric concentrations will increase, leading to potential long-term, but presently undefinable, consequences for California agriculture.

**Future Crop Yield Losses**

Although other photochemical oxidants can cause injury to vegetation, present evidence indicates that ozone is the one primarily responsible for adverse vegetation effects in California (ARB, 1987). Therefore, crop yield losses were estimated based on the ambient ozone air quality data for 1986 and projected data for 1995 and 2010. The general procedure for calculating yield losses involved use of crop productivity data, ozone concentration-yield loss models, and the projected ozone levels. Predicted percentage yield losses were obtained in comparison to potential yields if ambient ozone levels corresponded to "clean air," i.e., a daylight growing season ozone average of 2.5 ppqm (Olszyk, Thompson, and Poe, 1988). Losses were determined first for each major crop in each county in the Central Valley, and then for the entire valley, weighted by the production in each county.

Computer model results indicated that substantial yield
losses from current (i.e., 1986) ambient ozone levels are probably
already occurring for 31 important crops growing in the Central
Valley, the most important agricultural area of California. Current
losses of over 20 percent are estimated for beans, melons, and
grapes, and of 9-15 percent for alfalfa, alfalfa seed, cotton, lemons,
oranges, and potatoes (Table 2). Estimated losses are very low or
nonexistent for 18 other crops because they were either resistant to
ozone or their growing seasons include periods (i.e., winter) when
ambient ozone concentrations are normally low. Predicted losses for
1995 were found to be the same as for 1986 due to the small differ-
ence in projected NOx emissions (see Table 1).

For the worst-case scenario, predicted absolute crop yield
losses from ozone in the Central Valley in 2010 increase slightly over
the already large losses estimated for 1986 (Table 2). Some crops
show increased losses over the 1986 level, with the largest being for
corn silage, field corn, oranges, potatoes, tomatoes (fresh and pro-
cessing), and dryland wheat (Table 3). Of this group, however, only
those for oranges and potatoes would be likely to have a significant
impact on crop production since, despite the slight increases, the
2010 loss level would still be less than or equal to 5 percent.

The nearly 12 percent increase in crop losses in 2010 com-
pared to 1986 is less than the projected increase in ozone concen-
trations (about 20 percent). This is because ozone exposure is domi-
nated by long-term ozone averages in nearly all crop loss models.
As shown in Table 4, long-term averages (12- or 7-hour daylight
ozone concentrations for the growing season) tended to increase only
sightly between 1986 and 2010. The averages included all hourly
values or portions of hourly values less than or equal to 4 ppbm
which were assumed to be unchanged from 1986 to 2010. These
“background” ozone concentrations were considered to be una-
fected by NOx emission changes in the valley.

In contrast, peak ozone concentrations were predicted to
increase substantially between 1986 and 2010. For example, an
indicator of peak concentrations, i.e., the cumulative dose based on
ozone concentrations > 10 ppbm, more than doubled for many
counties (Table 4). If such a cumulative dose were used to estimate
yield losses instead of average ozone concentrations, then crop losses
would be expected to increase substantially between 1986 and 2010.
This was indeed the case for fresh tomatoes, the only crop where the
loss model used the > 10 ppbm dose. For this crop, predicted losses
in 2010 were more than twice those in 1986 (Table 3).

Therefore, a critical future need for air pollution research is
to determine the most appropriate way to characterize ozone expo-
sures for estimating crop yield losses. Although this question has
been considerably debated recently in the scientific literature (Lefohn
Table 2. Estimated Crop Yield Losses in the Central Valley from Observed Ambient Ozone in 1986, Forecasted Ambient Ozone in 2010, and Rollback to the California Air Quality Ozone Standard of 9 ppbm

<table>
<thead>
<tr>
<th>Crop</th>
<th>Ambient, 1986</th>
<th>Forecasted Ambient, 2010</th>
<th>Rollback to 9 ppbm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa Hay</td>
<td>10.6</td>
<td>11.5</td>
<td>6.7</td>
</tr>
<tr>
<td>Alfalfa Seed</td>
<td>8.5</td>
<td>9.2</td>
<td>4.6</td>
</tr>
<tr>
<td>Barley</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Beans, Dry</td>
<td>20.9</td>
<td>22.9</td>
<td>13.4</td>
</tr>
<tr>
<td>Broccoli</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cantaloup</td>
<td>33.5</td>
<td>36.2</td>
<td>19.2</td>
</tr>
<tr>
<td>Field Corn</td>
<td>1.7</td>
<td>2.1</td>
<td>0.8</td>
</tr>
<tr>
<td>Sweet Corn</td>
<td>2.0</td>
<td>2.1</td>
<td>1.7</td>
</tr>
<tr>
<td>Cotton</td>
<td>15.7</td>
<td>17.5</td>
<td>8.6</td>
</tr>
<tr>
<td>Grain Sorghum</td>
<td>1.0</td>
<td>1.3</td>
<td>0.5</td>
</tr>
<tr>
<td>Grapes, Raisin</td>
<td>26.5</td>
<td>28.7</td>
<td>15.6</td>
</tr>
<tr>
<td>Grapes, Table</td>
<td>25.3</td>
<td>27.6</td>
<td>15.9</td>
</tr>
<tr>
<td>Grapes, Wine</td>
<td>22.5</td>
<td>24.4</td>
<td>14.1</td>
</tr>
<tr>
<td>Honeydew Melons</td>
<td>21.3</td>
<td>23.3</td>
<td>16.0</td>
</tr>
<tr>
<td>Lemons</td>
<td>9.4</td>
<td>10.4</td>
<td>7.4</td>
</tr>
<tr>
<td>Lettuce</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Onions, Dehydrated</td>
<td>1.0</td>
<td>1.1</td>
<td>0.5</td>
</tr>
<tr>
<td>Onions, Fresh</td>
<td>0.9</td>
<td>1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>Oranges</td>
<td>9.3</td>
<td>11.9</td>
<td>4.8</td>
</tr>
<tr>
<td>Potatoes</td>
<td>10.6</td>
<td>11.4</td>
<td>7.1</td>
</tr>
<tr>
<td>Rice</td>
<td>2.5</td>
<td>2.8</td>
<td>1.9</td>
</tr>
<tr>
<td>Silage, Corn</td>
<td>2.1</td>
<td>2.5</td>
<td>0.9</td>
</tr>
<tr>
<td>Spinach</td>
<td>0.4</td>
<td>0.5</td>
<td>0</td>
</tr>
<tr>
<td>Strawberries</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sugar Beets</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Tomatoes, Fresh</td>
<td>2.4</td>
<td>5.3</td>
<td>0</td>
</tr>
<tr>
<td>Tomatoes, Processed</td>
<td>1.6</td>
<td>2.0</td>
<td>0.7</td>
</tr>
<tr>
<td>Watermelon</td>
<td>35.6</td>
<td>37.6</td>
<td>22.1</td>
</tr>
<tr>
<td>Wheat</td>
<td>0.7</td>
<td>0.8</td>
<td>0.4</td>
</tr>
<tr>
<td>Wheat, Dryland</td>
<td>0.3</td>
<td>0.4</td>
<td>0.2</td>
</tr>
<tr>
<td>Wheat, Irrigated</td>
<td>0.8</td>
<td>0.9</td>
<td>0.5</td>
</tr>
</tbody>
</table>

"Clean" air assumes a 12 hour (08:00-20:00) growing season ozone average concentration of 2.5 ppbm.
Table 3. Relative Change in Yield Losses from Ozone in the Central Valley with Rollback in Ozone Levels to 9 pphm versus Estimated Losses Based on 2010 Ozone Levels Forecast from 1986 Data, Selected Crops

<table>
<thead>
<tr>
<th>Crop</th>
<th>9 pphm rollback</th>
<th>2010 rollup</th>
<th>percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa Hay</td>
<td>-38</td>
<td>+9</td>
<td></td>
</tr>
<tr>
<td>Beans, Dry</td>
<td>-56</td>
<td>+10</td>
<td></td>
</tr>
<tr>
<td>Corn, Field</td>
<td>-59</td>
<td>+24</td>
<td></td>
</tr>
<tr>
<td>Cotton</td>
<td>-45</td>
<td>+12</td>
<td></td>
</tr>
<tr>
<td>Grapes, Wine</td>
<td>-37</td>
<td>+8</td>
<td></td>
</tr>
<tr>
<td>Oranges</td>
<td>-48</td>
<td>+28</td>
<td></td>
</tr>
<tr>
<td>Potatoes</td>
<td>-33</td>
<td>+17</td>
<td></td>
</tr>
<tr>
<td>Corn, Silage</td>
<td>-57</td>
<td>+19</td>
<td></td>
</tr>
<tr>
<td>Spinach</td>
<td>-100</td>
<td>+20</td>
<td></td>
</tr>
<tr>
<td>Tomatoes, Fresh</td>
<td>-100</td>
<td>+121</td>
<td></td>
</tr>
<tr>
<td>Tomatoes, Processing</td>
<td>-63</td>
<td>+25</td>
<td></td>
</tr>
<tr>
<td>Wheat, Dryland</td>
<td>-33</td>
<td>+25</td>
<td></td>
</tr>
</tbody>
</table>

*Assuming estimated losses were for a 12-hour growing season ozone concentration.

Table 4. Ozone Exposures for Alfalfa in Selected Areas, 1986 and 2010

<table>
<thead>
<tr>
<th>Region</th>
<th>1986 Ambient</th>
<th>2010 Estimated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cumulative dose</td>
<td>7 hr. ave.</td>
</tr>
<tr>
<td></td>
<td>pphm-hrs</td>
<td>pphm</td>
</tr>
<tr>
<td>Fresno East</td>
<td>313</td>
<td>6.3</td>
</tr>
<tr>
<td>Kern</td>
<td>204</td>
<td>6.5</td>
</tr>
<tr>
<td>Kings East</td>
<td>214</td>
<td>5.1</td>
</tr>
<tr>
<td>Tulare</td>
<td>252</td>
<td>7.2</td>
</tr>
</tbody>
</table>

*Alfalfa growing season considered to be February through October.

*Cumulative dose of hours times pphm for hourly average ozone concentration greater than 10 pphm.

*Hourly average between 9:00 am and 4:00 pm over the growing season.

*Hourly average between 8:00 am and 8:00 pm over the growing season.
and Runeckles, 1987), there are few experimental data available for determining the appropriate exposure form for California's crops.

For the best-case scenario, meeting the current ozone standard of 9 pp hm would result in substantial reductions in estimated crop yield losses from ozone. As illustrated by the rollback to 9 pp hm, losses would be reduced by one-fourth to two-thirds for most crops as compared to the estimated losses for 1986 (Tables 2 and 3). For two crops, spinach and fresh market tomatoes, losses were reduced to zero with the rollback. However, despite the impact of the rollback, many crops would still exhibit large (> 10 percent) absolute losses which could have significant economic effects. These yield losses are predicted because the crop loss models showed that ozone concentrations between the background average of 2.5 pp hm and the standard of 9 pp hm affected crop yields. If only peak values (such as > 10 pp hm) affected crops, then no yield losses would be predicted for any crop if the ozone standard was met.

Clearly, pollution control strategies to attain the current ozone standard in California would do much to reduce yield losses due to ozone for Central Valley crops, both now and in future years. In fact, the beneficial effects on yield of meeting the standard would be even greater in 2010 than estimated by this analysis because of the increased losses that would occur if ROG and NOx emissions are allowed to continue to grow. However, the policy question remains of how much crop loss from air pollution is acceptable given the costs of extra pollution controls to meet the 9 pp hm air quality standard. The following economic analysis, based on the crop loss estimates, indicates some of the economic benefits that might accrue from meeting the state ozone standard.

**Economic Assessment**

The basis for the pollution economic assessment is the California Agriculture and Resources (CAR) Model (Goodman et al., 1985) with its 17 agronomic regions aggregated from county level data (Figure 3). Only data from the Central Valley regions (1, 3, 8, 10, and 11) are discussed here.

The general structure of the CAR model is a constrained quadratic programming model, presently including more than 43 annual and perennial crop activities, with some crops having multiple activities (e.g., dryland vs. irrigated). For each crop, a linear demand function, estimated over the period 1969-1984, relates the price received by California producers to the quantity produced in

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3To assess the effect of regional standards, the agronomic regions were further aggregated into nine that coincide with the major air basins in the state (ARB, 1987).
Air Quality Impacts

Figure 3. Regions for the California Agricultural Resources Model

1 Westlands
2 North Coast
3 Delta
4 South Bay
5 Sacramento Valley
6 Mountain Valleys
7 Central Coast
8 Northern San Joaquin Valley
9 Central Coast Interior
10 Eastside San Joaquin Valley
11 Southwest San Joaquin Valley
12 South Coast
13 High Desert
14 Imperial
15 Coachella
16 Palo Verde
17 San Diego
California and marketed. The 31 linear regressions explain a substantial amount of the price variability for these crops. The constant terms in the demand functions are adjusted to allow for production in the rest of the United States and for demand shift factors, such as changes in income, population, and exports. For each production activity, there is a variable cost coefficient generated from a set of input coefficients and input prices. Currently, energy, labor, and fertilizer costs are included in the variable costs of production. For each activity, there is also an explicit cost coefficient for the fixed resources of land and water.

The quadratic objective function of the model reflects profit maximizing by producers and market preferences of consumers, represented by the demand functions. It maximizes producers' and consumers' surpluses, subject to regional or statewide constraints on the availability of the fixed land and water resources. The model is currently calibrated to predict expected conditions in 1987. The base run uses 1987 prices and quantities demanded and 1987 yields.4

As California production increases (decreases) due to lower (higher) ozone levels, crop prices can be expected to fall (rise). But the responsiveness (or flexibility) of California prices to these changes in production varies widely by crop. Prices of those specialty crops grown mostly or entirely in California are very responsive to changes in California production. However, feed and fodder crops are quite insensitive in price, because California production is only a small proportion of national output.

Unless potential adjustments by farmers and consumers to the lower yields and higher costs are accounted for, economic impacts would be overestimated. Economic theory and, more importantly, common sense tell us that farmers and consumers will change their respective production and consumption patterns to make themselves as well off as they can under new conditions. Thus, the CAR model adjusts the economic impact of ozone changes by allowing for the adjustments that producers and consumers would make as costs and prices change. Another implied constraint of the model is to allow farmers only short-run economic mitigating behavior in selecting their crop mix. Technological changes, such as a different input combination or the use of a new crop variety, are not incorporated. The effect is to produce conservative benefit estimates from air pollution control, but overestimate damages from increased air pollution.

Changes in crop yields per acre will shift the marginal value

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4While the air quality and relative yield changes are based on 1986 emissions data, the economic model base year is 1987 due to the availability of more complete cost data. Emissions did not change significantly between 1986 and 1987.

