

CHAPTER 1

The Evolution of California Agriculture 1850-2000

Alan L. Olmstead and Paul W. Rhode

Alan L. Olmstead is Professor of Economics and Director of the Institute of Governmental Affairs at the University of California, Davis; Paul W. Rhode is Professor of Economics at the University of North Carolina, Chapel Hill, and a Research Associate at the National Bureau of Economic Research. The authors would like to acknowledge the research assistance of Susana Iranzo.

Two competing legends dominate the telling of California's agricultural history. According to the first legend, California farmers are progressive, highly educated, early adopters of modern machinery, and unusually well organized. Through irrigation, they made a "desert" bloom. Through cooperation, they prospered as their high-quality products captured markets around the globe. This farmers-do-no-wrong legend is the mainstay of the state's powerful marketing cooperatives, government agencies, and agricultural research establishment. According to the opposing legend, the California agricultural system was founded by land-grabbers who continue to this day to exploit impoverished migrant workers and abuse the Golden State's natural environment. (Even in its mildest form, this view faults California farmers for becoming full-fledged capitalists, rather than opting for more traditional family farms like their midwestern brethren.) Although the contest between these competing interpretations of the nature of California's farm system has raged for the past one-and-a-half centuries, neither account has engaged in a systematic accumulation and dispassionate analysis of the available data, and both have generally lacked the comparative perspective needed to assess why California agriculture developed as it did.

This chapter analyzes major developments in California's agricultural history to provide a better understanding of how and why the state's current agricultural structure and institutions emerged. We will focus on major structural transformations: the growth and demise of the extensive wheat economy of the nineteenth century; the shift to intensive orchard, vine, and row crops; and the emergence of modern livestock operations. Intertwined with our discussion of sectional shifts will be an analysis of some of the special institutional and structural features of California's agricultural development. Here we offer a brief look at the subjects of farm power and mechanization, irrigation, the labor market, and farmer co-operatives. In all of these areas, California's farmers responded aggressively to their particular economic and environmental constraints to create their own institutional settings. The results have been remarkable. In recent years, this one state alone has accounted for one-tenth of the value of the nation's agricultural output. What distinguishes California from other regions more than the volume of output, however, is the wide diversity of crops, the capital intensity, the high yields, and the special nature of the state's agricultural institutions.

EXTENSIVE CROPS IN THE 19TH CENTURY

When disgruntled miners left the gold fields, they found an ideal environment for raising wheat: great expanses of fertile soil and flat terrain combined with a climate of rainy winters and hot, dry summers. By the mid-1850s, the state's wheat output exceeded local consumption, and California's grain operations began to evolve into a form of agriculture quite different from the family farms of the American North. The image of lore is of vast tracts of grain, nothing but grain, grown on huge bonanza ranches in a countryside virtually uninhabited except at harvest and plowing time. While this picture is clearly overdrawn, it contains many elements of truth. California grain operations were quite large by contemporary standards and extensively employed labor-saving, scale-intensive technologies. As examples, they pioneered the adoption of labor-saving gang plows, large headers, and combined harvesters.¹ Most of the wheat and barley was shipped to European markets, setting a pattern of integration into world markets that has characterized California agriculture to the present. Large-scale operations, mechanization, and a reliance on hired labor would also become hallmarks of the state's farm sector.

Not only were California wheat farms typically larger and more reliant on labor-saving machinery and animal (and later steam) power than midwestern and eastern wheat farms, Californians grew fundamentally different varieties of wheat and employed different cultural techniques than their eastern brethren. These biological differences, although not generally appreciated, were critical to the success of the early California wheat industry. In fact, when eastern farmers migrated to California they had to relearn how to grow the crop. In the eastern U.S. (as well as in northern Europe), grain growers planted either *winter-habit* varieties in the fall to allow the seedlings to emerge before winter or *spring-habit* varieties in the spring shortly before

¹ As we note later in this essay, ranchers vigorously pursued the development of technologies and production practices suited to early California's economic and environmental conditions. This search for economic large-scale, labor-saving technologies culminated in the perfection of the combined grain harvester by local agricultural implements' producers in the early 1880s and its widespread diffusion among the region's grain growers in the late 1880s and the 1890s. See Alan L. Olmstead and Paul Rhode, "An Overview of California Agricultural Mechanization, 1870-1930," *Agricultural History*, Vol. 62, No. 3, 1988.

the last freeze. The difference was that winter-habit wheat required prolonged exposure to cold temperatures and an accompanying period of dormancy (vernalization) to shift into its reproductive stage. Spring-habit wheat, by contrast, grew continuously without a period of vernalization, but generally could not survive extreme cold. With the mild winters of California, farmers learned it was advantageous to sow spring-habit wheat in the fall (as was common in the Mediterranean but unheard of in the eastern U.S.).

California's wheat experience exemplifies what happens in the absence of continual biological innovation. After learning to cultivate Sonora and Club wheats in the 1850s, 1860s, and 1870s, California grain growers focused most of their innovative efforts on mechanization, and purportedly did little to improve cultural practices, introduce new varieties, or even maintain the quality of their seed stock. According to contemporary accounts, decades of monocrop grain farming, involving little use of crop rotation, fallowing, fertilizer, or deep plowing, mined the soil of nutrients and promoted the growth of weeds. Complaints that the land no longer yielded paying wheat crops became common from the 1890s. The grain also deteriorated in quality, becoming starchy and less glutinous. It is interesting to note these unsustainable "soil mining" practices may well have been "economically rational" under the high interest rates prevailing in the state in the mid-nineteenth century. The result was such sharply declining yields in many areas that wheat, formerly the state's leading staple, ceased to be a paying crop and was virtually abandoned (as indicated in Figure 1).²

THE GROWTH OF SPECIALITY CROPS

Between 1890 and 1914, the California farm economy fundamentally and swiftly shifted from large-scale ranching and grain-growing operations to smaller-scale, intensive fruit cultivation. By 1910, the value of intensive crops equaled that of extensive crops, as California emerged as one of the world's principal producers of grapes, citrus, and various deciduous fruits. Tied to this dramatic transformation was the growth of allied industries, including canning, packing, food machinery, and transportation services.

A vantage point on the state's transformation is offered in Table 1, which provides key statistics on the evolution of California agriculture between 1859 and 1997. Almost every aspect of the state's development after 1880 reflected the ongoing process of intensification. Between 1859 and 1929, the number of farms increased about 700 percent. The average size of farms fell from roughly 475 acres per farm in 1869 to about 220 acres in 1929, and improved land per farm dropped from 260 acres to about 84 acres over the same period. Movements in cropland harvested per worker also point to increased intensity of cultivation after the turn of the century. The land-to-labor ratio fell from about 43 acres harvested per worker in 1899 to 20 acres per worker in 1929. The spread of irrigation broadly paralleled the intensification movement. Between 1869 and 1889, the share of California farmland receiving water through artificial means increased from less than one percent to five percent. Growth was relatively slow in the 1890s, but expansion resumed over the 1900s and 1910s. By 1929, irrigated land accounted for nearly 16 percent of the farmland.

² Shaw, *How to Increase the Yield of Wheat in California*, pp. 255-57; Blanchard, *Improvement of the Wheat Crop in California*, pp. 1-5.

Table 1. California's Agricultural Development

Year	No. of Farms	Land in Farms	Improved Land	Cropland Harvested	No. of Farms Irrigated	Irrigated Land	Ag. Labor Force
	(1,000)	------(1,000 Acres)-----			(1,000)	(1,000 Acres)	(1,000)
1859	19	8,730	--	--	--	--	53
1869	24	11,427	6,218	--	--	60-100	69
1879	36	16,594	10,669	3,321	--	300-350	109
1889	53	21,427	12,223	5,289	14	1,004	145
1899	73	28,829	11,959	6,434	26	1,446	151
1909	88	27,931	11,390	4,924	39	2,664	212
1919	118	29,366	11,878	5,761	67	4,219	261
1929	136	30,443	11,465	6,549	86	4,747	332
1939	133	30,524	--	6,534	84	5,070	278
1949	137	36,613	--	7,957	91	6,599	304
1959	99	36,888	--	8,022	74	7,396	284
1969	78	35,328	--	7,649	51	7,240	240
1978	73	32,727	--	8,804	56	8,505	311
1987	83	30,598	--	7,676	59	7,596	416
1997	74	27,699	--	8,543	56	8,713	260

Sources: Taylor and Vasey, "Historical Background," in Rhode, 1995.

U.S. Bureau of the Census: *Fifteenth Census 1930*, Vol. 4; *Census of Agriculture 1959*, California, Vol. 1, Part 48; *1980 Census of Population*, California, Vol. 1, Part 6; *Census of Agriculture 1997*, California, downloaded from http://www.nass.usda.gov/census/census97/volume1/ca-5/ca1_01.pdf; *1990 Census of Population*, California, Section 1; *2000 Census*, "Industry by Sex : 2000 Data Set: Census 2000 Summary File 3 (SF 3)—Sample Data" downloaded at <http://factfinder.census.gov>.

Thomas Weiss, Unpublished data.