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product (MVP) for each crop due to both productivity and price effects. While an increase in ozone reduces both the average and marginal physical products of a crop (given the quadratic production function which underlies the quadratic cost function), the reduction in total product increases the price which tends to increase MVP. If the crop is rather price responsive, i.e., has a relatively high price flexibility, say 1.65 as for wine grapes, the positive price effect will eliminate the negative productivity effect and, in the absence of crop acreage expansion, the MVP will increase. In this situation, a yield depression over all the major producing regions could theoretically increase producers' returns to land and management, but increase prices to consumers. In this way, the effects of ozone increases on growers could be, at least partially, offset.

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

Also, as described in Chapter 7, income growth, demographic and lifestyle changes are shifting U.S. consumer demand toward an increased emphasis on fruits and vegetables in the diet. In response, the Central Valley's crop mix will include a greater proportion of these high-value crops. But this will tend to increase the economic cost of ozone losses over time if the crops have a similar sensitivity to ozone. In fact, high-value crops are often more sensitive.

The economic impact over time is shown by comparing the 1987 level, and future extrapolated levels, with a reduced ozone scenario (shown in Table 2—the rollback to 9 pphm).

**Results**

Results are summarized in Table 5. For simplicity, only the benefits of air pollution reduction to growers are shown. These are in terms of changes in their returns to land and management. Of course, there are additional benefits to other industries and communities dependent on the agricultural industry (as well as benefits to human health). Benefits to consumers of California farm produce were not reported for two reasons. First, the air pollution scenarios were only run for the Sacramento and San Joaquin valleys, while consumer impacts are drawn from the overall market. Second, a proportion of California's produce is exported to other states and countries, biasing a simple addition of consumer benefits.

MVP is the value (using market prices) of the increase in output from an additional unit of input.
The producer benefits from ozone levels that meet state standards vary by region and time. In 1987, the benefits are positive for the San Joaquin Valley and slightly negative for the Sacramento Valley. The negative impact on Sacramento Valley returns is at first counterintuitive; it is caused by the economic costs of increased competition from the San Joaquin Valley outweighing the value of yield increases from ozone reduction. Given the lower ozone levels in the Sacramento Valley in 1986, the clean up would have mild effects on yield. The net annual benefit of ozone reduction is estimated at $205 million for the Central Valley as a whole. The results are higher but consistent with earlier estimates of agricultural ozone losses (Howitt and Goodman, 1988).6

The base year yields for 1995 due to ozone are not projected to change; therefore, differences in benefits noted in Table 5 are due solely to changes in crop mix as markets for California fruit, nut and vegetables expand with increased population and income. The net benefit to the Central Valley increases to $213 million.

The 15-year projection to 2010 introduces a substantial increase in benefits from ozone reduction. In 2010 the net benefit of Central Valley ozone reduction increases to $277 million/year. This improvement is driven by two phenomena: the increasing ozone pollution under the no action scenario in both the Sacramento and San Joaquin valleys and the shift in cropping patterns towards a greater proportion of higher valued crops by 2010. The difference between the no action and the improved ozone levels under the rollback to 9 ppb in the Sacramento Valley changed producer returns from a negative $0.3 million to a positive $1.2 million. San

6 Howitt and Goodman (1988) give estimates of producer benefits which yield net benefits of $44 to $156 million, using different ozone reduction standards and years.
Joaquin Valley producer benefits would be increased even more, to $276 million.

Given the high costs likely to be associated with reductions in air pollution throughout the Central Valley, both the level and growth of benefits over time should be considered when assessing regulatory action. Since most air pollution reductions require changes in capital equipment, preparation to implement the 2010 reduction should be made in the near future, if this is judged to be the appropriate policy.

The dollar values given in this study should be used with caution, and be regarded as orders of magnitude rather than precise projections. Apart from the many pitfalls for economic projections 20 years ahead, the ozone impacts need to be expanded to more crops and areas to increase confidence in the resulting benefit values.

Conclusions and Recommendations

Adverse air quality due to high ambient ozone concentrations currently is reducing crop yields in many areas of California, especially in the Central Valley. Yield losses of over 15 percent are estimated for beans, cotton, grapes and melons, and of 9-11 percent for alfalfa hay, lemons, oranges, and potatoes. If no new emission controls are implemented beyond those presently mandated, economic losses are predicted to increase over the next two decades, with approximately a $277 million annual producer loss estimated for 2010 in the Central Valley alone (relative to a best-case scenario where the current California air quality standard for ozone is met). We emphasize that this estimated economic loss for 2010 for the Central Valley is a conservative measure of the total loss for the state of California, and recall that it does not include losses to consumers. Moreover, the benefits of meeting the air quality standards to human health and in reduced damage to ecosystems and materials were not part of this analysis.

Achievement of better ozone air quality in California in general and the Central Valley in particular will require significant changes in policies with regard to air quality standards, land-use and transportation planning, and emission controls for mobile and stationary sources. Crop improvement to increase ozone resistance and crop management to reduce ozone susceptibility are necessary to insure high agricultural productivity until improved air quality objectives are met. Research to maintain crop productivity will be especially critical to meet the challenges posted by altered climates and water availability, and increased direct and indirect air pollution effects associated with global climate changes.

It should also be emphasized here that even for those sites which presently show compliance with the federal air quality
standard for ozone, reduction in the yields of certain crops are being observed. Thus, air quality standards based on peak ozone values may not adequately protect agriculture, and even under the most optimistic air quality scenario, impacts on California's agriculture will remain significant. In view of this, and the likelihood that the most favorable scenario is not necessarily the most probable, we identify below a number of policy issues and research needs related to the major topics in this paper.

**Improving Air Quality**

Analysis of air quality trends in the Central Valley for the past decade show little or no improvement despite significant reduction in ROG emissions, suggesting that future control programs emphasize reducing emissions of oxides of nitrogen. Present high rates of growth in the Central Valley and elsewhere in California are expected to continue over the next two decades, leading to many additional mobile and stationary emission sources. Although the ARB and Central Valley Air Quality Management Districts (AQMDs) have proposed additional control measures (ARB, 1988), it is not clear that all of these will be enacted, nor that, even if implemented, they will be adequate to offset the impacts of growth.

A regulatory problem of special concern in the Central Valley is that multiple AQMDs are responsible for the regulation of stationary source emissions. Yet the formation and transport of ozone and other secondary pollutants cross local jurisdictions. It seems axiomatic, therefore, that air pollution effects on crops in the Central Valley must be addressed on a regional basis, considering the locations of both sources and receptors of pollutants. This requires forming a regional AQMD similar to that created for the South Coast Air Basin in 1976.

A primary concern will continue to be determination of the relative contributions of distant and local sources to the ozone problem in the Central Valley. If, as is almost certainly the case, local pollutant emissions are a dominant and growing component of the air quality problems in the Valley, the tradeoffs between pollutant impacts resulting from urbanization and economic development versus continued high crop yields in the Valley must be faced. Legislators, regulatory agencies, residents of the Central Valley and members of the agricultural community must begin to consider the possibility that maintaining agricultural productivity may ultimately require measures nearly as stringent with as great a societal impact as those presently proposed for the South Coast Air Basin (AQMP, 1988).

Research of the kind proposed for the large multi-agency San Joaquin Valley Air Quality Study is needed to provide baseline
data to address many of the air quality policy issues discussed here. In addition, air quality and emissions trends and the effects of continued growth and urbanization in the Central Valley will need continual evaluation during the next two decades.

Protecting Vegetation

The exposure period and pollutant concentrations for which present ozone air quality standards are set are based primarily on human health considerations. Recent efforts to review and revise the primary one-hour California ozone standard considered the effects of different levels of ozone on crop productivity, primarily to indicate potential side benefits of tightening the one-hour standard to 9 ppb to protect human health. Thus, a relevant policy consideration is whether to establish a secondary ozone standard to protect against adverse effects of ozone on crops and other vegetation.

Such a secondary ozone standard could be based on exposure characteristics other than the maximum one-hour average used to protect human health. However, there is uncertainty about the relative importance of long-term averages versus short-term peak concentrations in setting a standard to adequately reflect the impact of ozone exposure on vegetation.

Secondary standards can be designed to provide more stringent ozone control in specific air basins. While this may be an effective way to protect the most susceptible agricultural crops, such as cotton, grapes, alfalfa, and citrus in the San Joaquin Valley, setting regional standards raises other issues related to the economic development and competitiveness of a region.

Crop Improvement

Despite current air pollution control efforts and new initiatives to achieve cleaner air, ozone will continue to decrease crop productivity for many years into the future. Past research efforts have focused on documenting and quantifying ozone effects on crops; little attention has been given to improving the crops' susceptibility to ozone. In particular, the ozone susceptibility of certain high-value crops could be altered through genetic improvement and management changes. The policy question here is to determine the extent to which university research should focus on adapting crops to ozone and other pollutants rather than on mitigating the occurrence of serious air pollution problems in California.

Any genetic engineering crop improvement program could explicitly integrate work on ozone susceptibility with other efforts to alter crops for increased pest resistance or enhanced productivity. The priority of the air pollution susceptibility aspect compared to other improvement efforts needs to be determined. At present, air
pollutant susceptibility considerations play little or no role in crop management considerations. Other more visible problems such as irrigation, pest control, and fertilization are of primary concern and are successfully being addressed in part through integrated pest management programs for major crops. But ozone susceptibility is related to these other considerations. For example, limited research has shown that crop-water relations are critical to ozone susceptibility. Thus, careful irrigation management could influence yield losses during ambient ozone episodes.

New initiatives in sustainable or low-input agriculture will further a holistic approach towards crop management. Specifically, future management programs should integrate ozone susceptibility with other aspects.

Global Warming and Stratospheric Ozone Depletion

At the present time, both direct and indirect impacts of global warming and stratospheric ozone depletion are believed to be in the direction of worsening regional air pollution problems in California. For example, higher mean temperatures and more frequent very hot days will increase the rates of evaporative emission of ROG from mobile and stationary sources, the rates of ROG emissions by vegetation, and the rates of volatilization of pesticides from soil, water and leaf surfaces. Increased energy demand for cooling will increase NOx emissions. As a result of these greater precursor emissions, photochemical air pollution and acidic deposition will increase.

Research is needed to predict quantitatively such effects and their possible impacts on agriculture. Similarly, further research is needed concerning the effect of temperature and sunlight intensity and spectral distribution on rates of formation of photochemical smog. In addition, specific issues such as the consequences of longer smog seasons resulting from drier autumn periods should be studied.

Since California is a major contributor to global warming (producing approximately 5 percent of the worldwide total emissions of carbon annually), the importance of enacting effective measures to mitigate greenhouse gas emissions within the state seems clear.

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Changes in Marketing, Trade, and the Delivery System:

Chapter 6. Transportation And Delivery: Congestion, Quality, And Cost

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Chapter 7. Perspective on Marketing and Trade of California Agricultural Products

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TRANSPORTATION ROADBLOCKS
The Sacramento Bee, Feb. 10, 1989
STUDY FORECASTS I-80 TRAFFIC NIGHTMARE
Sacramento Union, Jan. 31, 1989
BAD TRIP: AS HIGHWAYS DECAY, THEIR STATE BECOMES DRAG ON THE ECONOMY
The Wall Street Journal, August 30, 1989
ROADS JAMMED AS DRIVERS GO SOLO
The Sacramento Bee, June 3, 1989

With increased frequency, headlines such as these portray California’s worsening highway conditions—jammed freeways, slowing traffic flows, and deteriorating roads. Predictions of the future transportation environment are equally gloomy. All this is crucial for the state’s agricultural industry. Traffic conditions are important in maintaining a steady flow of produce to fresh markets and processing firms as well as delivery of final processed items to warehouses and retail outlets.

This chapter reviews the challenges confronting California agriculture in the next two decades as the demand for travel and transportation reaches the limits of a highway and road system that has not been expanded to meet that increased demand. We include a brief discussion of how important transportation is to agriculture, where that industry stands currently in terms of transportation
functions, what the future may bring and what the options are that the industry may wish to consider.

Transportation's Role in Agriculture

In recent years, highway trucks have supplanted rail transportation as the major means of moving California's farm produce to market. Today some 85 percent of the state's fresh produce is transported by truck (Garrett et al., 1987; Auburn et al., 1986). The remainder is shipped by rail, air, and water. Rail transport primarily provides a long distance link to the East, with little local pickup or delivery. Furthermore, over half of the rail shipment is trailer-on-flatcar (TOFC or piggyback). In these cases, trucks are used to transport the product from the point of shipment to the rail yard and the trailers are then transferred to a flat bed railcar. On the receiving end, the trailers are unloaded from the flatcars at a central location and trucks haul the trailers to their final destination. Similarly, truck-carried refrigerated containers have been developed which are transferred intact directly to and from ocean-going vessels. Highway travel, then, is paramount in the movement of agricultural products for California.

Between 1981 and 1986, the miles travelled in California on state-built-and-maintained highways alone jumped 30.6 percent (Fay, 1990), but the miles of such highways remained virtually unchanged at about 15,200. Similar use patterns have been observed for the federal system and for other roads (Deakin, 1987, p. 4). Furthermore, California's total annual traffic is estimated to grow another 30 percent in the next five years. Meanwhile, 98 percent of California's surface-transported commodity production is handled by truck. Clearly, the impact of traffic congestion and highway conditions is crucial (Deakin, 1987, p. 12).

The Assembly Function

The initial movement of agricultural commodities is from the field to either a processing plant or a fresh produce market, with the latter usually moving through an intermediate packing shed operation. Trucks are used almost exclusively for shipping at these stages. Much of the travel to processing firms is on rural roads. Based on discussions with industry personnel, this stage of transportation has not been hindered by congestion and probably would suffer only if peak use traffic snarls on state and federal highways caused an overflow to these lesser used roads. However, development in some of these rural areas may add to stress on the rural roads as expanding nonagricultural transportation needs come into conflict with those of farmers and processors. Truck shipments from producers to fresh markets or food store warehouses often involve
considerable highway travel because of the urban location of these businesses (Garrett et al., 1987).

The Distribution Function

Distribution of food items from processing firms to grocery warehouses focuses on highways and city roads, as does the final delivery from the warehouse to the retail outlet. These latter components of the transportation process in agriculture have already felt the impact of congestion in large metropolitan areas, such as Los Angeles, the San Francisco-Bay Area. As traffic conditions worsen, the processing and retail distribution operations will be forced to adjust.

In addition to shipment of produce and food products, many of the inputs used in agriculture also must be moved from central manufacturing to distribution points and then to the farm sites. For such inputs as fertilizers, pesticides, and equipment, rail may provide a sizeable share of the transportation service from manufacturer to local or regional distribution points. However, trucks again are the primary method in moving them to farm sites. Auburn et al. (1986) report that some 2,000,000 tons of fertilizers and 87,000 tons of pesticides are trucked over California roads and highways each year.