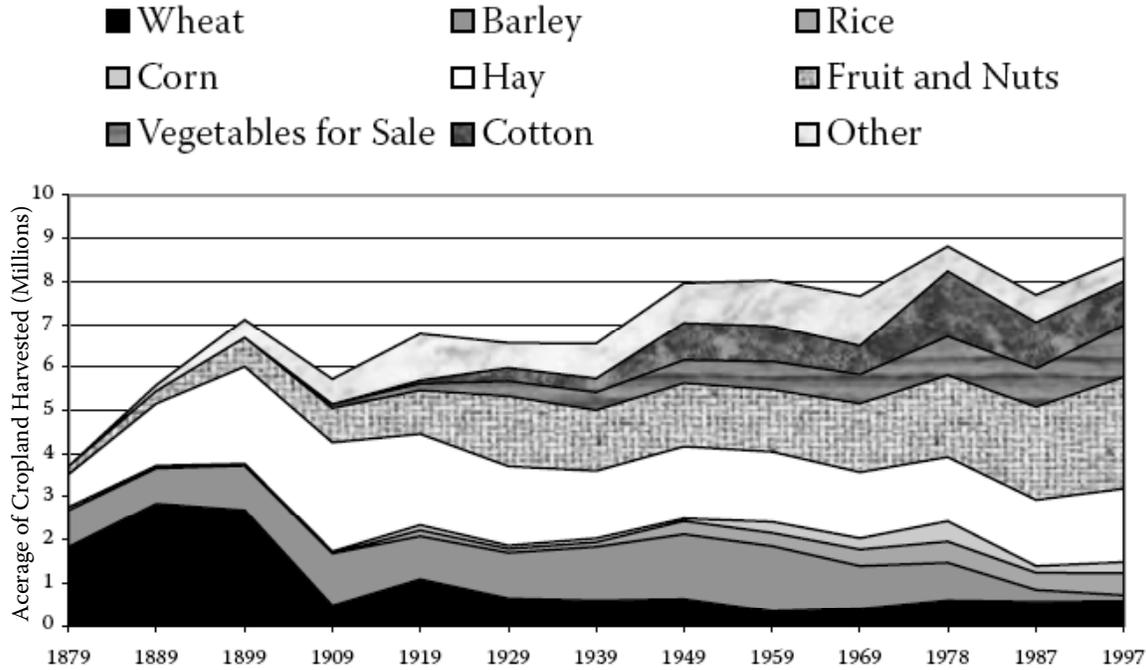
Data on the value and composition of crop output put California's agricultural transformation into sharper relief. Between 1859 and 1929, the real value of the state's crop output increased over 25 times. Growth was especially rapid during the grain boom of the 1860s and 1870s, associated primarily with the expansion of the state's agricultural land base. Subsequent growth in crop production was mainly due to increasing output per acre and was closely tied to a dramatic shift in the state's crop mix. After falling in the 1860s and 1870s, the share of intensive crops in the value of total output climbed from less than 4 percent in 1879 to over 20 percent in 1889. By 1909, the intensive share reached nearly one-half, and by 1929, it was almost four-fifths of the total.³

Figure 1 provides further documentation of the transformation of California's crop mix over the late 19th and early 20th centuries. The Figure shows how cropland harvested in California was distributed across selected major crops over the 1879-1997 period. The acreage data reveal that in 1879, wheat and barley were grown on over 75 percent of the state's cropland whereas the combined total for the intensive crops (fruit, nuts, vegetables, and cotton) was around five percent. By 1929, the picture had changed dramatically. Wheat and barley then accounted for about 26 percent of the

³ After 1909, cotton and sugar beets became important, contributing to the impressive rise of the intensive share in the 1910s and 1920s. For a more complete treatment of these issues, see Paul W. Rhode, "Learning, Capital Accumulation, and the Transformation of California Agriculture," *Journal of Economic History*, Vol. 55, No. 4, December 1995.

cropland harvested and the intensive crop share stood around 35 percent. In absolute terms, the acreage in the intensive crops expanded over ten times over this half-century while that for wheat and barley fell by more than one-third.⁴

Figure 1. Distribution of California Cropland Harvested, 1879-1997



Data on shipments of California fresh, dried, and canned fruits and nuts reveal the sector's spectacular expansion over this period. During the 1870s and 1880s, growth rates exceeded 25 percent per year (no doubt, in part, reflecting the small base). Shipments continued to grow at robust rates of about eight percent per annum over the 1890s and 1900s. By 1919, California produced 57 percent of the oranges, 70 percent of the prunes and plums, over 80 percent of the grapes and figs, and virtually all of the apricots, almonds, walnuts, olives, and lemons grown in the United States. In addition, California produced significant quantities of apples, pears, cherries, peaches, and other lesser crops.

The spectacular growth in California production of specialty crops had important international consequences as traditional Mediterranean exporters of many crops were first driven from the lucrative U.S. market and then faced stiff competition from the upstart Californians in their own backyard of northern Europe. California production significantly affected the markets and incomes of raisin growers in Málaga and Alicante, prune growers in Serbia and Bosnia, and citrus growers in Sicily.⁵

⁴ The data also show that the corn crop, which nationally always accounted for more acreage than the wheat and barley crops combined, was of far less significance in the state.

⁵ José Morilla Critz, Alan L. Olmstead, & Paul W. Rhode, "Horn of Plenty: The Globalization of Mediterranean Horticulture and the Economic Development of Southern Europe, 1880-1930," *Journal of Economic History* (June 1999), pp. 316-52.

Explanations for the causes and timing of California's structural transformation have long puzzled scholars. The traditional literature yields numerous causal factors, including: (1) increases in demand for income-elastic fruit products in eastern urban markets; (2) improvements in transportation, especially the completion of the transcontinental railroad; (3) reductions in the profitability of wheat due to slumping world grain prices and falling local yields; (4) the spread of irrigation and the accompanying breakup of large land holdings; (5) the increased availability of "cheap" labor; and (6) the accumulation of knowledge about California's environment and suitable agricultural practices. Yet a careful investigation of the transformation yields a surprising result: much of the credit for the shift to intensive crops must be given to exogenous declines in real interest rates and to "biological" changes as farmers learned more about how to grow new crops in the California environment.

Isolated from America's financial markets, California farmers faced high, even astronomical, interest rates, which discouraged capital investments. Rates fell from well over 100 percent during the Gold Rush to about 30 percent circa 1860. The downward trend continued with real rural mortgage rates approaching 8 to 12 percent by 1890. The implications of falling interest rates for a long-term investment such as an orchard were enormous. As one Bay Area observer noted in the mid-1880s, the conversion of grain fields to orchards "has naturally been retarded in a community where there is little capital, by the cost of getting land into orchard, and waiting several years for returns."⁶ Calculations indicate that the break-even interest rate for the wheat-to-orchard transition was about 10 to 13 percent (at rates above 15 percent the value of investments in orchards started to turn negative). These estimates conform fairly closely to the interest rate levels prevailing in California when horticulture began its ascent.

A second key supply-side force was the increase in horticultural productivity associated with biological learning. Yields for leading tree crops nearly doubled between 1889 and 1919. When the Gold Rush began, the American occupiers knew little about the region's soils and climate. As settlement continued, would-be farmers learned to distinguish the better soils from poorer soils, the more amply watered land from the more arid, the areas with moderate climates from those suffering greater extremes. Occasionally overcoming deep-seated prejudices, farmers learned which soils were comparatively more productive for specific crops.⁷ California fruit growers engaged in a similar time-consuming process of experimentation to find the most appropriate plant stocks and cultural practices. Existing varieties were introduced from around the world, and new varieties were created. In the early 1870s, USDA plant specialists established the foundation for the state's citrus industry with navel orange budwood imported from Bahia, Brazil. Plums and prune trees were brought in from France and Japan; grape vines from France, Italy, Spain, and Germany; and figs (eventually together with the wasps that facilitated pollination) from Greece and Turkey. Plant breeders also got in on the act. The legendary Luther Burbank, who settled in California in 1875, developed hundreds of new varieties of plums and other fruits over his long career.⁸

⁶ J. Burns, "A Pioneer Fruit Region," *Overland Monthly*, 2nd Series, Vol. 12, No. 67, 1888.

⁷ U.S. Weather Bureau, *Climatology of California*, Bulletin L, 1903; U.S. Bureau of the Census, *Tenth Census, 1880*, Vol. 6, Cotton Production, Part 2, 1884.

⁸ Warren Tufts, *Rich Pattern of California Crops*, University of California Press, Berkeley, 1946; Robert Hodgson, "California Fruit Industry," *Economic Geography*, Vol. 9, No. 4, 1993.

In part, the growth of horticultural knowledge occurred through the informal “folk process” highlighted in William Parker’s classic treatment of American agriculture. Over time, the process of research and diffusion became increasingly formalized and institutionalized. Agricultural fairs served to demonstrate new practices and plants. As an example, a series of major citrus expositions, held annually in Riverside from the late 1870s on, helped popularize the new Bahia orange variety. An emerging group of specialty farm journals, such as the *Southern California Horticulturist*, *California Citrograph*, and *California Fruit Grower*, supplemented the stalwart *Pacific Rural Press* to spread information about fruit growing.⁹ The California State Board of Horticulture, formed in 1881, provided an active forum for discussion of production and marketing practices, especially through its annual convention of fruit growers. The Agricultural College of the University of California, under the leadership of Eugene Hilgard and Edward Wickson, intensified its research efforts on horticultural and viticultural problems after the mid-1880s. By the early 1900s, the USDA, the state agricultural research system, and local cooperatives formed an effective working arrangement to acquire and spread knowledge about fruit quality and the effects of packing, shipping, and marketing on spoilage and fruit appearance. These efforts led to the development of pre-cooling and other improved handling techniques, contributing to the emergence of California’s reputation for offering higher-quality horticultural products. This learning process eventually propelled California’s horticultural sector to a position of global leadership.¹⁰ More generally, the example of the state’s horticultural industry highlights the important, if relatively neglected, contribution of biological learning to American agricultural development before the 1930s.¹¹

A second major transformation took place in the early twentieth century with the increased cultivation of row crops including sugar beets, vegetables, and most notably cotton (see Figure 1). These changes represented an intensification of farming with significant capital investments and often led to shifts onto what had been marginal or under-utilized lands. The advent of cotton, which by 1950 had become the state’s most valuable crop, offers another important case study in the continuing evolution of California agriculture.