Of course, the demand for transportation of both inputs and outputs by California agriculture is not steady, but rather exhibits seasonal variations. A progression of harvests from one commodity to the next may maintain the peak demand to some extent; but the periodic fluctuation in truck and rail requirements poses a challenge to both the food and transportation industries to assure adequate hauling capacity when needed without large excess capacity during other times of the year.

The efficiency of getting food products from farmers to consumers depends on many factors. In 1987, rail and truck shipping costs (excluding local hauls) were estimated to make up $17.2 billion, 6.1 percent, of the $283.2 billion U.S. marketing bill for agriculture, and 4.6 percent of the total U.S. expenditures for food products (U.S. Bureau of the Census, 1989, p. 639). This share will likely increase over the next two decades as congestion increases, roads continue to deteriorate, and fuel costs rise. In addition, the nature of the transportation linkage between producer and consumer places the entire process in jeopardy in the case of an any energy or fuel crisis.

The Current Situation

Most of California's major agricultural production areas are inland from the heavily congested coastal areas, so products intended for U.S. eastern markets can move by truck without trav-
elling through major metropolises. Many of the large food processing plants which at one time were located nearer Los Angeles and the Bay Area have moved to the Central Valley in recent years. Similarly, many dairy facilities have relocated away from highly populated Southern California areas to San Joaquin Valley sites. Grocery chain store warehouses also have decentralized somewhat, remaining near centers of population but moving out of central cities to less-congested suburbs.

The principal agricultural delivery corridors for processed food items are highways I-5, U.S. 99 and U.S. 101 running north and south; I-10, I-15 and I-40 going east and west in the southern part of the state; and I-80 and U.S. 50 going east and west in the northern half (see Figure 1). The "radial" pattern of major highway arteries, such as that shown by I-5, I-80, U.S. 50 and U.S. 99 converging in Sacramento, are dictated not only by location of population centers but by topography—the Sierra Nevada, the Coast Range, the Delta. These patterns mean that truckers frequently must travel to the center of the hub in order to change directions to another major highway. Although this lack of alternative routes may not have a major impact on truckers now, as major highways become more and more congested, this out-of-the-way routing will become more costly.

As indicated above, agriculture relies heavily on truck transportation, and the capacities and physical conditions of California roads have not kept pace with the expanding demand. Deakin (1987, p. 1) notes that "For many years, expansion and improvements in the quality of transportation systems were a hallmark of the California (and indeed, the American) scene. But over the past 15 years the topography has changed." She adds that one reason for increased congestion is (p. 4) "... the slowdown of highway building: Traffic growth has outstripped increases in capacity by a factor of nearly five to one over the past 20 years."

The Assembly Office of Research (AOR, 1988, pp. 8-9) states that "... we have seen new freeway construction drop off from a mid-1960s level of 100 freeway miles annually to current construction levels of approximately 10 ..."

Information about impacts of transportation trends on the state's agricultural industry is limited. Planners and policy makers would surely benefit from improved data on current transportation patterns—such as time of day for deliveries of agricultural goods, changes in processing locations, the direction and distance of shipments, and the impact of congestion.
Figure 1. Schematic Diagram of Major California Routes

Maintenance

Maintenance of existing facilities also has lagged behind needed levels. Although state and federal highways are considered to be in relatively good condition (with only about 13 percent deemed in need of repair), local and county roads are rated only fair or poor in most cases (see AOR, 1988, p. 23). Whereas needed repair and replacement expenditures for roads and bridges have been estimated as high as $914 million annually, current outlays are figured, at best, at only about 75 percent of that amount (Deakin, 1987). Furthermore, the AOR (1988, p. 25) estimates that the cumula-
tive shortfall facing state-supported highway expenditures could range from $1.94 billion to $4.8 billion for the decade of the 1990s.

Road deterioration means higher costs for fuel and repair for the state’s motorists, and will likely result in higher food costs and lower quality fresh produce for consumers because of damage in transit. Garrett et al. (1987, p. 6) listed the various physical stresses to which agricultural products are subjected by the transportation process as compression, impact, shear (one object rubbing past another), temperature and time in transit. These factors reduce the quality of the produce between harvest and arrival at the processor or fresh market outlet. Poor quality roads add to the non-temperature stress factors causing bruises and abrasions on fruits and vegetables. As congested highways and roads become more commonplace, temperature stress and quality deterioration related to time in transit can be expected to increase because longer travel times will be needed to cover the same distances to processing plant or fresh market outlets.

**Seasonality of Demand**

While processed products, dairy and livestock products are produced and/or distributed year round, agriculture’s greatest demand for transportation services comes in the summer and early fall when most commodities are harvested. This seasonality of production and the ensuing demand for transport services frequently strain available equipment and facilities to the limits of capacity. In addition, the availability of refrigerated trucks has decreased in the past three to five years. Before 1982 there was excess shipping capacity heading from the West to the East Coast, and therefore adequate capacity for California produce going in that direction. Eastbound truck space is now scarcer for various reasons, including more imports from the Pacific Rim, driver shortages, and poor profitability in the trucking business. This reduced shipping capacity has caused increased prices for shipping California products out of state, especially during the peak harvest periods when transportation demand is at a maximum.

**Technology**

Some technological solutions to the handling and hauling problems and future problems are now available; however, the trucking industry has been slow to adopt them. Garrett et al. (1987, p. 6) report “Air suspension systems on highway trailers have been shown to reduce vibration stress significantly, but they are rarely used because of their cost and added weight.” The tractors often are equipped with air suspension, but not the trailers.
Similarly, they comment that (p. 10) “Technology is available, but there seems to be a fairly widespread lack of understanding of the limited air circulation capabilities of the refrigeration equipment and of the importance of maintaining optimum product temperatures in transit.” While truckers strive to reduce costs of operations by using wind deflectors, low profile tires, etc., there seems to be little market incentive, in terms of higher rates received, for truckers to invest in items to provide correct air circulation and precooling functions (p. 18).

In the early 1980s, federal regulation of rail and truck rates was eliminated. Although agricultural haulers had already been exempt from most rate regulations, the net effect on agriculture of deregulating all of the trucking industry has yet to be determined. Lower profits because of unrestricted entry and the open rate of competition have resulted by many motor carriers leaving the business (Auburn et al., 1986). Deregulation also may have been an important, indirect factor in truckers’ delay in adopting improved technology because of the impact of reduced rates on profits.

Institutional Constraints

Besides factors related to the physical hauling and handling of the commodities, institutional constraints can also affect the transportation of agricultural products. Government agencies at various levels place outmoded restrictions on transportation of agricultural goods that may increase costs and even add to congestion. Garrett et al. (1987, p. 10) say that “Over-packing, a common cause of mechanical damage, is partly due to government requirements to pack by count into standard sized cartons even though the produce may be larger than what the carton was originally designed for.” Also, trucking companies are particularly concerned about proposed regulations in the Los Angeles Air Quality Management District that would limit truck traffic to night hours. These restraints may cause scheduling problems, leading to inefficient use of trucks as drivers and equipment are forced to wait in ports or outside metropolitan areas until allowed to use the urban road system. With labor costs accounting for about 40 percent of the total truck transportation bill (Garrett et al., 1987, p. 22), such delays mean increased costs to accomplish the same task.

Future Prospects

Continued population expansion in the state can be expected to increase both congestion on roads and highways and demand for food products. There are forecasts calling for traffic delays to increase 8 to 11 percent annually through the year 2000 with average speeds dwindling to as low as 7 miles per hour on some freeways.
Deakin (1987) observes that private automobile transportation accounts for 85-90 percent of all local person-trips. The AOR (1988, p. 8) concludes that the major problem surrounding California transportation is “the propensity of Californians to commute to work alone in their automobiles at the same time.” Perkins (1989, p. B-1), outlining a report by the Sacramento Area Council of Governments, states that the number of persons driving alone to work is increasing: “Ten years ago, 68 percent of the commuters drove alone and 2 percent of the total trips were on transit. Today, 78 percent of the commuters drive alone and 1.5 percent of all trips are on transit.”

In some instances, increased mass transit has been held to be the solution of commuting; however, Deakin (1987), citing the 1980 Census of Population, reports that transit conveyed only 16.4 percent of the workers in San Francisco-Oakland, 7 percent in Los Angeles-Long Beach, 3.5 percent in Sacramento and 3.3 percent in San Diego. According to The Wall Street Journal (1989), this pattern is pervasive nationally. Mass transit systems work in older, high population density areas, but face economic and political problems in most other environments.

Population growth and economic development also have supplementary impacts on transportation (and hence on agriculture). Both housing and commercial developments cluster around freeways, initially to provide or obtain improved access to nearby facilities and services. With the proliferation of highway on-off ramps, the result is increased use of freeways and major roads for local trips.

Thus, given the current policies and economic environment, the outlook is for greater congestion.

**Added Investments Needed**

California’s agriculture has much at risk in the predictions of heavy congestion and continued physical deterioration of highways and roads. Although many industry officials don’t anticipate major problems in the assembly operations from producers to processors, continued deterioration of rural roads will certainly add to the mechanical stress put on fresh commodities. As highway and freeway congestion builds and overflows to the rural roads, the delay in assembly operations will also grow, bringing additional problems with quality control on fresh produce.

Processors and retailers can expect to encounter problems with delivery and distribution, particularly in the metropolitan areas. Delays in getting food products from the warehouse to retail outlets are likely to increase as city streets are tied up.

Large delays in reaching destinations, whether for fresh
produce or processed goods, mean that the number of possible trips per truck in a given amount of time will decrease. In other words, if the industry is going to meet the same delivery (assembly) capacity it now has, more vehicles will be required as the time per trip goes up. This expansion of trucking capacity will also add to congestion and increase investment and operating costs without increasing productivity.

Most processors and retailers expect increased costs to be passed on to the consumers. Although total demand for food is relatively inelastic, higher prices for certain foods might well result in substitution of other items. Thus, higher costs which would be added to the consumers' bill might also result in lower revenues for some food products.

Location Effects

The effect of poor transportation conditions on the location of agricultural production and processing is uncertain. In the short run, firms will not be eager to relocate their activities because of investment in capital facilities. Thus, those enterprises will likely remain functioning for some time even with inefficiencies in their location patterns. Over a longer time period, if transportation costs for assembly and distribution become an even more important component of the industry's cost, firms may alter their location patterns as old plants become obsolete, or increased product demand calls for new plant capacity.

It may be that agricultural production beyond the year 2010 will be relocated to poorer quality land as economic development (housing, commercial and highway) takes up the better quality land surrounding our cities—land now used for farming. The potential effect on congestion of such relocation is not clear, but it would likely result in longer hauls from producer to processor or processor to retailer. In addition to such pressures from development, there is also a question of what effect increased air pollution (partially from increased travel) will have on agriculture. It too may become a force pressuring the relocation of agricultural production and processing. (See the chapter on air quality, Chapter 5.)

Options

Confronting the problems of transportation is not solely the responsibility of the government and/or only industry. Both the public and private sectors must evaluate the potential payoff from changes in policies and operations. Some alternatives will undoubtedly require joint ventures between government and commerce.

Unlike the development of rail transportation facilities, which for the most part has been left to private enterprise, the
building, maintenance, and operation of roads have generally been the task of government agencies. As Deakin (1987) points out, most response to traffic problems in the past has been one of additional supply—new highways, more lanes. The potential for this option in the future is partially limited by the clustering of houses and buildings around the major transportation corridors. Other suggestions of a supply-response nature have been to add new levels over existing highways, creating double-decked arteries. Given continued expansion in demand for transportation, these alternatives are at best are short term remedies, and might well be out-of-date by the time they are completed.

Mass transit plans frequently emerge, but these mechanisms generally have taken only a small percentage of the drivers off the highways.

**Operational Options**

Perhaps the options that bear most investigation are operational in nature. (However, these operational options would require current highways and roads to be better maintained than they now are.) A variety of proposals has been advanced by transportation analysts. Many of these are directed at reducing the demand for highway or street travel, particularly of single occupant automobile commuters, by offering rewards or penalties as incentives for more efficient travel (see Deakin, 1987, pp. 19-35 and AOR, 1988, pp. 10-12). But, as Perkins (1989, p. B-1) explains, “The pain level has to be excruciating before people can be wrenched from their cars . . . .”

Specialized high occupancy vehicle (HOV) lanes have been used on some highways. Constraints of time of usage (e.g., night time deliveries) for trucks is another possibility.

Charging highway and road users for access and/or time spent on that facility has been advocated as a mechanism to alter traffic patterns, although this concept raises the question of equity and fair access to facilities paid for by the public. *The Economist* (1989, p. 11) is adamant that any measure to reduce traffic directly will not succeed “so long as road use is free at the margin . . .” and that “The best way to ration roads whose capacity cannot be increased is to charge market prices for the right to use them.” For example, in Singapore, drivers must purchase daily permits to enter the central area during rush hour. *The Wall Street Journal* (1989) reports that in Dallas, cars on a new tollway will be charged for travel, with rates varying by time of day. Electronic tags will identify the car, and the owner will be billed later. The Journal also notes the development of private toll roads in Virginia and southern California.
Intermodal Coordination

One area in which state and private enterprise could integrate their efforts is in intermodal transportation coordination. For example, the use of river and coastal ocean transportation to move commodities in California could relieve the pressures on highway and rail facilities. However, the method of developing (e.g., financing) such operations and relating them to associated truck and rail services would be major issues. Even though regular ocean ports have long been in existence, problems of coordination with other modes remain. Deakin (1987) finds that access by rail and truck to the state’s ports may be constrained by both congestion and local regulations. She hypothesizes that (p. 19) “The construction of multi-modal freight facilities some distance from ports might permit congestion and other traffic problems to be avoided and simultaneously offer greater possibilities for joint development of adjacent land.”

While piggyback (TOFC) techniques combining rail and truck facilities have been available for some time, a related system has been developed—special rail cars built to accommodate a double layer of containers. This “stack train” concept allows inexpensive transport of refrigerated containers and can be coordinated with ocean-going shipments. Domestically, trucks are still used to move the containers from point of production to the rail head and from rail head to point of final delivery. The ocean-going containers are loaded or unloaded at the port facility onto rail cars or trucks (see Sanchez, 1989).

However, the planning for expanded use of such transportation conveyances needs to be coordinated among the several users. Where local traffic regulations preclude movement of trucks during certain time periods, the resulting flow of commodities to and from the ports may be less efficient. The state government could play an important role in coordinating the planning for such intermodal operations.

Agriculture’s Options

These various alternatives outlined above would have differing effects on agriculture. Regulating time of use of highways and roads would require careful planning and scheduling of agricultural transportation to avoid idle trucks and drivers. Charges for roadway use, through either permit or use monitoring, would mean higher costs in one sense, but could also help reduce costs from increased travel time and product deterioration. HOV lanes might ease the traffic flow on those lanes normally used by truckers, but given the propensity of California motorists to hold firm to single person occupancy, the reward from HOV lanes may not be great.
Agriculture may have to expand its night-time operations. Already, many producers utilize night harvesting in order to obtain better quality fruit and vegetables (Garrett et al., 1987, p. 9). Because processors typically work 24 hours a day during peak harvest seasons, they are prepared to handle night deliveries of raw products.

One option for processors and retail distributors is to engage in more night operations themselves. Much loading of trucks for delivery to warehouses and retail outlets now is done at night, but the receiving operations more often are available only during the day. One grocery chain which has experimented with night deliveries to its retail outlets reports the changes have been more economically successful than had been predicted. While there are additional costs for night shift workers, driving times as well as some unloading times are much shorter. The company currently receives dry goods for about 18 hours per day, but forecasts it will be receiving for 24 hours.

Of course, some practices which seem efficient for commercial interests may impinge on the quality of life for other segments of society. Some locales have adopted noise abatement ordinances that prohibit truck deliveries during certain times of the night or early morning. Such laws require the distributing company to schedule so that those locations are last on the route.

Other operational changes could include better use of available technology for handling and shipping. Road deterioration may require transportation firms to adopt air suspension and utilize better air circulation techniques in order to preserve the quality of produce being hauled. Longer shipping times will also place added emphasis on proper cooling, packaging and loading methods for agricultural commodities.

Higher Costs

If congestion is not eased, companies will be forced to expand their investment in transportation equipment just to remain at their current levels of shipments. Longer travel time for a given trip means increased fuel and labor costs. By the same token, more trips will be needed to deliver or receive the same amount of merchandise that is now handled in a particular period of time. Added investments and operating costs (labor, fuel) without increased productivity result in higher costs for the same output. Another option in this context would be to allow larger hauling units on the highways, e.g., triple trailers. Such changes by one segment of agriculture would require adjustments by other related sectors in order to make the total product flow effective—that is, supply sources and receiving facilities would need to have the capacity to
service the larger transportation units. In addition, larger vehicles would be associated with increased highway maintenance and construction costs.

Long-run alternatives include altering shipment patterns from producer to processor to warehouse. As indicated above, there is considerable "fixity" in the processing location and contractual arrangements between producers and processors. The net result is an apparent economic contradiction when, for example, consumers see truckloads of tomatoes going out of a region while other shipments of tomatoes come in. If transportation problems become as acute as some forecasters believe, the long-term implications would be to better coordinate the processing capacities among various locations in order to take advantage of transportation economies.

Political or Economic Initiative?

One might expect that as transportation conditions worsen and travel costs go up, the economic system would provide incentive for changes to more efficient commuting and shipping methods, e.g., mass transit, relocation, new highways. However, given the tenacity with which commuters hold to their automobiles, it may be that legislation, unpopular though it will be, may be required to help the transportation system work itself out of a massive traffic jam.

References

Perspective on Marketing and Trade of California Agricultural Products

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Overview

California produces over 250 agricultural commodities, and it is said that if markets could be developed (or discovered), California could grow literally hundreds of new crops. California’s agriculture serves three markets—the state’s own population, the rest of the United States, and the rest of the world. All three markets have grown, with the proportions to each varying over time. The export market is essential to some California commodities (almonds, cotton) but not to others (fluid milk). The export share varies depending on such factors as exchange rates, economic conditions in importing countries, trade barriers, California’s changing comparative advantage, and the extent of promotion and/or subsidy for California products.¹ California sales and purchases of all agricultural products have been increasingly integrated into the national and international markets. In today’s agribusiness climate, borders have less meaning.

Despite its great distance from major U.S. markets, California agriculture has developed as a unique source of many of the nation’s specialty products, from artichokes to zinfandel. The state has been blessed by its climate, investment in infrastructure to

¹California’s agricultural exports represented 14 percent of the value of production in 1965; they were up to almost 25 percent in 1987.
supply irrigation water, and access to capital and a large migrant labor force. Another important benefit is the contribution of the University of California in developing and extending new technologies, including chemical and mechanical innovations, integrated pest management, other new cultural and harvesting techniques, and special plant varieties. These and other advantages have made California the least-cost producer-shipper of a multitude of fruit, nut, and vegetable fresh and processed products. However, this unique marketing position is now threatened by changing conditions in the state, nation, and world.

Meanwhile, the well being of the state's livestock and field crop industries also depends on national and international conditions—and, for several commodities, on federal farm programs. In 1987, 37 percent of California’s crop acreage was planted in crops that directly benefit from federal farm programs. Of these program crops, cotton and rice are the most important in California. California's dairy industry also benefits substantially from a federal price support program. The state's producers of nonprogram commodities are indirectly affected by farm programs in several ways (see Lear and King, 1986). For example, the acreage reduction plan to control supply of a program crop frequently disallows production of any other commercial crop and thus indirectly protects the price of what would otherwise have been grown on that land (e.g., dry beans on cotton set aside). Another example is alfalfa hay which does not enjoy direct benefits of federal farm programs, but gains indirectly from the dairy program by being the major feed input.

In this paper we begin by briefly describing the marketing environment of the past. Then we look around at the rapidly changing U.S. market and attempt to project observed trends toward 2010. We also analyze the present and likely future situation in important world markets for California agriculture. We discuss marketing strategies appropriate for these dynamic markets at home and abroad.

**Looking Back**

Since before the development of hybrid corn and through the decades of the agricultural chemical revolution, agricultural research funded by the University of California Agricultural Experiment Station and elsewhere was largely oriented toward increasing yields and physical output. Improvements in productivity permitted agriculture to expand to meet mass market requirements, both domestically and globally. Firm-level strategies were also production oriented—that is, produce and hope to sell—with relatively little attention directed to marketing.
Looking Back at the Domestic Market

This production orientation was related to underlying demographic trends driving the U.S. market. The post-World War II era was characterized by an increasing rate of population growth, growing affluence, and a relatively homogeneous population. Under the joint conditions of population growth and its relative homogeneity, mass-marketing strategies for food were the norm. Much less variety in food products was available than today, in terms of number, form, and quality of products.

However, in the 1980s, the U.S. population growth rate dropped to its lowest level since the Depression. It is projected to decline further, from 0.9 percent annually today to 0.5 percent by 2015. A slower rate means sales increases are more difficult for food firms to achieve. Companies/ producers are no longer able to expand sales simply by letting the natural growth of the market absorb more of their products. The U.S. market has become “mature.”

Furthermore, in the 1980s the trends established in earlier years began to have significant impacts on consumer demand—trends including the entrance of women into the work force in large numbers; an increase in ethnic expression; regional population shifts; changing income distribution; growing concerns over health and fitness; the coming of age of the baby boomers; and the overall aging of the population.

These demographic and lifestyle changes have caused the American mass market to disintegrate into a highly segmented one with a marked increase in the diversity of products demanded. Competition has intensified and firms have been compelled to adopt more of a marketing orientation.

Looking Back at the World Market

A corollary to the produce-and-hope-to-sell approach toward the domestic market is the past stance toward exports taken by a number of California producers. For some, exports were considered only a residual market; exports were at times sold at prices below domestic levels as a means to unload surplus, in order to maintain the domestic price. Frequently export shipments were in bulk rather than in value-added, differentiated products and insufficient attention was paid to the significant differences among the various foreign markets. (Major exceptions include the state’s almond and citrus industries.)

The nation’s sale of vast tonnage of wheat and feed grains to the USSR in 1973 was symbolic of an awakening interest in the potential of export markets. As crop prices (and farmland values) soared in response to the outward shift in demand for grains and
other commodities, producers began to change their approach. It was no longer good business sense to regard the world market as residual disposal for our excess production.

Then in the early 1980s, the combination of a strong dollar, a worldwide recession, and increased supplies from competitors severely cut U.S. and California agricultural exports. In an attempt to regain market share, the federal government, among other actions, initiated an Export Enhancement Program (export subsidy) and a Targeted Export Assistance Program (promotion and subsidies). The 1985 farm bill included a section allowing states to submit proposals to set up trade centers for research and promotion. Several states have received grants for centers.

Parallel actions were initiated at the state level. In 1983, the California World Trade Commission with an important agricultural component was established by the state. The commission was charged to provide market information, including detailing existing barriers to agricultural trade in the Pacific Rim and the European Community (EC). It also began to remedy the apparent lack of a California presence at various trade fairs (California Assembly, 1983). In 1986, the commission established trade offices in Tokyo and London. Also in 1986, the state legislature enacted the Agriculture Export Incentive Market Development Program under the California Department of Food and Agriculture (CDFA). This is a five-year matching fund program for agricultural companies, cooperatives, marketing boards, and commissions or associations who want to begin or expand export operations. It supports various export marketing activities such as promotion, advertising, demonstrations, participation in trade shows and exhibits, and market research.

Looking Around and Toward 2010

While continuing to give increased attention to the value of export markets, California agriculturalists must at the same time keep in mind the importance of the market right here in the state. California’s population continues to grow, with an expected 9 million more inhabitants by 2010. California’s demographic patterns are changing faster than those in the rest of the nation, as the state rapidly becomes more ethnically diverse. This diversity creates marketing niches for specialized products; demand for these products frequently grows as others learn about them.

Yet international competition for many of California’s products is increasing as production regions with similar climates, e.g., Mexico, Brazil, Turkey, are expanding their markets. For many reasons, California technology is more readily being transferred abroad to these competing regions. The computer and communica-
tion revolution has speeded up the transfer of technology, facilitated by global deregulation of financial flows. Foreign students are applying California-developed technology at home. Private firms are accounting for an increasing share of research and are disseminating results wherever profitable markets exist. Finally, large, multinational food firms are transferring U.S.-acquired technologies from their domestic operations to their foreign subsidiaries. A case in point is the development of the frozen vegetable industry in Mexico and Guatemala.

Chilean fruit provides another example of the ongoing internationalization of agriculture. Fruit imports from the Southern Hemisphere began in an effort to complement U.S. supplies and provide consumers with more fresh produce year round. Yet the phenomenal growth in Chilean grape and other fruit imports now means direct competition with California production during the overlapping seasons. Aggregate U.S. fruit imports from Chile increased from 81 million pounds in 1977-78 to 720 million pounds in 1986-87 (U.S. Department of Agriculture). It is also probable (and is currently being empirically tested at UC Davis) that California produce prices are lower relative to the period before Southern Hemisphere imports were available. Consumers who now enjoy a fruit year round may, in the future, no longer be willing to pay a premium as the California crop first appears on the market (i.e., demand is more elastic than before).

Year-round demand in the United States for fresh fruits and vegetables has caused many California grower/shippers and multinationals to establish joint ventures with producers in Mexico and other Latin American countries. This effort to extend shipping seasons is contributing to an even greater international integration and interdependence in the production and marketing systems for California specialty crops. In the dynamic, international agricultural marketing environment in which California now finds itself, will the state lead or falter? The rules of the game are radically changing.

The Domestic Market

In order to look ahead with accuracy at the dynamically evolving U.S. market, we need to detail the demographic and lifestyle trends, mentioned earlier, that are significantly affecting the market for California agricultural products.

Age Structure

While the maturity of the U.S. market forebodes greater competition within the food system, the changing age structure of the population brings good news to the food industry. By the year 2000, fully 54 percent of food store spending is expected to be
accounted for by households headed by 35- to 54-year olds. People in this age group are moving into the peak of their income earning years and spend proportionally more on food than younger people. These higher expenditures reflect in part an increase in the quality level purchased. Mature consumers frequently have sufficient buying power to "trade up" and purchase higher value products and greater diversity, changing the product mix within the food industry as a whole. For example, after age 45, people consistently increase their expenditures on fresh produce. Consumers over 35 are more likely to have traveled abroad and to have experienced a variety of ethnic foods, making them candidates for many of the exotic products currently being sold.

**Income Distribution**

Census Bureau data indicate that the number of households earning $50,000 and more a year (in 1987 constant dollars) increased from 15.4 percent of the total in 1970 to 22.9 percent in 1987, while those in the middle-income ranges declined proportionately over the same period and lower income households remained stable (Food Institute Report, Oct. 1, 1988). A continuing growth in high income households will present new food marketing opportunities by increasing the demand for high value, high quality products.

**Household Size**

Household size is another key demographic variable affecting food marketing. Average household size in the United States (currently 2.66 members) will continue to decline. The "nuclear family of four represents only 13 percent of U.S. households; individuals living alone, almost one-fourth. Many firms are beginning to address the food product needs of these smaller households, with significant implications for food packaging and product form. Food industry analysts predict that 50 percent of all supermarket food sales will be products packaged in one- or two-person servings by the year 2000.

**Ethnic Populations**

The growth in ethnic populations in the United States is a major factor contributing to the demand for product diversity. In California, minority ethnic groups are projected to comprise almost half of the population by the year 2000 (Bovier and Martin, 1985). Nationally there are 19 million Hispanics (8 percent of the population), but Hispanics accounted for 17 percent of all births in 1985. Foods previously considered to be ethnic or regional in nature are increasingly consumed by a broader portion of the population, presenting major marketing opportunities for several food catego-
ries. This helps explain the recent growth in shipments of oriental, Mexican, tropical, and other unusual vegetables—about 5 percent of the fresh vegetable market in 1988.

**Food Service Sector**

Another important dimension in changing markets for agricultural products is the rapidly growing food service sector. U.S. consumers spend 45 percent of their food dollar on food away from home (*Restaurants and Institutions*, 1988). By the mid-1990s, the retail and food service industries are expected to share a 50-50 split in food dollars. Already, food service uses more than 40 percent of total meat purchased, 55 percent of the lettuce, 60 percent of the butter, 65 percent of the potatoes, and 70 percent of the fish (Mayer, 1988). Marketing to food service will dominate grower and food manufacturer strategies in the next century.

**Food Safety**

The issue of food safety has been thrust into the national spotlight, focusing on pesticide residues on plant products and drug residues in animal products. Several factors have combined to make food safety a high profile issue: the advent of more sensitive residue testing technology, the news media's fear-producing style of reporting, inconsistencies in regulatory policies, exploitation of the food safety issue by parts of the food industry, and the politicization of the food safety issue as advocacy groups link it to their own agendas.

According to national surveys conducted by *The Packer* ("Focus: Fresh Trends 1990") and the Food Marketing Institute (FMI), 86 and 82 percent, respectively, of U.S. consumers say they are concerned about pesticide residues on food. However, only 26 percent are concerned enough to modify their buying behavior ("Focus: Fresh Trends 1990"). Further, 81 percent say they are completely or mostly confident in the safety of the food supply (FMI). This would indicate that while consumers may be concerned in a general sense, this concern does not outweigh an underlying confidence in the system.

Nevertheless, in an effort to restore a perceived decline in public confidence, many growers and retailers are developing their own food safety labels, residue testing, and information programs (thereby attempting to gain a strategic marketing advantage relative to competitors in the process). Labels developed in California such as Probiotic, Naturite, Primus, Pesticide Free, and No Detectable Residues are now present in the national marketplace.