The California Cotton Economy

From Spanish times, visionaries attempted to introduce cotton into California on a commercial basis. A variety of factors, including the high cost of labor, the distance from markets and gins, and inadequate knowledge about appropriate varieties, soils, etc. doomed these early efforts. The real breakthrough came during World War I when high prices coupled with government research and promotional campaigns encouraged farmers in the Imperial, Coachella, and San Joaquin Valleys to adopt the crop. Figure

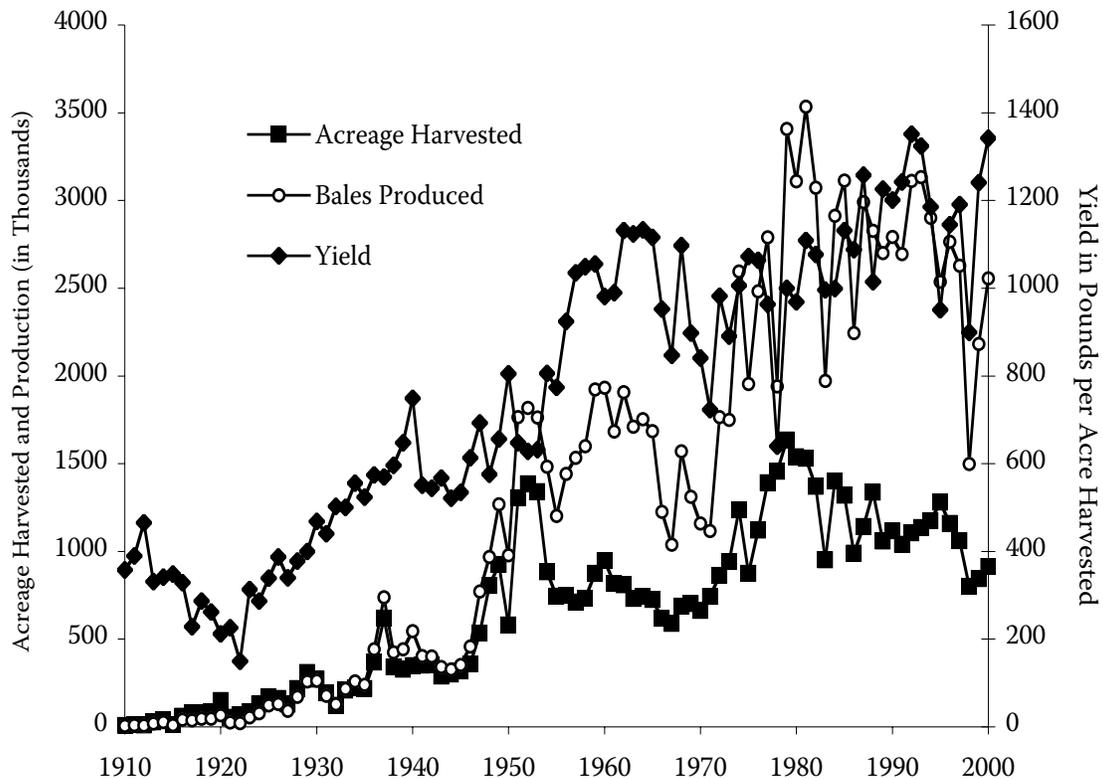
⁹ William Parker, “Agriculture,” *American Economic Growth: An Economist’s History of the United States*, Lance Davis et al., Editors, Harper and Row, New York, 1972; Charles Teague, *Fifty Years A Rancher: The Recollections of Half a Century Devoted to the Citrus and Walnut Industries of California and to Furthering the Cooperative Movement in Agriculture*, Ward Ritchie, Los Angeles, 1944; Robert Cleland and Osgood Hardy, *March of Industry*, Powell, Los Angeles, 1929.

¹⁰ The initially high cost of capital helps explain why the learning process concerning the best practice in fruit cultivation was so prolonged. The discovery process involved both actual investment in learning, and learning by doing, utilizing a capital-intensive production process. The high initial rates of interest almost surely reduced the amount of investment undertaken and lengthened the learning process. Edward Wickson, *California Fruit*, Pacific Rural Press, San Francisco, 1900, p.50, notes one interesting response of early fruit growers to the high value of capital and time: orchardists in the 1850s frequently planted dwarf trees, which began bearing sooner than standard stocks.

¹¹ Alan L. Olmstead and Paul W. Rhode, “The Red Queen and the Hard Reds: Productivity Growth in American Wheat, 1800-1940,” *Journal of Economic History*, Vol. 62, No. 4, December 2002, pp. 929-966.

2 illustrates acres harvested, bales produced, and yields per acre, from 1910 to 1964. The tremendous absolute increase in California's cotton acreage since the 1920s contrasts with the absolute decline nationally. California's acreage in cotton ranked 14th out of 15 cotton-producing states in 1919; by 1959 it ranked second.

Figure 2. California Cotton, 1910-2000



Several factors distinguished California's cotton industry from other regions. First, cotton yields were typically more than double the national average. High yields resulted from the favorable climate, rich soils, controlled application of irrigation water, use of the best agricultural practices and fertilizer, adoption of high quality seeds, and relative freedom from pests. Second, the scale and structure of cotton farms was remarkably different in California. From the mid-1920s through the 1950s, the acreage of a California cotton farm were about five times that of farms in the Deep South. As an example of the structural differences between California and other important cotton states, in 1939 farms producing 50 or fewer bales grew to about 17 percent of the output in California, but in other leading cotton states, farms in this class produced at least 80 percent of all cotton output. One-half of the output in California was grown on farms producing more than 200 bales. For the nation as a whole, one-half of the output was raised on farms producing fewer than 13 bales. Thus,

it is not surprising that California's gross income per cotton farm was almost nine times the national average.¹²

Other distinctive features of California cotton farms were their more intensive use of power and their earlier mechanization of pre-harvest activities. In 1929, a California farm was almost 20 times more likely to have a tractor than a Mississippi farm.¹³ The *Pacific Rural Press* in 1927 offered a description of the highly mechanized state of many California cotton farms: "[M]en farm in sections...By the most efficient use of tractor power and tools, one outfit with a two-man daylight shift plants 100 acres per day, 6 rows at a time, and cultivates 70 acres 4-rows at a time."¹⁴ The more rapid adoption of tractors (besides reducing pre-harvest labor demands) created a setting favorable to further modernization. When picking machines became available, farmers already possessed the mechanical skills and aptitudes needed for machine-based production.

The larger size of cotton operations in California and the more intensive use of tractors reflected a fundamentally different form of labor organization than that which dominated the South. By the 1940s, on the eve of cotton harvesting mechanization, most cotton in California was picked on a piece-rate basis by seasonal laborers under a contract system.¹⁵ Although conditions varied, a key ingredient was that a labor contractor recruited and supervised the workers, and dealt directly with the farmer, who might have had little or no personal contact with his laborers. This type of arrangement implied different class and social relationships from those that prevailed in much of the South. The California farm worker was more akin to an agricultural proletariat than to a rural peasant. The proverbial paternalism of southern planters toward their tenants had few parallels in California.

As with many crops, California cotton growers also led the way in harvest mechanization. Many of the factors discussed above, including pre-harvest mechanization (and familiarity with machines), relatively high wages, large-scale operations, high yields, a flat landscape, and a relative absence of rain during the harvest season all aided in the adoption of the mechanical harvester. Spindle picking machines first appeared on a commercial basis following World War II. In 1951, over 50 percent of the California crop was mechanically harvested compared to about 10 percent for the rest of the nation. At that time, about 50 percent of all the machines in operation in the United States were at work on California farms.¹⁶

LIVESTOCK PRODUCTION

Similar forces—early adoption of large-scale operations and advanced technologies—characterized California's livestock economy. The broad trends in livestock production in California since 1850 are reflected in Figure 3, which graphs the number of head of various types of livestock in the state as aggregated into a

¹² Moses S. Musoke and Alan L. Olmstead, "The Rise of the Cotton Industry in California: A Comparative Perspective," *Journal of Economic History*, Vol. XLII, No. 2, June 1982.

¹³ U.S. Bureau of the Census, U.S. Census of Agriculture: 1959, *General Report: Statistics by Subjects*, Vol. II.

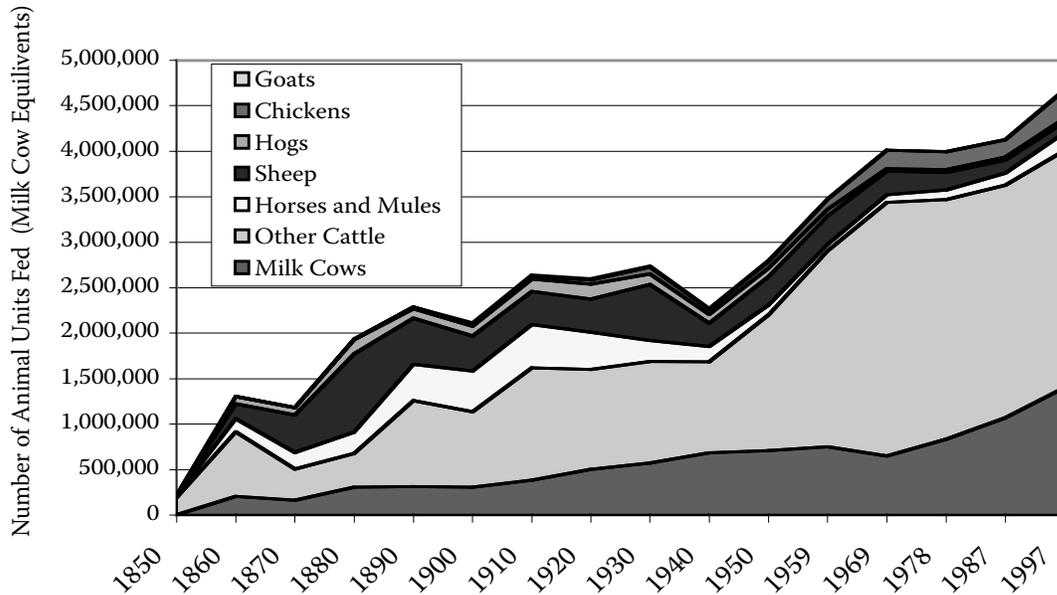
¹⁴ *Pacific Rural Press*, April 2, 1927. One of the more notable growers in Kern County was Herbert Hoover, who regularly raised 400 acres of cotton on his 1,200 acre farm during the 1920s. See *Los Angeles Times*, *Farm and Tractor Section*, May 8, 1921; *California Cotton Journal*, April 1926.

¹⁵ California Committee to Survey the Agricultural Labor Resources, *Agricultural Labor in the San Joaquin Valley: Final Report and Recommendations*, Sacramento, March 15, 1951; Lloyd H. Fisher, *The Harvest Labor Market in California*, Cambridge, 1953.

¹⁶ Musoke and Olmstead, 1982.

measure of animal units fed.¹⁷ The region emerged from the Mexican period primarily as a cattle producer. A series of droughts and floods in the 1860s devastated many herds, and when recovery occurred in the 1870s, sheep-raising had largely replaced cattle-ranching. Indeed, by 1889, the state became the nation's leading wool producer, with almost 13 percent of national output.¹⁸

Figure 3. California Livestock Inventories, 1850-1997



Many of the livestock ranches of the nineteenth century operated on extremely large scales. Examples of these operations include Miller-Lux, Tejon, Kern County Land Company, Flint-Bixby, Irvine, Stearns, and Hearst. With the intensification of crop production in California, livestock activities tended to grow slowly. Although the smaller family-sized farms began to replace the large bonanza grain farms and livestock ranches, “general” or “mixed” farms modeled on midwestern prototypes remained rare. This is reflected in the relatively small role of swine production in Figure 3. Largely as a result, over the 20th century, livestock production was relatively less important in California than in the country as a whole. For example, over the 1930-97 period, the share of the market value of sales of livestock and livestock products in the combined market value of sales of crops, livestock, and livestock products has almost always exceeded one-half nationally whereas, in California it usually hovered around one-third.

¹⁷ This measure combines livestock into dairy-cow-equivalents using the following weights: dairy cows=1; non-dairy cows=0.73; sheep=0.15; goats=0.15; hogs=0.18; horses and mules=0.88; chickens=0.0043. The weights are derived from FM 64. There may be slight discrepancies arising from their application to census-based animal stock.

¹⁸ U.S. Bureau of the Census, *Census of Agriculture 1959*, General Report, Vol. II.

The chief exceptions to the generalized pattern of slow growth over the early 20th century were dairy and poultry raising. These activities steadily expanded, primarily to serve the state's rapidly growing urban markets. In 1993, California replaced Wisconsin as the nation's number one milk producer.¹⁹ Between 1900 and 1960, the number of milk cows grew at a rate of 1.5 percent per annum and the number of chickens at a 3.3 percent rate. Output growth was even faster as productivity per animal unit expanded enormously, especially in the post-1940 period. From the 1920s, California was a leader in output per dairy cow. For example, in 1924 milk production per dairy cow in California was 5,870 lbs., while similar figures for Wisconsin and the U.S. were 5,280 and 4,167 lbs. respectively.²⁰ A similar pattern is found more recently. In 2000, California dairy cows produced an average of 21,169 lbs. of milk. The U.S. average was 18,204 lbs., while Wisconsin lagged behind with an average of 17,306 lbs.²¹

The post-1940 period also witnessed a dramatic revival of the state's cattle sector outside dairying. The number of non-milk cows in California increased from about 1.4 million head in 1940 (roughly the level prevailing since 1900) to 3.8 million in 1969. This growth was associated with a significant structural change that was pioneered in California and Arizona—the introduction of large-scale commercial feed-lot operations.²² By 1953, large feedlots had emerged as an important feature of the California landscape, with over 92 percent of the cattle on feed in lots of a capacity of 1,000 or more head. Between 1953 and 1963, the number of cattle on feed in California and the capacity of the state's feedlots tripled. At the same time the average size of the lots soared. By 1963, almost 70 percent of the cattle on feed were in mega-lots of 10,000 or more head. A comparison with other areas provides perspective. In 1963, there were 613 feed lots in California with an average of about 3,100 head per lot. By contrast, Iowa had 45,000 feedlots with an average of less than 63 head per lot; Texas had 1,753 feed lots with an average of 511 head per lot. More generally, by the 1960s the size of cattle herds in California far exceeded the national average. Employment of state-of-the-art feed lots and modern science and veterinary medicine along with favorable climatic conditions allowed ranchers in California and Arizona to achieve significant efficiencies in converting feed to cattle weight. In the 1960s, larger commercial feedlots started to become more prevalent in the Southwest and in the Corn Belt.²³ Thus, as in other cases, technologies developed in California spread to reshape agricultural practices in other regions.

MECHANIZATION AND FARM POWER

A hallmark of California agriculture since the wheat era has been its highly mechanized farms. Nineteenth-century observers watched in awe as cumbersome steam tractors and giant combines worked their way across vast fields. In the twentieth century, California farmers led the nation in the adoption of gasoline tractors,

¹⁹ U.S. Department of Agriculture, *Agricultural Statistics*, 1995.

²⁰ U.S. Department of Agriculture, *Statistics Bulletin* 218, 1957.

²¹ U.S. Department of Agriculture, *Agricultural Statistics*, 2002. http://www.usda.gov/nass/pubs/agr02/02_ch8.pdf. The 2002 data are preliminary.

²² Committee on Agriculture, Nutrition, and Forestry, U.S. Senate, "Farm Structure: A Historical Perspective on Changes in the Number and Size of Farms," April 1980.

²³ John A. Hopkin and Robert C. Kramer, *Cattle Feeding in America*, Bank of America, San Francisco, February 1965.

mechanical cotton pickers, sugar beet harvesters, tomato harvesters, electric pumps, and dozens of less well-known machines.

The story of agricultural mechanization in California illustrates the cumulative and reinforcing character of the invention and diffusion processes. Mechanization of one activity set in motion strong economic and cultural forces that encouraged further mechanization of other, sometimes quite different, activities. On-farm mechanization was closely tied to inventive efforts of local mechanics. Specialized crops and growing conditions created demands for new types of equipment. Protected by high transportation costs from competition with large firms located in the Midwest, a local farm implement industry flourished by providing Pacific Coast farmers with equipment especially suited to their requirements. In many instances the inventors designed and perfected prototypes that later captured national and international markets. Grain combines, track-laying tractors, giant land planes, tomato pickers, and sugar beet harvesters, to name but a few, emerged from California's shops.

Several factors contributed to mechanization. In general, California farmers were more educated and more prosperous than farmers in many areas of the country. These advantages gave them the insight and financial wherewithal to support their penchant for tinkering. Nowhere was this more evident than on the bonanza ranches, which often served as the design and testing grounds for harvester prototypes. The large scale of many California farms allowed growers to spread the fixed cost of expensive equipment. The scarcity of labor in California meant relatively high wage rates and periods of uncertain labor supply. The climate and terrain were also favorable. Extensive dry seasons allowed machines to work long hours in near-ideal conditions, and the flat Central Valley offered few obstacles to wheeled equipment. In the cases of small grains and cotton, mechanization was delayed in other regions of the country because free-standing moisture damaged the crops. Such problems were minimal in California. All things considered, the state's climatic and economic conditions were exceptionally conducive to mechanization.