The organic industry has also grown, partially as a marketing strategy designed to allay consumer concern—at a price pre-
mium. However, the organic market remains small. For example, sales of organic fruits and vegetables through conventional supermarkets represent less than 1 percent of total produce department sales. Organic farmgate sales in California are about $100-110 million, less than 2 percent of California’s production of horticultural commodities. As conventional California growers transition land into organic production, they frequently encounter demand for only a portion of what they can grow organically. As in any niche market, saturation can easily occur.

While consumer interest in food safety-oriented marketing labels (including organic) is expected to grow, consumer willingness to pay price premiums for these labels is another matter. Producers developing these labels would be advised to strive for production and marketing costs which are competitive with those of conventional producers.

As we move into the 1990s and beyond, marketers must keep in mind that “marketing” food safety can be a double-edged sword. The array of food safety labels already being marketed appears to be sending mixed and confusing signals to consumers. During the Alar controversy, retailers posting “No Alar” signs suffered a greater loss in apple sales than those who did nothing. The question arises: Are firms providing useful information to consumers (i.e., adding value to their products), or are they simply adding costs which increase the price of food without any clear benefit to consumers?

Indeed, while many consumers are apparently concerned about pesticide and drug residues, the scientific community tells us that the number one food safety hazard is microbial contamination, 60 percent of which is due to mishandling while food is being prepared in the home. Currently, estimates range from 6.5 million to 81 million cases of food-borne microbial contamination in the United States each year, with an estimated 9,100 deaths (Bennett et al., 1987). This could become a greater threat in the future due to expanded offerings of lightly processed foods and, as yet, uninspected fish and seafood products. Further, natural toxins in food are estimated to be 10,000 times more hazardous than any synthetic residue. In the future, if there are effective public education efforts, consumer understanding of these matters may increase, so that perceptions about food hazards may eventually be more in line with scientific assessments.

The best advice for health is to eat a balanced and varied diet, and California surely has the needed variety to offer. Producers, packers, processors, and shippers must stand ready to adjust practices in response to consumer concerns about the use of various chemicals. Many of these adjustments are inevitable; most can be
anticipated. And having done so, they must effectively communicate their response, both nationally and internationally, promoting the fact that they have a "safe" product to offer.

Health and Nutrition

There has been a sizable increase in general knowledge about how diet and health are linked and the importance of maintaining physical fitness throughout life. Health and nutrition attitudes have significantly affected food consumption patterns, e.g., lower consumption of eggs, milk, and red meat, and higher consumption of poultry, fish, and fresh fruits and vegetables. In general, there is a trend toward more fresh-like and "natural" products.

Many marketers have incorporated "lite" or "natural" on their labels, along with a myriad of stronger health claims, e.g., reduction of heart disease or cancer prevention. The development of new lightly processed food, such as refrigerated pasta, salads, and sauces of all types, has exploded in response to consumer interest in "fresh."

Yet consumer intentions to make healthful eating choices are not always consistent with actual practice. For example, per capita consumption of sugar and sweets grew to 122 percent of its 1967 level by 1984 (McCracken, 1988). To help consumers "have their cake and eat it too," the food industry will increasingly develop synthetic foods with simulated taste, texture, and appearance. The two new fat substitutes, olestra and simplesse, are examples.

Convenience

A critical factor affecting food consumption patterns has been the entrance of women into the work force in record numbers. In 1987, 55 percent of women worked, with this proportion expected to continue increasing. The main impact has been to decrease time available for food preparation and to increase the demand for high and predictable quality foods, offering convenience and variety (Kinsey, 1986). Sales of prepared takeout foods, not only from fast food outlets, but premium foods from upscale restaurants and delicatessens have escalated. The takeout market reached $62.4 billion in 1987 and is expected to exceed $100 billion by 1992 (the Packer, March 26, 1988). Sixty-three percent of all food stores offered prepared foods in 1987 (Food Institute Report, May 16, 1987).

The Bureau of Labor Statistics forecasts that the female labor force participation rate will have increased to 62 percent by the year 2000. By then, the home microwave market will be completely penetrated and microwaves will begin to appear in automobiles to allow for mobile food preparation of hand-held foods by busy commuters. Food industry firms will continue to "build in" conven-
ience into their products, targeting specific market segments with specially designed products and packaging. As we move in this direction, more firms will seek out “environmentally sound” packaging materials, creating another market opportunity.

Health versus Convenience

Thus, there are two seemingly divergent trends—convenience seeking and nutrition awareness. According to a study by Pillsbury, the fastest growing consumer segment, now representing 26 percent of the adult population, is made up of the “chase and grabbits” (Morris, 1986). Yet, another rapidly growing segment, now 20 percent of the adult population, is classified by Pillsbury as highly health-conscious “careful cooks” (Ibid.) These two food trends—towards convenience and healthfulness—will require an integrated approach in food marketing—for example, better nutritional information on a convenient package. Products and firms that can meet the demand for convenient, yet healthful, flavorful, and safe foods will be well positioned in the food marketing industry of the 1990s and beyond.

Agricultural Pesticide Usage

The number and uses of agricultural pesticides are bound to continue to decline into the next century. Pesticides approved before 1984 are now required to undergo a reregistration process implemented by the U.S. Environmental Protection Agency. Specialty crops will likely be the most adversely affected since chemical companies frequently consider their economic importance to be insufficient to warrant the costs of pesticide reregistration. Mounting registration costs are also limiting the development of alternative chemicals.

California’s competitive position depends on whether state referendums and other legislation restrict pesticide usage to a greater extent here than elsewhere. Wholesale reduction of pesticides in California (of the type proposed by the Van de Kamp Initiative) could seriously undermine California’s future as an abundant supplier of high quality, safe, and diverse crops to U.S. and world markets. This type of legislation would push production out of California to other locations where there is less control over growing practices.

Limited studies comparing profitability between conventional agricultural production practices and alternative methods (fewer chemicals), frequently indicate that alternative methods (especially organic) require price premiums to be profitable. If environmental legislation severely restricts pesticide usage before the development of economical, widely applicable alternatives, food
prices could be substantially increased. Currently, the University of California and private industry are investing in research and development aimed at reducing agriculture's dependence on synthetic chemical inputs in order to address current and anticipated food safety and environmental concerns; yet it may be years before widely applicable alternatives are available.

The World Market

The trade environment in the late 1980s is a "mixed bag." Abroad there are two trends. One is toward greater protectionism; the other toward freer trade, making it difficult to generalize.

The Western European market for California products has continued to grow, but at a much slower rate than it would have in the absence of the EC. As the EC expanded, it has taken in countries that compete directly with California specialty products on European markets—Greek raisins and Spanish almonds and oranges, for example. California processed fruits have been almost entirely squeezed out of the market. The EC's high price supports have stimulated more production than could be consumed there, changing the EC from a net importer to a net exporter in many products—wheat and processed tomatoes, for example. Still, the EC accounted for 29 percent of California's agricultural exports in 1987 (CDFA, 1987b).

It is unlikely that the EC market for California agricultural products will grow much; in fact, it may even decline from its second place position as an importer of California agricultural products. With internal barriers coming down by 1992, local specialty crop production will flow more easily throughout the EC. If external barriers were to increase, California products would be at an even greater disadvantage.

Canada (with a 13 percent share of California's agricultural exports in 1987) is a dominant market, ranking third as an importer of California agricultural products—after Japan and the EC. Canada is a particularly important market for California specialty crops. Although Canada has some seasonal tariffs, these have been diminished in the previous two GATT rounds. The recent U.S.-Canada free trade agreement established a schedule for reducing existing barriers. This will have important effects for California agriculture, possibly moving Canada up from third position as an importer. However, problems remain for U.S. wine shippers because of provincial marketing rules.

A number of California specialty crops under federal marketing orders have long treated Canada as part of the domestic market. It may be beneficial for them, instead, to recognize existing differences and adapt marketing strategies accordingly. For, if
marketers are to develop “niches,” so often advocated, they must study well the detailed differences among various locales, at home and abroad.

A big unknown is the potential free trade agreement being negotiated between the United States and Mexico. While some agricultural commodities would benefit from expanded Mexican demand, many California specialty crops would likely be adversely affected by growth in competing Mexican imports. Many experts believe that a sweeping free trade agreement of the type negotiated with Canada will not be forthcoming; however, Mexico is expected to receive Generalized System of Preferences, i.e., no tariffs, treatment on more commodities. The potential of Mexico as an expanded market for California agricultural products largely depends on Mexico’s ability to diversify its economy and improve its international competitiveness in manufactured consumer goods.

California technology will continue to be transferred abroad, potentially creating more formidable competitors in our markets. The phenomenal growth in Chilean fruit production exported to the U.S. market is due in a large part to success in technology transfer. Many other parts of Latin America will increasingly produce more in direct competition with California specialty crops. However, Latin America shows little promise of developing into a large import market for California products. If and when incomes in Latin America and other developing countries rise, demand shifts will occur—tubers to grain to increased meat consumption, finally to specialty crops (Learn et al., 1987). California could some day enjoy a seasonal advantage, marketing products in the Southern Hemisphere. However, any resulting increase in demand for California crops will depend on whether California can compete favorably with other source countries in quality and price.

Pacific Rim markets have been growing for California crops. Japan ranks as the number one importing country, purchasing 29 percent of the state’s total agricultural exports in 1987 (CDFA, 1987b). Other Asian countries bring the Pacific Rim total to over half of the state’s agricultural exports (Taiwan, 4 percent; Indonesia, 2 percent; Hong Kong, 6 percent; South Korea, 11 percent; and Singapore, 1 percent (CDFA, 1987b)). Korea is expected to follow Japan’s path of development which means a substantially increased market there for California products. Hong Kong’s becoming part of China in 1997 may adversely affect that market, but that will depend on developments in China. Consumer demand in these countries is not as constrained by custom as was once believed; for example, in Japan, beef and red wine have become important imports.

Trade barriers show signs of subsidence. Fifteen years ago, U.S. citrus was prohibited in Japan. Now, through bilateral agree-
ments, the orange quota has been increased and will be eliminated in 1991; quotas on lemons and grapefruit have been eliminated. Beef quotas will be eliminated in 1991 and replaced by an ordinary, but still significant, tariff. However, health and phytosanitary restrictions have been increasing in some countries. Thailand and Indonesia want to diversify their agriculture toward exports in order to earn foreign exchange. Taiwan and Korea have had very high protectionist policies for any locally-produced products. The result has been increased production of certain products in fresh and processed forms, which are exported in competition with U.S. products on world markets. Nevertheless, Taiwan is a booming market for California fresh fruit exports. And Hong Kong and Singapore have no trade barriers.

Expansion throughout the rest of the Asian Pacific Rim will hinge on economic improvement in countries like Indonesia and the Philippines and on the removal of trade barriers. Our policy should be to systematically apply pressure to existing trade barriers. The first step is to determine the real reason or reasons behind a particular restriction. Reasons include benefiting the importing nation’s domestic producers, importers, or processors; alleviating a foreign exchange crisis; raising government revenues; increasing domestic self-sufficiency in food production; promoting the importing nation’s exports; and favoring low-income consumers through income redistribution, where California specialty crops are sometimes viewed as luxury goods (Wright et al., 1988). Official policies are rarely explicit, so untangling the real reasons can be difficult.

Another large unknown with some possibility as a market outlet is Eastern Europe. Currently, they import feed grains and soybean meal, to increase livestock production and offset grain production shortfalls. There may be a tremendous pent up demand in many of these countries. If these countries experience rapid growth in income, production may lag behind. Imports of meat could increase, and, eventually, they might buy from California those specialty products that are not supplied by Western Europe.

The food safety issue is likely to affect the flow of international trade. Increased concern over the health and safety of imports may generate nontariff barriers that offset some of the gains from reduced tariffs achieved under GATT. Further, as international trade in fruit and vegetable commodities grows, phytosanitary restrictions will receive intensified scrutiny in trade negotiations.

Marketing Strategies

In the mature domestic market, there are a number of ways to attempt to increase sales. One is to become the lowest cost producer, but this is difficult when faced with worldwide competition.
Another is to take market share away from competitors by an aggressive use of promotional and advertising programs. Yet in today’s fragmented consumer and media markets, the productivity of promotional efforts is declining—that is, dollars spent yield less. Consequently, market share battles will become more costly in the future, requiring regional and increasingly sub-regional approaches.

A third strategy is to differentiate products in reality or at least in perception in order to gain market share or increase profit. A related strategy is to broaden product lines and sell new products. Despite the approximately 80 percent failure rate for new products, widespread use of this strategy has occurred in the 1980s (Food Institute Report, May 9, 1987). In 1989, 12,055 new products were introduced into the food system, compared with about 1,000 in 1980. While the growth rate for new products will slow, new product development will remain an important strategy into the 1990s and beyond.

Another way for firms to increase sales when facing a mature market is to merge and grow by acquiring the products of other firms, with established consumer brand loyalty. This is less risky than new product development and is advantageous from a distribution standpoint. In the ongoing “battle for shelf space” in retail outlets, controlling a broader product line can improve a supplier’s bargaining power with retailers, thereby enhancing shelf positioning. Several forces favor continued mergers at all levels of the system, contributing to further economic concentration.

Further, greater expenditures on advertising and marketing services (including value-added products), will cause the producers’ share of the consumer food dollar to decline. Efforts to augment producer bargaining power will be made through producer marketing associations and expanded use of cooperatives, with existing cooperatives becoming more vertically integrated and more diversified in product lines handled.\(^2\)

In the future, market research will become even more essential for all agricultural/food firms, regardless of size. Successful marketers must place greater emphasis on identifying market segments and positioning themselves to meet the needs and preferences being expressed.\(^4\) A good example to keep in mind is Blue

\(^2\)For example, fewer people watch network television and must be reached through local programming offered by cable companies.

\(^3\)For example, in addition to avocados, Calavo now handles other complementary fruits to improve its negotiating position with wholesale and retail buyers.

\(^4\)Attention to the life cycle of individual products facilitates the development of effective marketing strategies, including determining when to divest out of declining products into higher growth categories.
Diamond Growers' almond-sardine treat produced exclusively for the Japanese trade. Better communication systems will assist in identifying specialized demands and adapting or developing appropriate products.

California consumers will continue to lead the nation in an era of rapidly changing demand. But competition with California-grown products to meet that demand will intensify. California's success at competing will depend on the strategic choices made in the 1990s. California firms have the opportunity to lead the transition to these more market-driven strategies.

While our production technology has proved to be readily transferable, we have a clear advantage in knowing our market. Marketing knowledge will become increasingly critical as consumers demand more value-added products that "build" convenience into fresh products. Many of our competitors are not making the necessary investments in research and development to compete in this arena.