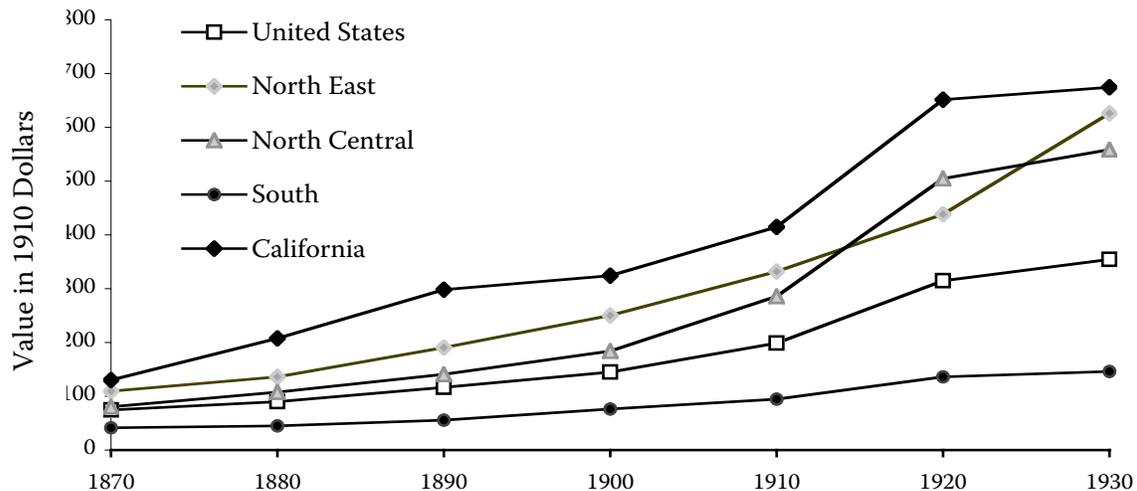
As an index of the level of mechanization, Figure 4 shows the real value of implements per farm in California and other major regions. Over the years 1870 to 1930 the average value of implements per California farm was about double the national average. The new generation of farm equipment of the nineteenth century relied increasingly on horses and mules for power. Horses on any one farm were essentially fixed assets. A stock of horses accumulated for a given task was potentially available at a relatively low variable cost to perform other tasks. Thus, once a farmer increased his pool of horses, he was more likely to adopt new power-intensive equipment. For these reasons, an examination of horses on California farms will yield important insights into the course of mechanization. In 1870 the average number of horses and mules on a California farm was almost three times the national average, and the number of horses and mules per male worker was more than twice the national average. Throughout the nineteenth century, California farmers were using an enormous amount of horsepower.²⁴

California was a leader in the early adoption of tractors. By 1920, over 10 percent of California farms had tractors compared with 3.6 percent for the nation as a whole. In 1925, nearly one-fifth of California farms reported tractors, proportionally more

²⁴ Alan L. Olmstead and Paul Rhode, 1988.

than in Illinois or Iowa, and just behind the nation-leading Dakotas. These figures actually understate the power available in California, because the tractors adopted in the West were, on average, substantially larger than those found elsewhere.²⁵ In particular, western farmers were the predominant users of large track-laying tractors, which were invented in California. The state's farmers were also the nation's pioneers in the utilization of electric power. The world's first purported use of electricity for irrigation pumping took place in the Central Valley just before the turn of the century. Consistent data on rural electricity use are not available until 1929. At that time, over one-half of California farms purchased electric power compared with about one-tenth for the United States as a whole.²⁶ One of the best proxies for electrification is the number of agricultural pumps. Over the period 1910 to 1940, the state accounted for roughly 70 percent of all of the nation's agricultural pumps.²⁷

Figure 4. Real Value of Implements Per Farm, 1870-1930



The abundant supply of power on California farms encouraged local manufacturers to produce new types of equipment, and in turn, the development of new and larger implements often created the need for new sources of power. This process of responding to the opportunities and bottlenecks created by previous technological changes provided a continuing stimulation to innovation. Tracing the changes in wheat farming technology will illustrate how the cumulative technological changes led to a distinctly different path of mechanical development in the West as compared to that which occurred elsewhere.²⁸

²⁵ U.S. Bureau of the Census, *Sixteenth Census of the United States: 1940, Agriculture Vol. 1, Part 6.*

²⁶ *Electrical Times*, January 2, 1948; U.S. Bureau of the Census, *Fifteenth Census of the United States: 1930, Agriculture Vol. 11, Part 3.*

²⁷ In the early period many of these pumps were driven by steam and internal combustion engines.

²⁸ For further development of these general themes, see Nathan Rosenberg, *Inside the Black Box: Technology and Economics*, Cambridge University Press, Cambridge, 1982.

Almost immediately after wheat cultivation began in the state, its farmers developed a distinctive set of cultural practices. Plowing the fertile California soil was nothing like working the rocky soils in the East or the dense sod of the Midwest. In California, ranchers used two, four, and even eight-bottomed gang plows, cutting just a few inches deep. In the East, plowing one-and-one-half acres was a good day's work in 1880. In most of the prairie regions, two-and-one-half acres were the norm. In California, it was common for one man with a gang plow and a team of eight horses to complete six to ten acres per day. The tendency of California's farmers to use larger plows continued into the twentieth century. After tractors came on line, the state's farmers were also noted for using both larger models and larger equipment. This pattern influenced subsequent manufacturing and farming decisions.²⁹

The preference for large plows in California stimulated local investors and manufacturers who vied to capture the specialized market. As evidence of the different focus of their innovative activity, the U.S. Agricultural Commissioner noted that "patents granted on wheel plows in 1869 to residents of California and Oregon largely exceed in number those granted for inventions of a like character from all the other states of the Union."³⁰ Between 1859 and 1873 California accounted for one-quarter of the nation's patenting activity for multi-bottom plows. By way of contrast, the state's contribution to the development of small single-bottom plows was insignificant.³¹ The experience with large plows directly contributed to important developments in the perfection and use of listers, harrows, levelers, and earth-moving equipment.

The adoption of distinctive labor-saving techniques carried over to grain sowing and harvest activities. An 1875 USDA survey showed that over one-half of midwestern farmers used grain drills, but that virtually all California farmers sowed their grain.³² California farmers were sometimes accused of being slovenly for using sowing, a technique which was also common to the more backward American South. However, the use of broadcast sowers in California reflected a rational response to the state's own factor price environment, and bore little resemblance to the hand-sowing techniques practiced in the South. Among the broadcasting equipment used in California were advanced high-capacity endgate seeders of local design. By the 1880s improved models were capable of seeding up to 60 acres in one day. By contrast, a standard drill could seed about 15 acres per day and a man broadcasting by hand could seed roughly 7 acres per day.³³ The use of labor-saving techniques was most evident on the state's bonanza wheat ranches, where some farmers attached a broadcast sower to the back of a gang plow and then attached a harrow behind the sower, thereby accomplishing the plowing, sowing, and harrowing with a single operation.³⁴

California wheat growers also followed a different technological path in their harvest operations by relying primarily on headers instead of reapers. This practice

²⁹ U.S. Bureau of the Census, *Tenth Census of the United States: 1880, Agriculture* Vol. 3; U.S. Department of Agriculture, *Monthly Crop Report*, 1918.

³⁰ U.S. Department of Agriculture, *Agricultural Report*, 1869.

³¹ U.S. Patent Office, *Subject-matter Index of Patents for Inventions Issued by the United States Patent Office from 1790 to 1873, inclusive*, Government Printing Office, Washington, D.C., 1974.

³² U.S. Department of Agriculture, *Agricultural Report*, 1875.

³³ Leo Rogin, *The Introduction of Farm Machinery in its Relation to the Productivity of Labor in the Agriculture of the United States During the Nineteenth Century*, University of California Publications in Economics, Vol. 9, University of California Press, Berkeley, 1931; R.L. Adams, *Farm Management Notes for California*, UC Associated Students' Store, Berkeley, 1921.

³⁴ For example, Reynold Wik, *The Mechanization of Agriculture and the Grain Trade in the Great Central Valley of California*, Pioneer Museum Project Grant Proposal, 1974. A copy is held in the F. Hal Higgins Library of Agricultural Technology at UC Davis; Rogin, 1931.

would have important implications for the subsequent development of combines in California. The header cut only the top of the straw. The cut grain was then transported on a continuous apron to an accompanying wagon. Headers typically had larger cutting bars and, hence, greater capacity than reapers, but the most significant advantage was that headers eliminated the need for binding. The initial cost of the header was about 50 to 100 percent more than the reaper, but its real drawback was in humid areas where the grain was not dry enough to harvest unless it was dead ripe. This involved huge crop risks in the climate of the Midwest, risks that were virtually nonexistent in the dry California summers. For these reasons California became the only substantial market for the header technology.

The header technology evolved in an entirely different direction from the reaper, leading directly to the development in California of a commercial combined harvester. From the starting point of the header, it was quite simple and natural to add a thresher pulled along its side. There had been numerous attempts in the East and Midwest to perfect a machine that reaped and threshed in one operation. Among those that came closest to succeeding was Hiram Moore's combine built in Kalamazoo, Michigan, in 1835. But in the humid Midwest, combining suffered from the same problems with moisture that had plagued heading. In 1853 Moore's invention was given new life when a model was sent to California, where it served as a prototype for combine development.³⁵ After several decades of experimentation in California, workable designs were available by the mid-1880s and the period of large-scale production and adoption began. Most of the innovating firms, including the two leading enterprises—the Stockton Combined Harvester and Agricultural Works and the Holt Company—were located in Stockton.

During the harvest of 1880 “comparatively few” machines operated in California, and agricultural authorities, such as Brewer and Hilgard, clearly suggest that even those machines should be considered as experimental. In 1881 about 20 combines were under construction in Stockton.³⁶ By 1888, between 500 and 600 were in use. The first truly popular model was the Houser, built by the Stockton Combined Harvester and Agricultural Works. In 1889, its advertisements claimed that there were 500 Houser machines in use, and that they outnumbered all of the competitors put together.³⁷ Soon thereafter, machines in the Holt line overtook the Houser. The innovative products of the Holt company, which included in 1893 the first successful hillside combine, became dominant on the West Coast. By 1915 Holt's advertisements boasted that over 90 percent of California's wheat crop was harvested by the 3,000 Holt combines in the state.³⁸ It is important to recognize that the adoption of combine-harvesters east of the Rockies was only in its infancy at this date.

Combine models that eventually were adopted in the Midwest and Great Plains were considerably smaller than West Coast machines. The primary reasons for the differences were undoubtedly cost and scale considerations, but the prejudice in the East that large teams of horses were unworkable and the lack of practice probably played important roles.³⁹ In California the opposite attitudes were said to prevail. The

³⁵ F. Hal Higgins, “John M. Horner and the Development of the Combine Harvester,” *Agricultural History*, Vol. 32, 1958; *Farm Implement News*, 1888.

³⁶ U.S. Bureau of the Census, 1883.