Major investments in consumer brands for fresh produce are being made by large U.S. food firms dependent on international sourcing to assure year-round supply. Modified atmosphere packaging will both provide opportunities in new export markets but will also make us more vulnerable to imports of certain commodities from distant regions. Although the location of production may change, California firms are bound to continue to play a major role in the financing and marketing of production from new regions. To maintain a leadership role, California firms must increase their investment in research and development in both production and marketing technology.

Those growers who aren't integrated nationally or internationally may be at a disadvantage. The trend toward international integration will likely cause greater concentration at the shipper level. Smaller firms will increasingly focus on special market "niches." Some California farmers are targeting niches for high quality or exotic products—for example, specialty lettuce, baby vegetables.

While most marketing orders do not include market control provisions, those that do will be pressured to refrain from such attempts. Market control is coming under increasing public

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5Many California fruit and nut crops are under federal and/or state marketing orders. Growers of storable commodities have been able to implement various market control provisions. Dried fruits and nuts use a reserve pool—holding back a portion of the crop to market later in the season or the next season, or to dispose of in "noncompetitive" outlets (subsidized exports, PL-480, school lunch, cattle feed, etc.). (When used as a buffer to
scrutiny for allegedly raising consumer prices, so it is possible that these practices may not survive into the next century. Although the purpose of market control provisions is to stabilize (not raise) prices, the political perception is growing that marketing orders harm consumers. Meanwhile, other marketing order provisions will be less controversial—for example, quality and maturity standards will continue for stone fruit. Demand expansion programs and production research sponsored by marketing orders and commodity commissions have greatly contributed to the strategic position of many California commodities. As international competition intensifies, more commodity groups will seek the advantages of these programs.

Recommendations

Marketing

The segmentation and internationalization of food markets require a revitalized market research agenda. We recommend that the state, in collaboration with private industry and universities, establish a competitive grants program to stimulate more research on marketing issues. Research should be expanded on: (1) competitive marketing strategies; (2) international marketing; (3) consumer behavior and food demand, including expanded data collection on food consumption patterns; (4) market information systems; and (5) evaluation of promotional programs.

For example, there is a critical need for market research on consumer willingness to pay for various perceived quality/safety attributes of fresh produce. While survey data on consumer attitudes about food safety are available, actual buying behavior may be quite different from survey claims. In-store experiments are needed to measure actual behavior. If agriculture is to make major adjustments in farming practices to meet consumer demand, responses should be based on sound data about the size of various consumer segments and their preferences and price sensitivity.

The proliferation of food safety-oriented marketing labels and retail-sponsored private residue detection programs are leading to marketplace confusion and the communication of misinformation to consumers. We recommend that labeling standards be established at the federal level for food safety claims, including national har-

footnote 5 continued

even out supplies between high and low production years, as for example in almonds, a reserve pool can benefit both producers and consumers by stabilizing prices.) Citrus growers have used a rate-of-flow to market provision, allocating only designated amounts to market each week, storing the rest on the tree (oranges) or under refrigeration (lemons).
monization of organic standards. Standardization of nutritional labeling would also benefit consumers and is currently under discussion at the federal level.

Supply management provisions of marketing orders are likely to remain controversial. Consequently, we recommend greater emphasis on shifting out the demand curve using promotion and market development strategies.

Farm Production

Investment in new agricultural technology will remain vital to maintain California’s international competitiveness. Substantial new investment is needed in research to develop farming practices requiring fewer synthetic chemical inputs. In light of growing environmental restrictions on farming, without this investment we could face a significant disruption in agricultural production and higher food prices. Research on alternative production practices should also attempt to measure the economic impact of these new methods on the food supply, grower and retail prices, and any net benefits to the environment.

The 1984 Task Force on Agricultural Issues Facing California recommended that the state be more active in providing information about bearing acreage, production, and supply of specialty crops, so that potential entrants become aware of conditions before deciding to plant. This was seen as a measure to help control surpluses. When perennial crops are involved, the situation is considerably more complex, due to the lag between planting and bearing. A number of very thorough studies have been done at UC Davis, modeling supply response for California crops. However, much of this work needs interpretation to the industry to make it more directly usable. If funding and research personnel were available, existing models could be updated and used for further analysis.

Education

In order to insure that new production and marketing techniques are broadly available to California agriculture and to those being trained to work in the food system, the state should strengthen public university resources in these program areas. Incentives should be established within the UC system to encourage more applied research in agricultural marketing.

California citizens increasingly make decisions with sweeping implications for agriculture and the food industry, using statewide referendums. Consequently, there is a need for improved public education on the food production/marketing system and the costs and benefits of various practices associated with agriculture, such as pesticide usage. Again, the University of California could
play a major role in this process, particularly through the Cooperative Extension system.

California should also support strengthened federal food safety legislation with provisions to pre-empt risk standards set by states. Such action would place California in a better position to compete with products from the rest of the country.

Policy

California legislators and policy makers should carefully consider the effect of new policies and laws on the competitiveness of the state's agriculture. While California agriculture has major natural strategic advantages, these are increasingly offset by regulatory constraints imposed at the state level. Far too frequently benefits from new policies do not outweigh the costs. Those proposing major changes in the regulatory climate for agriculture might be asked to first conduct an environmental/producer/consumer impact study.

It is important that state policy makers become more aware of the direct and indirect impacts of federal farm policy changes on California agriculture. Federal farm policy will continue to be oriented toward the Midwest and other U.S. production areas, making it vital to represent California interests more effectively in Washington. A closer Washington watch would help anticipate changes in the wind and allow better calculation of potential effects on California agriculture. The University of California has taken an important step in this direction by greatly expanding its facility in Washington, DC, including employing a person to represent the Division of Agriculture and Natural Resources there.

Trade

California is perfectly positioned to be a key player in expanding agricultural trade with the Pacific Rim. The California World Trade Commission should continue to support this effort through strengthened promotion of California products in the Pacific Rim and by establishing trade offices in other countries.⁵

California has been attempting to develop a more unified effort for its agricultural trade interests. These efforts should be encouraged so that a more coordinated representation could be achieved at the national and international levels. The diversity of California agriculture makes this difficult, yet a more cohesive agenda would be beneficial for California agriculture in Washington, in the GATT negotiations, in bilateral trade negotiations with Mexico, and in all of our dealings abroad.

⁵The state recently established a trade office in Mexico.
Marketing and Trade

Critical to the long-run success of California agriculture will be a recognition of our over-riding interest in free trade. California’s policy efforts at the national and international levels should focus on liberalization rather than protectionism. Attempts to erect nontariff barriers, such as country-of-origin labeling will be unsuccessful due to the divergence of interest within agriculture and uniform opposition at the retail level.

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Changing Needs in Education and Research:

Chapter 8. New Approaches for Better Understanding of Agriculture

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Chapter 9. The University's Response

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New Approaches for a Better Understanding of Agriculture

Daniel J. Desmond, James G. Leising, Nicelma J. King, Ellen L. Rilla, and Raymond Coppock

Agriculture today is integrated into a social and economic system that is far more specialized, complex and interdependent than ever before. The well-known gap between farmers and consumers is one result, but it is only part of the larger problem of agricultural literacy.

Today's role for education about the agricultural system is to make possible not only better public understanding of agriculture, but better public policies; to train not only technologists for the food system, but professionals serving both agriculture and the public interest.

Paradoxically, the United States has one of the world's most plentiful food supplies and possibly the least agriculturally-informed public. For most Americans, agrarian life and farming have been transformed from a harsh reality to dream-like images on Christmas cards. Food travels hundreds or thousands of miles between farm and table; it is processed, shipped, stored and packaged before it reaches the consumer. It loses virtually all traces of its on-farm origin.

With no apparent reason to worry about food scarcity, and with food prices relatively low in relation to income, U.S. consumers are concerned with another set of questions about food—those involving nutritional value, food safety, and convenience. These are important consumer decisions. Lack of agricultural literacy makes
such decisions both difficult and more subject to error.

It might be argued that there is little reason for consumers to understand agriculture as long as a safe, reliable, diverse food supply is at hand. However, mass media reports about pesticide residues in food and public reaction to those reports have raised questions not only about food safety itself but about the accuracy of the public’s perception of the food supply. A major dilemma for both agriculture and society is the lack of cognitive context in which to rationally evaluate events in agriculture.

A news report about actual or potential danger in food has little or no realistic context in the mind of the average reader or listener. Such reports are seen only in relation to the other stories already heard about similar topics, rather than to the reality of a global industrial complex that provides food to billions of people—with benefits as well as problems.

For example, the National Research Council (NRC) estimated dietary cancer risks from pesticides on food (NRC, 1987). Its report, widely publicized, used the conservative assumption that the maximum legal amounts of all pesticides registered for a crop are in fact applied; and that the maximum legal residues are present in the resulting food. Studies by the Food and Drug Administration, allowing for real-life pesticide use patterns and the effects of transportation and processing, have indicated that the actual risk is several orders of magnitude lower. The NRC’s risk estimates were scientifically defensible, but most news reports did not make clear their highly conservative assumptions—and the public generally was not able to provide the missing context. (For a recalculation of the NRC dietary cancer risk estimates, see Archibald and Winter, 1990.)

A similar, but even more complex, problem involves genetic engineering. Future development of biotechnology, in agriculture and in other fields, may encounter obstacles based not only on reasonable caution but on fear resulting from lack of information.

Two Approaches

All this constitutes one rationale for a broader mission for agricultural education. If most American consumers have little or no global context in which to view agriculture, then they are ill prepared to make intelligent decisions about food systems, or even about their own diets. In any event, it is apparent that increased understanding of the history and current directions of agriculture, as well as its economic, social, and environmental significance, is needed among both adult and student populations in the United States.
Understanding Agriculture

As a process to create this understanding, we need to consider the potential of two processes—education in agriculture and education about agriculture. This is a useful distinction between the two closely related purposes of agricultural education. (For a description of this widely-used distinction, see NRC, 1988.)

Education in agriculture means preparing a student for a career in one of over 200 different agricultural careers. Education about agriculture is one of many kinds of knowledge a well-rounded citizen might be expected to have in order to participate meaningfully in public policy decision-making in a democratic society.

Education About Agriculture

Education about agriculture focuses on agriculture in the context of the environment, society, and the economy. It deals with both agriculture as an industry and with the relationship between agriculture and resources—natural and human. It analyzes local, national and international policy issues involving agriculture. It can be viewed as a lifelong process, beginning in the primary grades and continuing through public information mechanisms into adulthood. In short, it provides a cognitive context that permits more rational public decisions about agriculture and the food supply.

Agriculture in the Environment

Another rationale for education about agriculture involves the environmental role of farms and the farm production system in an increasingly urbanized state. Agricultural literacy can present a framework within which to value, understand, and manage largely natural landscapes. Agriculture provides huge greenbelts which contribute not only to economic productivity but to the quality of life and to climatic stability. As urban development dominates California's coastal areas and spills eastward into the Central Valley, this is an increasingly important arena of public and private decision-making.

Agriculture also provides an experimental context in which communities can examine the surrounding natural resources. The current growing interest in sustainable agricultural systems developed out of a movement on the fringe of the mainstream agricultural community; but now others are seeing sustainable agriculture as a means of understanding and protecting natural systems operating within various environmental settings. The harvesting of food and fiber should be viewed—within agriculture and by the public—not only in terms of rows of corn or pens of pigs, but also as millions of acres of productive natural range, forests, and marine and fresh water fisheries. Understanding the functioning of this diverse collection of food and fiber resources can provide a valuable context
within which to evaluate other natural resource issues, such as the greenhouse effect, population growth, and genetic diversity.

Training in Science

Still another rationale for the importance of education about agriculture is its potential for science training in the school system, beginning in the lower grades. Evidence of this is emerging from Desmond and Rilla’s current research project on agricultural literacy. In a survey of county superintendents of schools in California, 89 percent ranked education about agriculture as an important concept for integration into public school curricula. Most of the administrators believed that this integration should occur in grades 4th to 6th. At this grade level, interest in science is first stimulated.

Educational research has shown that elementary students require an area of application in which to learn scientific theory. Food and fiber issues provide a practical, real, and accessible arena in which scientific ideas can be explored. This means not just observation of a bean sprout germinating in a paper cup, but sophisticated ideas and experiments designed to expose youth to the scientific process and to current issues in science.

To summarize: In California, the most populous state in the nation, where spreading urbanization must co-exist with a strong and growing agricultural economy, education about agriculture holds promise for:

• Citizens who can make decisions about their food supply based on better understanding, in context, of the complex biological and economic system that provides it.
• Citizens with increased understanding of the managed natural landscapes that surround them, and the environment in general.
• A science education curriculum that contains an applied arena in which students can explore the scientific method and principles of science.

Education in Agriculture

Today, although the U.S. farm population is only about 2.2 percent of the overall population, technological evolution has transformed the nature and vastly broadened the range of agricultural occupations and professional careers. U.S. industries that produce, process, market and prepare food and fiber products account for about 16.5 percent of the gross national product and about 20 percent of the nation’s jobs. Clearly, education in agriculture still deserves high priority.

Enrollment in California’s secondary-level education pro-
grams in agriculture steadily increased from 1917 to a peak in the late 1970s, reached a low point in 1987 and is currently increasing. In 1989-1990, the California Department of Education reported secondary agriculture enrollment of approximately 42,000 in 375 local programs.

Agricultural education in California public schools has a long history of success and is widely praised by students and graduates. Most programs consist of three parts: classroom and laboratory instruction, supervised occupational experience and leadership development through Future Farmers of America (FFA). The curriculum has traditionally focused primarily on production agriculture. The NRC (1988) report concluded that those vocational agricultural programs "that have changed little over the past decade prepare students for a rather limited and generally shrinking component of the job market. These programs are also geared to a shrinking segment of the student population. They probably give some students an unrealistic view of agricultural job prospects, while failing to alert them to other opportunities in agriculture."

Although not all secondary agricultural programs have a production orientation, it is clear that if career/vocational programs are going to survive into the 21st century they must demonstrate their ability to prepare students for careers in the agricultural sector growth industries such as scientific research, technology development, medical and social services, finance, law, business, management and marketing.

The vocational agriculture program has traditionally been justified on the basis of labor market demand for entry-level production agriculture workers or, at most, preparation for a two-year degree program. However, the most outstanding secondary agriculture programs in California and the United States all have a common goal of providing opportunities for college or university training as well as for entry level agriculture careers.

Rural Focus

About one-third of California's high schools, scattered throughout the state, offer programs in agriculture. A few urban school districts, such as Los Angeles and San Jose, have agricultural programs. However, most secondary agricultural programs, in California as elsewhere, are found in school districts where the local economy is closely and visibly tied to agriculture. This system of education in agriculture, with its rural emphasis, has produced many of California's current agricultural practitioners: farmers, ranchers, extension educators and those involved in formal agricultural education.