³⁷ Rogin, 1931; William H. Brewer, “Cereal Report,” U.S. Census of 1880, *Agriculture*, Vol. 3, 1883.

³⁸ *Economist*, Nov. 28, 1914.

³⁹ Alan L. Olmstead and Paul W. Rhode, “The Agricultural Mechanization Controversy of the Interwar Years,” *Agricultural History*, Vol. 68, No. 3, Summer 1994.

Pacific Rural Press boasted “(i)f one man could drive all the mules in the State it would be the acme from one point of view.”⁴⁰ California farmers had gradually developed their ability to manage large teams as a result of their experience with gang plows and headers.⁴¹

The difficulties associated with controlling large teams induced Holt and others to perfect huge steam tractors to pull their even larger harvesters. While steam-driven combines never came into vogue, these innovative efforts did have one highly important by-product—the track-laying tractor. The first practical track-laying farm tractors (identified with Holt’s first test in 1904) were initially developed to operate on the soft soil of the Sacramento-San Joaquin Delta.⁴² Although the crawlers were first designed to solve a local problem, this innovation was of global significance. The Caterpillar Tractor Company (formed by the merger of the Holt and Best enterprises) would build larger, more powerful equipment that rapidly spread throughout the world.

The reoccurring pattern of one invention creating new needs and opportunities that led to yet another invention offers important lessons for understanding the lack of development in other times and places. The key to explaining the progression of innovations in California was the close link between manufacturers and farmers that facilitated constant feedback between the two groups and the keen competition among producers that spurred inventive activity. Entrepreneurs seeking their fortunes were in close tune with their potential customers’ needs and vied with one another to perfect equipment that would satisfy those needs. Where these forces were not at work, the burdens of history severed the potential backward linkages that are so critical for economic development.

BRINGING WATER TO THE FIELDS

Just as there were major investments in mechanical technologies to increase the productivity of labor, there were also substantial investments to increase the productivity of California’s land. These included agro-chemical research, biological learning concerning appropriate crops and cultural practices, and land clearing and preparation, but the most notable were investments in water control and provision. These took two related forms. The first consisted of measures primarily intended to drain and protect agricultural land. In this realm, Californians literally re-shaped their landscape as individual farms leveled the fields and constructed thousands of miles of ditches. In addition, individual farms, reclamation districts, and the Army Corps of Engineers built several thousand miles of major levees to tame the state’s inland waterways.

The second form consisted of a variety of measures to supply the state’s farms with irrigation water. Table 1 details the growth in the state’s irrigated acreage between 1890 and 1997. Expansion occurred in two main waves: the first lasting from 1900 through the 1920s and the second, linked to the Central Valley Project, during the decade after World War II. Much of the historical growth of irrigation was the result of small-scale private initiatives rather than large-scale public projects that have

⁴⁰ Wesley Buchele and Graeme Quick, *The Grain Harvesters*, American Society of Agricultural Engineers, St. Joseph, 1978.

⁴¹ Olmstead and Rhode, 1988.

⁴² Caterpillar Tractor Company, *Fifty Years on Tracks*, Caterpillar Tractor Co., Peoria, IL, 1954.

attracted so much scholarly attention. Up until the 1960s, individuals and partnerships were the leading forms of organization supplying irrigation water. These forms accounted for roughly one-third of irrigated acres between 1910 and 1930, and over one-half by 1950.

These small-scale irrigation efforts were closely associated with the rising use of groundwater in California over the first half of the twentieth century. Between 1902 and 1950, the acreage irrigated by groundwater sources increased more than thirty-fold, whereas that watered by surface sources only tripled. Groundwater, which had supplied less than 10 percent of irrigated acreage in 1902, accounted for over 50 percent of the acreage by 1950. This great expansion was reflected in the growing stock of pumping equipment in the state. Underlying this growth were significant technological changes in pumping technology and declining power costs. During the 1910s and 1920s, the number of pumps, pumping plants, and pumped wells doubled each decade, rising from roughly 10,000 units in 1910 to just below 50,000 units in 1930. Pumping capacity increased two-and-one-half to three times per decade over this period. Expansion stalled during the Great Depression, but resumed in the 1940s with the number of pumps, plants, and wells rising to roughly 75,000 units by 1950. Individuals and partnerships dominated pumping, accounting for about 95 percent of total units and approximately 80 percent of capacity over the 1920-50 period.⁴⁵

Since the 1950s, there has been a shift away from individuals and partnerships, as well as groundwater sources. By the 1970s, irrigation districts—public corporations run by local landowners and empowered to tax and issue bonds to purchase or construct, maintain, and operate irrigation works—had become the leading suppliers. The district organization rapidly rose in importance over two periods. In the first, lasting from 1910 to 1930, acreage supplied by irrigation districts increased from one-in-fifteen to approximately one-in-three. Much of this growth came at the expense of cooperative and commercial irrigation enterprises. Between 1930 and 1960, the district share changed little. During the 1960s, the district form experienced a second surge in growth, which was due in part to the rising importance of large-scale federal and state projects, which distributed water through these organizations. By 1969, irrigation districts supplied more than 55 percent of all irrigated acreage.

LABOR

Few issues have invoked more controversy in California than recurrent problems associated with agricultural labor. Steinbeck's portrayal of the clash of cultures in *The Grapes of Wrath* represents the tip of a very large iceberg. The Chinese Exclusion Act, the Gentlemen's Agreement aimed at Japanese immigrants, the repatriation of Mexicans during the Great Depression, the Great Cotton Strikes of 1933, 1938, and 1939, the Bracero Program of the 1940s, '50s, and '60s, the UFW and Teamsters organizing campaigns and national boycotts, the state's Agricultural Relations Act, the legal controversy over the mechanization of the tomato harvest, and the current battles

⁴⁵ Data on pump type are more limited. They show a rise of the turbine, which was used exclusively for well pumping, relative to the centrifugal, rotary, and plunger types. The turbine's share increased from 33 percent in 1930 to 62 percent in 1940. Associated with the 1910-30 expansion was a transition from steam and internal combustion engines to electric motors. In 1910, internal combustion engines comprised about 67 percent of pumping capacity, electric motors 17 percent, and steam engines 11 percent. Over the next twenty years, the relative roles shifted; in 1930, electric motors accounted for 84 percent, internal combustion engines 11 percent, and combinations of the electric and internal combustion methods an additional four percent. By 1950, electric motors made up 92 percent of the total capacity.

over illegal immigration are all part of a reoccurring pattern of turmoil deeply rooted in California's agricultural labor market. There are few if any parallels in other northern states; clearly, the history of agricultural labor in California is very different.

For all the controversy, however, the state's farms have remained a beacon attracting large voluntary movements of workers seeking opportunity. Chinese, Japanese, Sikhs, Filipinos, Southern Europeans, Mexicans, Okies, and then Mexicans again have all taken a turn in California's fields. Each group has its own story, but in the space allotted here we attempt to provide an aggregate perspective on some of the distinguishing characteristics of California's volatile agricultural labor market. The essential characteristics of today's labor market date back to the beginning of the American period.

Table 2 offers a view of the role of hired labor in California compared to the nation as a whole. Expenditures on hired labor relative to farm production and sales have generally been two-to-three times higher in California than for the United States. Within California the trend shows some decline. Another important perspective is to assess the importance of agricultural employment in the economy's total labor force. Here the evidence is somewhat surprising. Both agriculture and agricultural labor play a relatively prominent role in most renderings of the state's history. But as Table 2 indicates, until the last two decades, agricultural employment in California has generally been less important to the state than for the country. Clearly, it is the special nature of the state's labor institutions, not their overall importance in the economy, that warrants our attention.

From the beginning of the American period, California farms have relied more extensively on hired labor than their counterparts in the East. At the same time Californians never developed the institutions of slavery or widespread share-cropping as did their counterparts in the South. The parade of migrants who have toiled in California's fields has often been described as "cheap labor." But this appellation is something of a misnomer, because the daily wage rate in California was typically substantially higher than in other regions of the United States, one of the world's highest wage countries.⁴⁴ In an important sense the "cheap labor" in California agriculture was among the dearest wage labor on the globe.⁴⁵ In addition, one of the remarkable features of California agriculture is that the so-called "development" or "sectoral-productivity" gap—the ratio of income per worker in agriculture to income per worker outside agriculture—has traditionally been relatively narrow.⁴⁶ This finding in part reflects the relatively high productivity of the state's agricultural sector. It also reflects demographic factors. Due to low rates of natural increase, California's farm sector never generated a large home-born surplus population putting downward pressure on rural living standards. Instead, the sector attracted migrants from the surplus populations of other impoverished regions of the world. For these migrant groups, agricultural labor was an entry point into a generally robust and dynamic economy. To a significant extent, past cohorts or their descendants, through hard work and high savings rates, have managed to advance up the occupational ladder.

⁴⁴ The available statistics suggest that circa 1900-10, Asian workers in California were paid within 10-15 percent of the wage of white workers.

⁴⁵ Almost surely, if more migration of non-white population was permitted in the late nineteenth century, the state could have attracted more labor.

⁴⁶ The "development" gap is measured as $(Y_{ag}/L_{ag})/(1-Y_{ag})/(1-L_{ag})$ where Y_{ag} is the share of income generated in the agricultural sector and L_{ag} is the share of the labor force employed there.