To the extent that the availability of vocational education in
agriculture is limited to parts of California where agriculture is the dominant industry, the pool of entrants into agriculture-related professions has narrowed. As a result, agriculture competes less effectively for talented young people. Under this system, those involved in agriculture-related professions will become even less ethnically representative of the labor force in California. All this has implications for the continued competitiveness of agriculture within California's total economy—and for the widening gulf between the perceived best interests of agriculture and those of the public at large.

There is another reason to broaden the pool of young people entering agriculture. In addition to understanding science and problems faced in the field by the producer, agricultural professionals of the future will be expected to know about problems, conditions and attitudes affecting other aspects of economic and cultural life in California. They will be called upon to understand and respond to such concerns as the environment, water supply, global marketing, food-related social issues, and the safety and nutritional value of food.

Thus, it seems vitally important that the agricultural professions become more available and attractive to young people from urban and suburban backgrounds. This will assure the continued drive for excellence in California's food and fiber related industries. It also will help to maintain a balanced perspective between the economic interests of those industries and the economic, environmental and social interests of the majority of the state's population. Without it, there is likely to be some reduction in the capacity of California's agricultural system to innovate and develop new and better solutions to the problems facing agricultural industries in the 21st century.

**Challenge for the School System**

Currently, there is no specific requirement by the state that any information about agriculture should be provided at the elementary or secondary level. Furthermore, agriculture education programs have existed primarily in high schools and colleges, with little connection to elementary schools or junior high schools.

This gap caused few problems when most Americans were employed in agriculture and understood the system. Today, however, the challenge for agriculture and all of society is to develop an articulated system that will provide for education both in agriculture and about agriculture—one that will produce both broadly-trained professionals and an agriculturally literate population who understands and appreciates the importance of agriculture from both economic and social perspectives. In order to do this:
Understanding Agriculture

• All primary students should develop fundamental understanding and appreciation of agriculture and its economic and social significance.
• When possible, agriculture, as a modified biological system, should be used as a vehicle to teach academic skills in science from kindergarten on.
• Study of agriculture should be viewed as both college preparatory and as preparation for entry into the agricultural labor market.
• Beginning in grade 9, students should have the option to begin either courses in career/vocational preparation in agriculture, or more general courses oriented around agricultural and environmental issues.

The California Department of Education’s Agricultural Education Unit, in cooperation with the Agricultural Education program at UC Davis, has developed an innovative secondary-level model curriculum that integrates academics with career education. As a result, many local curricula are being revamped to use agriculture as a vehicle to teach the biological sciences and also provide broad-based study for students preparing for agricultural careers. The state university system has accepted the basic core of the model curriculum as appropriate for satisfying the “college elective” admission requirement for entering freshmen.

Although this effort is only a beginning, it provides evidence that education in agriculture is changing to meet the challenges. The question is whether these changes will move rapidly enough and include a large enough segment of the student population so that schools will perceive and respond to a continuing need for such career/educational programs.

Besides the school system itself, who might be involved in improving agricultural literacy? The 4-H program, traditionally a mainstay of education about agriculture in California, is conducting research to provide direction and design for increased involvement in the agricultural literacy movement. Another well known current program is “Ag in the Classroom,” initiated by the U.S. Department of Agriculture and developed in states such as California where the California Farm Bureau Federation, through the Ag in the Classroom Foundation, has developed the leadership and an extensive network of activities to introduce students and teachers to agriculture.

Such efforts to improve agricultural literacy, while small at this stage, may become caught up in the educational reform movement that began in the 1980s. What is needed now is leadership and strategic planning to integrate up-to-date and unbiased information about the food system and agricultural resources into formal and
non-formal educational systems—in California and throughout the nation. In other words, better education both in agriculture and about agriculture.

This would mean that (1) the next generation of agriculturalists will come from a larger and more diverse pool of young people and that (2) future public policy will be developed by citizens more knowledgeable about agriculture and its associated resources. In an era when technological decisions are becoming more important and more complex, and when most Americans are far removed from rural life, those are crucial public goals.

References


The University’s Response

Kenneth R. Farrell

This volume describes the profound changes and formidable challenges that California agriculture faces at the beginning of a new millennium. The authors, assembled by the Agricultural Issues Center at my request to assess and anticipate the most important issues relating to the state’s agriculture, have done an admirable job. The University and its Division of Agriculture and Natural Resources must address these (and other) issues, but finding solutions will severely test their research and education capabilities. How effectively the University can accomplish this important task could be an important determinant of the present and future quality of life for all Californians.

Clearly, the current and emerging issues discussed in this volume open new, exciting opportunities for the Division’s resident instruction, research, and extension. However, innovation is called for to grasp these opportunities and to gain the public support needed to get the job done. New strategies are needed, enabling the Division to (1) strengthen its research and education capabilities as an institution, (2) augment its considerable talents and resources by tapping into needed expertise from the rest of the University and the science and technology communities elsewhere, and (3) provide the incentives to faculty and staff to carry out programs and projects of highest priority.

Virtually every issue will require the Division to draw on outside experts, especially from other colleges and campuses of the University of California and, as appropriate, from the California
State University System, sister state land grant universities, private institutions, federal agencies such as USDA and EPA, and the international and national agricultural research centers. Expertise is needed from disciplines in the natural and social sciences as well as the professions (business, education, engineering, law, medicine, public health, etc.). In doing this, the Division would be using its existing experiment station and cooperative extension infrastructure to extend the land-grant model to the University as a whole. The Division also should be ready to respond to research and educational opportunities presented by the growth of existing and new campuses.

Under normal circumstances the Division would be inclined to adjust the scope and level of its programs to fit highly restrictive budgets. But these are not normal times—these are extraordinary times that require bold approaches. The population of the state continues to grow in numbers as well as diversity. Some of the best agricultural lands and natural areas are irrevocably being converted to urban and other uses. The salinity, water and air pollution problems are worsening. The public will not settle for less than a safe, nutritious and plentiful food supply. Profitability and competitiveness must be maintained in the face of increasing internationalization of markets and trade. Further, the accumulation of scientific evidence on acid rain and global warming demonstrates—once again—the interdependence of agriculture, natural resources, and environmental quality; and the need for more unified science, research, and public policy to address such issues on a broader, if not global basis.

High priority should be placed on the need to move more quickly toward environmentally sensitive, sustainable cropping and animal culture systems, particularly with regard to reducing the use and adverse impacts of pesticides and other chemicals. At the same time agriculture will continue to be dependent on new or improved production technologies and marketing strategies to maintain competitiveness in global markets. But these approaches will need to be balanced against natural resource, environmental, and food safety constraints and objectives.

I believe that there are two very fundamental areas in which the University and the Division need to strengthen their efforts. First, it is critical that we fill in broad gaps in our overall knowledge. In the areas of soil, water, insects, and plants—and, particularly their interactions—our impressive body of knowledge still pales by comparison to what we don’t know.

Second, as we develop information, we must integrate that knowledge into practical systems that make it useful to production agriculture as quickly as possible. New and innovative ways to
develop and effectively transfer technology from the University to the industry, from the lab to the field, must be found. This is because the balance between basic research to create new knowledge and applied action to develop, adapt, and transmit that knowledge to users has been disturbed. The pace of science today has quickened, and results are rapidly being diffused globally—sometimes before they are usefully applied at home. There must be a continuum of programs of the Agricultural Experiment Station and Cooperative Extension extending from basic research, to developmental and adaptive research and the processes by which research-based knowledge is transferred and transformed for practical use at the “field” level.

We are in the midst of an electronic revolution and on the threshold of a biological revolution. In agriculture, these may dwarf the mechanical and chemical revolutions that preceded them. I believe that biotechnology holds tremendous potential to enhance agricultural productivity and to do so in ways that will better protect the quality of the natural resource base. But the path to this Brave New World will not be without its pitfalls; nor will it be of benefit to all.

The ultimate goal is responsible implementation of these new technologies. This will require a coordinated effort from research and development to the ultimate adoption of the technology. In particular, the anticipated flow of biotechnology results makes it necessary to reexamine the public-private relationships in transfer of technology from the lab to the field.

Modern telecommunication devices should enable the Division to deliver more information more effectively from more sources to more people than ever before. Closer links between research and extension centers, such as those at Kearney and the Imperial Valley, with the UC campuses could provide bases of operations closer to the users of the technology. Other technology transfer centers located in rural and selected urban areas can provide both the multidisciplinary specialization as well as the broader geographic coverage needed to solve increasingly complex problems.

Gone is the time when agriculture could be characterized as a unique, isolated sector of the California economy. Agriculture is now an integral part of more complex, interdependent social and economic systems. Resolution of many issues “down on the farm” now requires reaching well beyond the farm gate, to incorporate interests of urban as well as suburban and rural people in both research and extension programs.

As the new millennium opens, an urban society will see agriculture as one of many uses for natural resources; it will no
longer accept the primacy of agriculture in its use of those resources. The effect of agriculture on environmental quality and on the quality of life of the predominantly urban population will pose increasingly complex, controversial public policy issues with profound economic effects on the future of agriculture in the state.

The Division, through its resident instruction, research, and extension components, is uniquely positioned to contribute to the development of agriculture and management of natural resources in the future. Both research and education must sustain broader, more holistic programs serving the interrelated interests of all people in an urban-oriented society.
Appendix: A Description of California Agriculture by Commodity Groups

About 250 different crop and livestock commodities are produced in California. Table 1 ranks more than 50 of the major products by 1988 gross sales value. California is best known for its specialty products (fruits, tree nuts, vegetables, and related products), but milk and cream, and cattle and calves consistently lead in value of sales by commodity being worth $2.1 billion and $1.6 billion, respectively. (The sales figures for cattle and calves include the value of animals and feed shipped into the state but not produced here.)

In aggregate, California’s fruit and nuts were worth $4 billion in 1988, with grapes accounting for nearly one-third of the total. Vegetable crop sales brought $3.7 billion. The state’s field crops (cotton, rice, alfalfa, sugar beets, wheat, and feed grains—corn, barley, sorghum, oats), worth nearly $3 billion in 1988, together represented approximately 20 percent of the nation’s production of these commodities. Although much more could be said, here we give a brief description of California agriculture by commodity group—field crops; dairy, poultry, and livestock; and specialty crops. (For more detail see Scheuring, 1983).

Field Crops

Although there are some important differences in California’s wheat, rice and cotton crops from those grown in the rest of the nation, market conditions for most field crops depend on production elsewhere. Many of these crops are under federal price
Table 1. California's Leading Agricultural Commodities, 1988

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Value</th>
<th>Acres Harvested</th>
<th>Share of U.S. Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk &amp; cream</td>
<td>$2,080,739</td>
<td>—</td>
<td>13.0</td>
</tr>
<tr>
<td>Cattle &amp; calves</td>
<td>1,613,819</td>
<td>—</td>
<td>4.8</td>
</tr>
<tr>
<td>Grapes (all)</td>
<td>1,356,250</td>
<td>654.2</td>
<td>91.6</td>
</tr>
<tr>
<td>Nursery products</td>
<td>919,049</td>
<td>—</td>
<td>27.6</td>
</tr>
<tr>
<td>Cotton, lint</td>
<td>682,537</td>
<td>1336.8</td>
<td>18.3</td>
</tr>
<tr>
<td>Hay, alfalfa &amp; other</td>
<td>817,614</td>
<td>1680.0</td>
<td>6.8</td>
</tr>
<tr>
<td>Flowers &amp; foliage</td>
<td>654,947</td>
<td>—</td>
<td>28.6</td>
</tr>
<tr>
<td>Lettuce</td>
<td>632,424</td>
<td>159.5</td>
<td>73.0</td>
</tr>
<tr>
<td>Almonds, shelled</td>
<td>600,075</td>
<td>407.0</td>
<td>99.9</td>
</tr>
<tr>
<td>Oranges (all)</td>
<td>458,446</td>
<td>172.0</td>
<td>26.0</td>
</tr>
<tr>
<td>Strawberries</td>
<td>388,998</td>
<td>17.6</td>
<td>73.9</td>
</tr>
<tr>
<td>Tomatoes, processing</td>
<td>385,669</td>
<td>226.1</td>
<td>88.4</td>
</tr>
<tr>
<td>Chickens</td>
<td>343,090</td>
<td>—</td>
<td>5.1</td>
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<td>Eggs, chicken</td>
<td>297,786</td>
<td>—</td>
<td>11.1</td>
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<tr>
<td>Broccoli</td>
<td>265,954</td>
<td>101.1</td>
<td>90.9</td>
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<td>Tomatoes, fresh</td>
<td>264,075</td>
<td>37.5</td>
<td>25.0</td>
</tr>
<tr>
<td>Carrots</td>
<td>247,366</td>
<td>51.1</td>
<td>65.1</td>
</tr>
<tr>
<td>Avocados</td>
<td>205,200</td>
<td>74.8</td>
<td>86.1</td>
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<tr>
<td>Turkeys</td>
<td>200,340</td>
<td>—</td>
<td>11.3</td>
</tr>
<tr>
<td>Rice</td>
<td>197,583</td>
<td>420.0</td>
<td>18.5</td>
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<td>Walnuts</td>
<td>190,962</td>
<td>174.0</td>
<td>100.0</td>
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<tr>
<td>Sugar beets</td>
<td>178,080</td>
<td>212.0</td>
<td>21.4</td>
</tr>
<tr>
<td>Peaches (all)</td>
<td>177,880</td>
<td>53.7</td>
<td>58.7</td>
</tr>
<tr>
<td>Lemons</td>
<td>171,436</td>
<td>48.9</td>
<td>82.3</td>
</tr>
<tr>
<td>Wheat</td>
<td>164,860</td>
<td>519.0</td>
<td>2.4</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>161,514</td>
<td>48.0</td>
<td>79.2</td>
</tr>
<tr>
<td>Celery</td>
<td>147,740</td>
<td>20.3</td>
<td>68.4</td>
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<tr>
<td>Potatoes</td>
<td>143,673</td>
<td>47.2</td>
<td>4.8</td>
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<tr>
<td>Apples</td>
<td>117,750</td>
<td>23.0</td>
<td>6.9</td>
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<tr>
<td>Cantaloupe</td>
<td>114,075</td>
<td>84.5</td>
<td>—</td>
</tr>
<tr>
<td>Prunes, dried</td>
<td>113,925</td>
<td>76.7</td>
<td>100.0</td>
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<tr>
<td>Mushrooms</td>
<td>110,189</td>
<td>0.5</td>
<td>17.8</td>
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<tr>
<td>Beans, dry</td>
<td>104,473</td>
<td>150.0</td>
<td>15.0</td>
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<tr>
<td>Pistachios</td>
<td>104,340</td>
<td>44.1</td>
<td>100.0</td>
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<tr>
<td>Onions</td>
<td>104,082</td>
<td>40.5</td>
<td>32.1</td>
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<tr>
<td>Plums</td>
<td>102,661</td>
<td>40.8</td>
<td>80.6</td>
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<tr>
<td>Corn for grain</td>
<td>86,768</td>
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<td>Asparagus</td>
<td>83,431</td>
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<td>Nectarines</td>
<td>78,861</td>
<td>24.2</td>
<td>97.0</td>
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continued
### Table 1 continued

<table>
<thead>
<tr>
<th>Item</th>
<th>Acres</th>
<th>Value</th>
<th>Percent</th>
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</thead>
<tbody>
<tr>
<td>Pears</td>
<td>74,540</td>
<td>23.0</td>
<td>35.1</td>
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<tr>
<td>Sheep &amp; lambs</td>
<td>66,547</td>
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<tr>
<td>Grapefruit</td>
<td>55,404</td>
<td>20.6</td>
<td>13.0</td>
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<tr>
<td>Olives</td>
<td>50,449</td>
<td>31.5</td>
<td>99.9</td>
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<td>Honeydew</td>
<td>47,435</td>
<td>21.3</td>
<td>69.1</td>
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<td>Barley</td>
<td>46,116</td>
<td>280.0</td>
<td>3.7</td>
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<tr>
<td>Alfalfa seed</td>
<td>41,665</td>
<td>67.0</td>
<td>—</td>
</tr>
<tr>
<td>Safflower</td>
<td>32,000</td>
<td>115.0</td>
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<tr>
<td>Apricots</td>
<td>29,613</td>
<td>17.8</td>
<td>92.9</td>
</tr>
<tr>
<td>Hogs &amp; pigs</td>
<td>22,146</td>
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<td>0.2</td>
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<tr>
<td>Cherries, sweet</td>
<td>20,040</td>
<td>10.3</td>
<td>14.0</td>
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<tr>
<td>Sweet potatoes</td>
<td>15,329</td>
<td>7.1</td>
<td>10.5</td>
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</tbody>
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and income support programs.

As essential inputs such as water increase in price, growers tend to look to higher-valued crops, for example, putting barley acreage into grapes. This type of shift occurs despite the higher valued crops' requiring a more intensive use of many inputs. California acreage in field crops, which has varied between 6 and 7 million acres since World War II (Nuckton and Johnston, 1983), was down in the mid-1980s and after to just over 5 million acres; there were 5.3 million acres in field crops in 1988. As competition for water and land increases and associated prices rise, the state's field crop acreage may be further reduced.

Cotton, grown in California's San Joaquin Valley, is the state's top field crop and leading agricultural export. California cotton represents only about 20 percent of the nation's total, but it is a high quality, long-staple variety meeting a significant demand on world markets. Cotton represents about 18 percent of the state's cropland, so small changes in cotton acreage have potential to significantly alter prices of alternative crops.

The state's largest crop in terms of acreage is alfalfa at 1.68 million acres in 1988. Even so, considerable alfalfa must be shipped in from other states to feed the state's dairy herd, cattle, and horses. Alfalfa is a relatively large user of irrigation water, but an efficient producer of high quality forage.

California has 1.2 million acres of irrigated pasture (the second largest acreage after alfalfa). With increased competition for a limited water supply, this crop, with its relatively low per-acre value and high water use, could be reduced—with consequent impacts on the state's dairy and horse industries.
Over 90 percent of California’s rice production is in the Sacramento Valley where ample irrigation water, good drainage systems, appropriate soils, hot summers, and the existing system of storage, drying, and milling facilities favor production. In contrast to cotton land, only a few alternative crops are available to rice producers. And on much of the state’s rice land, rice is the only production option.

Given federal budget constraints and the U.S. proposal on the GATT table to eliminate any trade-distorting subsidies, there is increased deliberation about eliminating federal price and income supports. However, since the European Community shows little willingness to reciprocally reduce its subsidies, eliminating price support programs is unlikely in the next farm bill (1991). Nevertheless, during the next 20 years there is increasing possibility of their reduction and possible elimination. Because of the interdependencies between program and nonprogram commodities, such an event would immediately cause adjustments; prices of many commodities would be lowered. In response, California’s cropping patterns would alter. Cotton acreage might be cut back and rice and sugar beet acreage would be reduced and could go out completely. Without dairy price supports, alfalfa acreage could be reduced. Decreased field crop acreage could mean increased acreage in certain specialty crops (with possible adverse price effects), but it is difficult to say what would be planted. Increased planting “flexibility,” being seriously discussed for the next farm bill could have similar effects if certain nonprogram crops were allowed on program crop set-aside acreage.

Dairy, Poultry, and Livestock

Dairy

The California dairy industry has changed dramatically in the last two decades. It was once primarily a fluid market; now, fluid milk accounts for only 33 percent of the total. Over 50 percent of all milk produced is manufactured into butter, nonfat dry milk, and cheese. About 15-20 percent of these commodities are sold to the government; another 12-15 percent to markets outside of California; the rest is marketed in the state. Despite the recent tremendous growth in California’s cheese manufacturing, the state still imports

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1 When new lands were opened by the State Water Project deliveries in the late 1960s, considerable acreage was planted in almonds, walnuts, grapes, and—more recently—pistachios.

2 Information about the California dairy industry is from L.J. (Bees) Butler, Agricultural Economics, UC Davis.
about 40-50 percent of its cheese requirements. Imports of other dairy products are minor.

The state’s dairy industry has long benefited from federal price supports. Because of California’s moderate climate and economies of scale enjoyed by large operations, production costs are lower than in other parts of the nation; therefore the state’s dairy industry has benefited relatively more than other areas from price supports which tend to be based on average U.S. production costs. However, California’s cost of production (and profitability) is highly sensitive to the cost of feed and concentrates, because producers purchase most of their feed requirement.

California has a relatively innovative milk pricing program. Its component pricing policy allows the prices of fat and solids-not-fat to vary independently. This may allow California to gain an upper edge in terms of reducing fat in dairy products and encouraging higher protein production.

The eventual adoption of the growth hormone, bovine somatotropin, will mean higher production per cow, but not necessarily a downsizing of the state’s herd. One driving force is of demand for dairy products is population growth, since Californians typically have a higher per capita consumption, especially of fluid milk, cheese, and ice cream. Expansion of California’s dairy industry may make it the top dairy state during the first decade of the next century.

The increased interest in sustainable agriculture in California is creating new markets for dairy (and other animal) manures. This development may increase the efficiency of dairy in the state.

Poultry

California used to ship in about 50 to 60 percent of its poultry needs. Broiler production has more than tripled over the last two decades (from 60 million birds in 1965 to 212 million in 1988) and will continue to increase, but population growth and increased demand for poultry will mean that California will continue to be a net importer of broilers. Turkey production is also increasing; the 20 million birds currently grown here are sufficient to meet the state’s consumption needs and allow some out shipment. However, much of the grain needed to feed the broilers and turkeys will continue to be shipped into the state.

California is the leading egg-producing state. Ten years ago its 38 million laying hens produced enough to ship eggs to several

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*Information on poultry and eggs is from Ralph Ernst, Avian Science, UC Davis.*
other western states, including Hawaii. A number of California producers have set up egg farms in other western states, closer to markets there. These producers, together with expansion of other operations, have made these states more self-sufficient in egg production. Meanwhile, declining demand for eggs associated with concerns about cholesterol has meant that some 28 to 29 million layers are now sufficient to meet the state’s needs, despite California’s population growth. Demand for eggs is expected to continue to decline, so that California should remain self-sufficient with even fewer layers.

Beef

California’s beef producers enjoy the advantages of millions of acres of snow-free range and the availability of by-products from fruit and vegetable processing for feed, but the industry depends heavily on trucking animals around the West, taking advantage of seasonal environmental and climatic conditions. Feeder cattle may come from Colorado, Texas, and even as far away as Arkansas, to winter on California’s range. Then, they may spend some time in Oregon, be fed in Idaho, and slaughtered in Utah. Much of the meat is then shipped to the California market. California, because of higher labor costs, is at a disadvantage at slaughter. Only about 30 percent of the beef consumed in California is slaughtered here.

In response to consumer demand, the beef industry is producing a much leaner product. It is important that the industry improve its marketing strategy and promotional effort, if it is to convince the nation’s consumers that it actually does have a leaner, healthier product.\(^5\)

Japan is a growing export market for California beef. To service its expanding consumer market, Japanese companies have purchased both feedlots and packing plants in California. Thus, beef, which knows no state borders, is also becoming internationalized.

Other Livestock

Although California is currently the second largest lamb and wool producing state, most of the state’s consumption of these products is and will continue to be shipped in from other states and imported from other countries. Most pork products will also continue to be shipped into the state from elsewhere.

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\(^4\) Information about California beef is from John Ross, Executive Vice President, California Cattlemen.

\(^5\) However, consumers’ stated intentions about wanting a lean product are not always consistent with their buying behavior.
Specialty Crops

U.S. demand for specialty crops is expected to increase at a faster pace than total food demand, which will merely keep pace with population growth. The expansion will come primarily from changes in income distribution, household size, age structure, and consumer preferences and lifestyles. California will continue to have an exclusive position in the nation as a producer and long-distance shipper of many fruits, nuts and vegetables. Yet the internationalization of specialty crop production will undoubtedly continue.

Fruits and Tree Nuts

California leads the nation in the production of many fruits and nut crops and is the nation's exclusive supplier of almonds, clingstone peaches, dates, figs, kiwifruit, olives, pistachios, pomegranates, prunes, raisins, and walnuts. Statewide fruit and nut acreage has increased substantially in recent decades as new irrigated land was opened from State Water Project deliveries beginning in the 1960s and as some farmers shifted from field crops. Almonds and wine grapes are notable examples. Bearing acreage in almonds increased from 100,000 acres just after World War II to over 400,000 in the 1980s. A tremendous expansion in wine grapes occurred in the early 1970s when bearing acreage increased from less than 50,000 acres in 1970 to over 300,000 by the mid-1970s.

Even given the perennial nature of tree and vine crop plantings, there are often significant shifts in location of acreage that occur over time. Urbanization in California's coastal areas has moved much fruit production to the Central Valley—e.g., prunes from the Santa Clara Valley to the Sacramento Valley, oranges from the southern coastal areas to the San Joaquin Valley. Shifts in location of perennial crop production are also caused by the relative profitability of alternative crops due to changed demand (e.g., cling peaches to nectarines) and to changes in the cost and availability of water for irrigation, land prices, and an area's susceptibility to disease and pest problems. Shifts in acreage among production areas has meant increased yields for some crops as new, vigorous trees replaced older orchards.

New higher-yielding varieties of some fruits are continually being developed and other important technological changes have improved yields. For example, California has increased its market share in strawberries relative to other states and countries due to the industry's investment in research to develop high yielding varieties.\(^6\)

\(^6\) Much of this section is from Nuckton and Johnston, 1985.

\(^7\) U.S. per capita consumption of strawberries has grown by 72 percent since 1980. In response, acreage expanded from 11,000 acres in 1980 to 19,700 acres in 1989.
Another important example is the dwarfing of fruit trees that has allowed much denser planting with greater yield per acre. The Granny Smith apple acreage planted in the Central Valley in the early 1980s is largely on dwarf stock.

Despite improved yields, many fruit and nut trees have a large variation in yield from year to year. Bad weather in one year can start such a cycle. Olive trees exhibit the most pronounced alternate bearing tendency, but avocados, almonds, and many other tree crops also experience extremes.

An important, relatively recent development is the expansion of fresh fruit shipments from the Southern Hemisphere—especially Chilean table grapes—making fruit available to consumers year round. U.S. fruit imports from Chile increased from 52,788 metric tons in 1979 to 387,940 metric tons in 1988 (Foreign Agricultural Service, 1989). The impact on the U.S. market for California fresh fruit varies with the type of fruit. For some, year-round availability may help California sales as consumers become more familiar with a product, e.g., kiwifruit. For others, year-round availability decreases the early season California price, and overlapping seasons mean greater competition on the market.

Vegetable Crops

California is the principal producer of vegetables in the United States with 54 percent of the 10 major fresh market vegetables and 57 percent of the five major processing vegetables. The state leads the nation in the production of lettuce, processing tomatoes, broccoli, cauliflower, carrots, and celery. California vegetable production has grown in response to expanded consumer demand, with both acreage and production up by 30 percent over the 1978-1988 decade.

Important regional shifts in vegetable production took place during the 1980s. For example, urbanization and high water costs caused a 19 percent decline in acreage between 1977 and 1987 in the South Coast region, down to only 65,890 acres in 1987. In contrast, the Desert Region grew by 57 percent over the same period to 193,309 acres in 1987, in part due to increased demand for year-round availability of produce. The Central Coast area, dominated by the Salinas Valley, is thought of as the “salad bowl” of the world. The Salinas Valley is recognized for its state-of-the-art production and post-harvest technology practices and year-round shipping seasons for many commodities. Nevertheless, the San Joaquin Valley actually ranks first in terms of vegetable acreage, with 537,918 acres.

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Information on California vegetables is from Roberta Cook, Agricultural Economics, UC Davis.
harvested acres in 1987, compared to 322,285 on the Central Coast.

California’s preeminence in vegetable production will likely be threatened by increased production in other states and in Mexico. States in nontraditional vegetable production regions (in the South and the Northeast) have recently been diversifying into vegetable production, due to low returns in food and feed grains. Maine, for example, expanded broccoli acreage from 300 in 1982 to 3,035 acres in 1986 (Cook and Amon, 1988). Yet, these new U.S. production regions have limited shipping seasons and are frequently nonirrigated, increasing production risks. While some demand for locally-grown produce has developed as part of the growing consumer preference for “fresh” and as a retail differentiation strategy, it still remains a minor part of the market. The dominant industry trend is toward expanding retail and food service demand for year-round availability of produce—and herein lies one of California’s most important strategic advantages.

California fruit and vegetable grower-shippers are frequently multi-regional and multi-commodity and increasingly either purchase or grow products internationally by means of joint ventures with producers in other countries. This makes them year-round marketers, selling products grown in several locations using the same marketing arm. The rapid growth in multi-location firms has contributed to a high degree of integration of the Mexico-California-Arizona vegetable industries. Since most vegetable crops are not perennials, the location of production will shift readily, based on relative production and marketing costs, and growing season.

Urbanization and environmental pressures on California production and lower labor costs in Mexico will continue to create incentives for greater vegetable production in Mexico. However, rising production costs and water constraints in Mexico are reducing that nation’s competitive edge in some crops—making any further expansion partly dependent on the negotiation of a Generalized System of Preferences, i.e., no tariffs, status for vegetable crops (Cook, 1990). Meanwhile, machine-intensive crops will likely remain in California. For example, fresh, hand-picked pole tomatoes have almost entirely moved from San Diego County to Baja California (with distributors on the California side), while California continues to dominate in mechanically harvested processing tomatoes.

References