Table 2. Agricultural Labor in California and the United States

	Hired Labor Expenditures as a Share of					
	Farm Labor Force as a Share of Total Labor Force		Gross Value of Farm Production		Market Value of Farm Products Sold	
	California %	U.S. %	California %	U.S. %	California %	U.S. %
1870	29.3	52.3	20.8	12.7	--	--
1880	28.6	49.4	--	--	--	--
1890	29.0	41.2	--	--	--	--
1900	25.0	37.6	19.6	7.6	--	--
1910	17.9	31.1	22.2	7.7	--	--
1920	17.3	27.0	16.4	6.3	--	--
1930	13.3	21.4	--	--	21.4	9.9
1940	11.0	18.9	--	--	25.3	11.7
1950	7.5	12.3	--	--	21.8	11.0
1960	4.7	6.7	--	--	17.7	8.5
1970	3.0	3.5	--	--	16.2	7.4
1980	2.9	3.0	--	--	14.7	6.4
1990	3.0	2.5	--	--	17.1	8.0
2000	1.8	1.5	--	--	14.7	7.7

Sources: Margaret Gordon, *Employment Expansion and Population Growth*, UC Press, Berkeley, 1954.

U.S. Dept. of Commerce, *Regional Employment by Industry, 1940-1970*.

U.S. Census Office: *Compendium of the Ninth Census 1870*; U.S. Bureau of the Census: *Twelfth Census 1900, Agriculture*; *Fourteenth Census 1920, Agriculture*, Vol. 5; *Census of Agriculture 1959, California*, Vol. 1, Part 48; *1980 Census, Population*, Vol. 1; *1990 Census, "Labor Force Status and Employment Characteristics: 1990 Data Set: 1990 Summary Tape File 3 (STF 3)—Sample data"* and *2000 Census, "Industry by Sex—Percent Distribution: 2000 Data Set: Census 2000 Summary File 3 (SF 3) —Sample Data"* downloaded at <http://factfinder.census.gov>.

U.S. Dept. of Agriculture, *Census of Agriculture 1997*, Table 1 on "Historical Highlights" for United States and California downloaded from: http://www.nass.usda.gov/census/census97/volume1/us-51/us1_01.pdf and http://www.nass.usda.gov/census/census97/volume1/ca-5/ca1_01.pdf.

Over the long run of California's history, agricultural labor has not been a dead-end pursuit creating a permanent class of peasant laborers. This is an important point, because the agricultural history literature laments the end of the "agricultural ladder," whereby workers start off as laborers or sharecroppers and work their way up to cash tenants and then owners of their own farms. According to the traditional literature, ending this process represents one of the great failings of nineteenth century American society. The literature is particularly critical of California because of its large farms and high ratio of hired workers to farm owners. But a little serious thought suggests how misguided these concerns are. Engel's Law tells us that as income per capita grows, a smaller percentage of income will be spent on food. This suggests that in a growing economy the agricultural sector would diminish in size relative to the non-agricultural sector. At the same time the closing of the frontier meant that the total supply of agricultural land could not continue to grow as it did for most of the nineteenth century. Thus, unless farms were Balkanized into smaller and smaller units there was no possible way for the nineteenth century ideal to have continued. In California, although many members of immigrant groups succeeded to move up the rungs of the

agricultural ladder, the focus on agriculture totally misses the key point. The descendants of the past waves of Chinese, Japanese, Portuguese, Sikh, Italian, and Armenian laborers who now work outside of the agricultural sector are generally not anxious to give up their white and blue collar jobs to return to farming.

Economic historians often explain the prevalence of the family farm in the northern United States by the working of the Domar model—if there is free land and a crop production technology offering little economies of scale and requiring little capital, then anyone can earn as much working for themselves as for anyone else.⁴⁷ There will be no free hired labor, and if bound labor (slavery) is illegal, no farm will be above a family's scale. Like many simple abstract models, the implications of the Domar hypothesis are starker than the realities. But its fundamental logic is thought to explain many central features of the development of northern agriculture.

California's so-called "exceptionalism" also follows from the Domar model. In this state, production tended to involve larger scale and greater quantities of capital (for machinery, irrigation works, and orchards). In addition, due to the environment and the "initial" distribution of property rights, land (especially land with good access to water) was not free in California. Hence, the assumptions of the Domar model were violated. It proved possible for farmers to pay workers more than they could earn working for themselves and still earn a profit. From the mid-nineteenth century on, California was characterized by "factories in the fields" or "industrial agriculture" or, in more modern terms, "agribusiness." But it is important to note that agriculture based on profit-oriented commodity production employing a substantial amount of hired labor was a widespread phenomenon in the period, and by no means limited to California. This organizational form was common to the agriculture of many capitalist countries (i.e., Britain, Germany) in the late-nineteenth century, and it has arguably become increasingly common throughout the United States over the twentieth century. From a global historical perspective, the stereotypical midwestern commercially-oriented family farm employing little or no hired labor is probably a greater exception than what prevailed in California.

International Competition and the Puzzling Success of Labor-Intensive Crops in a High-Wage Economy

Today California farmers often complain about the high cost of labor relative to what their international competitors have to pay. But when the state first moved into the production of specialty crops, California producers of fruit and nuts faced labor costs several times higher than their competitors in the Mediterranean Basin. Given these conditions how did the early Californian producers not only survive, but in many cases actually drive European producers out of markets that were in their own backyards? For many crops such as wheat and cotton, California producers competed by relying more on mechanization to save labor, but that option was less available to orchardists. More fundamentally, the Hechsher-Ohlin model predicts that countries or regions should produce commodities that intensively use their abundant factors and sparingly use their scarce factors. Given this insight, why would the Californians even choose to try to produce labor-intensive crops?

⁴⁷ E. Domar, "The Causes of Slavery or Serfdom," *Journal of Economic History* (1970).

There is no doubt that California was a high-wage economy in the national, not to mention global, context. For example, in 1910, California farmers paid monthly agricultural laborers 71 percent more than did their counterparts nationally; day harvest labor was paid a 36 percent premium. The wage differentials with traditional producing countries in the Mediterranean Basin were much larger, with California farmers paying roughly 4 to 8 times more. Moreover, most fruit and nut crops were characterized by high labor-to-land ratios. For example, the U.S. Department of Agriculture estimated that in 1939 producing almonds on the Pacific Coast required 96 hours per bearing acre, dates 275, figs 155, grapes 200, prunes 130, and walnuts 81 hours; this compared with only 6.6 hours of labor per acre of wheat.⁴⁸

Underlying the Hechsher-Ohlin analysis is the notion that wheat farmers competed directly with fruit and nut growers for the labor and land. But this notion needs to be qualified in ways that help explain the success of California fruit producers. On the Pacific Coast, the labor requirements of both activities were highly seasonal and their peak harvest demands did not fully overlap. In California, for example, the wheat harvest was typically completed by early July whereas the raisin and wine grape harvest did not commence until September and continued through late October. Hence, a worker could, in principle, participate fully both in the grain and grape harvests. Rather than conceiving of the different crops as being competitive in labor, we might be better served by considering them as complimentary. As an example, in the lush Santa Clara Valley harvest workers would migrate from cherries to apricots to prunes to walnuts and almonds over a roughly six month season. Adding other semi-tropical crops, such as cotton and navel oranges, stretched the harvest season in large sections of California into the winter months. By filling out the work year and reducing seasonal underemployment, the cultivation of a range of crops in close proximity increased the attractiveness to labor of working in Pacific Coast agriculture. The succession of peak-load, high-wage periods allowed California workers more days of high-intensity and high-pay work in a year than was possible in most other regions.⁴⁹

It is also important to recognize that the land used for grain and fruit crops was largely “non-competing.” Prime quality fruit lands, with the accompanying climatic conditions, were so different from the lands that remained in grain production that they constituted a “specific input.” Differences in the land values help bring these points home. According to R. L. Adams’ 1921 California farm manual, the market value of “good” wheat land in the state was approximately \$100 per acre in the period immediately before the First World War. “Good” land for prune production was worth \$350 even before planting and valued at \$800 when bearing. The “best” land for prunes had a market value of \$500 not planted and \$1000 in bearing trees. Similarly, “good” land for raisin grape production was worth \$150 raw and \$300 in bearing vines; the “best” sold for \$250 not planted and \$400 bearing. Focusing on physical labor-to-land ratios in comparing wheat and fruit production can be seriously misleading because the

⁴⁸ Rueben W. Hecht and Glen T. Barton, *Gains in Productivity of Labor*, USDA Technical Bulletin No. 1020. Washington, D.C.: USDA, Dec. 1950, pp. 38, 98.

⁴⁹ This argument also draws attention to the important role of labor mobility in the region’s agricultural development, and in particular to the manifold and often conflicting efforts of local authorities to encourage, discourage, and otherwise control the migrant flows of specific ethnic groups. By focusing on the political economy of migration, this literature helps undermine the notion that labor scarcity was a “natural” immutable feature of the region. Rather it was in part an outcome of collective political decisions. The migrant flows presumably would have been far larger but for exclusionary agitation and legislation.

acreage used for fruit cultivation was of a different quality (and ultimately higher market value) than that used for grains.⁵⁰

A further reason why horticultural crops could compete was that, unlike the key agricultural staples, many fruit and nut products enjoyed effective tariff protection during the late-19th and early-20th centuries. Tariffs almost surely sped up the growth of Mediterranean agriculture in the United States and were strongly supported by domestic producers, railroads, and packers.⁵¹ One of the recurrent justifications for tariffs offered by domestic growers was to help offset high transportation differentials. Almost across the board, Mediterranean producers enjoyed lower freight rates to the key markets of the northeastern United States (not to mention northern Europe) than their American rivals did. For example, circa 1909, shipping currants from Greece to New York cost 17 cents per hundred weight while the freight on an equivalent quantity of California dried fruit averaged about one dollar.⁵²

For the Pacific Coast fruit industry, the cost of transportation remained an important factor, shaping production and processing practices. This is reflected in an observation that has entered textbook economics, that the best apples are exported because they can bear the cost of shipping. It also helps explain one of the defining characteristics of the region's fruit industry, its emphasis on quality. Local producers and packers devoted exceptional efforts to improving grading and quality control, removing culls, stems and dirt, reducing spoilage in shipment, and developing brand-names and high quality reputations. This focus makes sense given the high transportation cost that western producers faced in reaching the markets of the U.S. Atlantic Coast and Europe.

To a large extent, the ability of Californians to compete with the growers in southern Europe depended on capturing the higher end of the market. With only a few exceptions, California dried fruits earned higher prices than their European competition because the state's growers gained a reputation for quality and consistency. As an example, the U.S. produced far higher quality prunes than Serbia and Bosnia, the major competitors, and as a result American prunes sold for roughly twice the price of the Balkan product in European markets. Not only were California prunes larger, they also enjoyed other significant quality advantages stemming from the state's better dehydrating, packing, and shipping methods.⁵³ Similar quality advantages applied virtually across the board for California's horticultural crops.

It is interesting to note that at least some of California's current problems with foreign competition stem directly from the ability of others to copy the state's methods. After the California horticultural industry established its strong market presence, the message eventually got through to other producers. The extensive efforts that producers in other New Areas (such as South Africa, Chile, and Australia) and in Europe made to copy the California model provides another indicator of the

⁵⁰ For an analysis of the competition between wheat and fruit for an earlier period, see Rhode, "Learning," pp.773-800. R. L. Adams, *Farm Management Notes* (Berkeley, University of California Associated Students' Store, 1921), pp. 53, 81, 97.

⁵¹ But it is worth noting that prunes and raisins successfully competed in international markets by the mid-1890s, suggesting that, in the known absence of dumping policies that discriminated between domestic and foreign markets, the tariffs on these crops had little remaining impact. These cases conform nicely to the prescriptions of those favoring infant industry protection. The tariffs helped the industries, comprised of a large number of small producers, overcome high learning costs, but market forces ceased to have significant adverse efficiency or distribution effects once the industries matured. By contrast, the tariffs on fresh grapes, figs, dates, and the nut crops appear to have had a continuing impact on imports, prices, domestic production, and grower profits through the 1930s.

⁵² The U.S. competitive disadvantage was declining over time. Transportation rates on Greek currants declined by roughly one-third in real terms between 1889 and 1909; those on California raisins by more than one-half.

⁵³ Shear, *Prune*, pp. 5, 37-57; Stroykowitz, *Recherches*, pp. 186-93.

importance of superior technology and organization in establishing California's comparative advantage.

COOPERATIVES

California agriculture was uncommonly successful with collective action. By the 1930s, the state's farmers supported a powerful Farm Bureau, organized labor recruitment programs, numerous water cooperatives and irrigation districts, and a vast agricultural research establishment. Here we will focus on the state's experience with cooperatives designated to provide farmers with an element of control over the increasingly important marketing, middleman, and input supply functions. One of the most notable was the California Fruit Growers Exchange organized in 1905. By 1910 it marketed 60 percent of the citrus shipped from California and Arizona under its Sunkist label; in 1918 it marketed 76 percent of all shipments, and for most years between 1918 and 1960 Sunkist accounted for over 70 percent of citrus shipments.⁵⁴ The Exchange also entered the farm supply business through its subsidiary, the Fruit Growers Supply Company. In the late 1920s it was purchasing for its members \$10,000,000 a year worth of nails, tissue wraps, fertilizer, orchard heaters, box labels, orchard stock and the like. The company also controlled 70,000 acres of California timber land and manufactured huge quantities of boxes.⁵⁵

Other co-ops emerged catering to California's specialized producers. After more than 20 years of unsuccessful experiments, raisin growers banded together in the California Associated Raisin Company (CARC) in 1911. Between 1913 and 1922 the CARC handled between 87 percent and 92 percent of the California raisin crop, successfully driving up prices and members' incomes. But success brought Federal Trade Commission investigations and an anti-trust suit, which the CARC lost in 1922. In 1923 CARC was reorganized into Sun Maid Raisin Growers of California. Although that brand name still survives, the co-op was never again as successful as it was in its first decade.

Co-ops potentially offered their members several services. First, they could help counteract the local monopoly power of railroads, elevators, packers, banks, fertilizer companies and the like by collectively bargaining for their members; or as in the case of the California Fruit Growers Exchange, the co-op could enter into the production of key inputs and offer its own warehouses, elevators, and marketing services. Several co-ops representing various specialized crops have developed very successful marketing campaigns that have significantly increased consumer awareness and consumption.

While perhaps providing countervailing power and overcoming market imperfections on the output side, many co-ops strove to introduce their own imperfections by cartelizing the markets for agricultural goods. A leader in this movement was a dynamic lawyer, Aaron Sapiro, who had worked with several of California's co-ops in the early twentieth century. His plan was to convince farmers to sign legally binding contracts to sell all of their output to the co-op for several (typically five) years. If a high percentage of producers in fact signed and abided by such contracts, then the co-op could act as a monopolist limiting supply and increasing

⁵⁴ Kelsey B. Gardner and Irwin W. Rust, *Sunkist Growers, Inc.: A California Adventure in Agricultural Cooperation*, USDA, Farmer Cooperative Service, Circular 27, 1960.

⁵⁵ Cleland and Hardy, 1929; Elizabeth Hoffman and Gary D. Libecap, "Institutional Choice and the Development of U.S. Agricultural Policies in the 1920s," *Journal of Economic History*, Vol. 51, No. 2, June 1991.

prices. Since the demand for agricultural products is generally thought to be highly inelastic, farm income would rise. The surpluses withheld from the market would either be destroyed or dumped onto the world market. The co-op could also help increase demand by advertising and developing new markets.

The whole scheme depended on: (1) avoiding federal anti-trust actions like that which hit the raisin growers between 1919 and 1922; (2) preventing foreign producers from importing into the high priced American market; and (3) overcoming the free-rider problem. Even if these problems could be solved in the short-run, the longer-run problems of controlling supply in the face of technological change and increasing productivity in other countries would still exist.

The first two problems were fairly easily dealt with. The cooperative movement received federal encouragement in the form of highly favorable tax treatment and considerable exemption from anti-trust prosecution with the passage of the Capper-Volstead Act in 1922. Subsequently, the Cooperative Marketing Act of 1926 and the Agricultural Marketing Act of 1929 further assisted the cooperative movement by helping to gather market information (that was useful in limiting production and generating new market outlets), and by helping co-ops enforce production and marketing rules. In addition, the 1929 Act provided up to \$500 million through the Federal Farm Board to loan to cooperatives so they could buy and store commodities to hold them off the market.

The federal government also provided a shot in the arm to the cooperative movement through a series of tariff acts that separated the domestic and foreign markets. The tariffs were in large part endogenous because co-op leaders and California legislators lobbied furiously for protection. But overcoming the “free rider” problem was a harder nut to crack. Every farmer benefited from the co-op’s ability to cut output, and every farmer would maximize by selling more. There was thus a tremendous incentive to cheat on the cartel agreements or to not sign up in the first place. The early California fruit co-ops were successful in large part because they dealt with crops grown in a fairly small geo-climatic zone for which California was the major producer. Many growers were already members of cooperative irrigation districts and thus linked by a common bond. These factors made it much easier to organize and police the growers, and it reduced the chance that higher prices would immediately lead to new entrants who would, in a short time, drive the price level down. The fact that most output was exported out of the state via relatively few rail lines also made monitoring easier. If California raisin prices increased, it was not likely that Minnesota farmers would enter the grape market; but if Kansas wheat farmers banded together to limit their output, farmers in a dozen states would gladly pick up the slack. For these reasons the success of cooperatives in California was seldom matched elsewhere in the United States.

CONCLUSION

This essay has necessarily been cursory, neglecting many important crops and activities.⁵⁶ Nevertheless, it should provide a historical context for other chapters in

⁵⁶ More so than most states, California’s agricultural economy is really many economies. The grape and wine industries, the specialized citrus economy, the growers of vegetables, and many others have stories of their own that deserve detailed analysis. In a similar vein, our treatment of mechanization represents only a fraction of the more general category of science, technology, and productivity change.

this volume. Responding to market forces, the state has witnessed numerous transformations in cropping patterns, labor sources, and technologies. Among these changes, however, many fundamental characteristics have endured; many of the institutional and structural features found today have deep roots in the state's past.

In closing, we would like to comment on two issues of interest in the literature of agricultural development. First, the history of agricultural mechanization in California appears to conform nicely with the familiar predictions of the induced innovation model: mechanization represented a rational response by the state's farmers and mechanics to factor scarcities and the state's particular environmental conditions. But to fully capture the reality of the state's development, it is useful to supplement the induced innovation model with three additional insights: the importance of path dependency (whereby early investment decisions paved the way for subsequent developments); the importance of learning by doing; and the close, ongoing interactions between farmers and inventor-manufacturers.

Secondly, California's history does not conform to the standard paradigm that treats biological productivity changes as primarily a post-1930 phenomenon in American agriculture. The settlement process, the worldwide search for appropriate crops and cultural practices, the wholesale shift in crop mixes, and the massive investments in water control and irrigation, along with numerous other measures, are fundamentally stories of biological investment in a labor-scarce, land-abundant environment. These biological investments transformed the state's agriculture, vastly increasing productivity per acre.⁵⁷

⁵⁷ Alan L. Olmstead and Paul Rhode, "Induced Innovation in American Agriculture: A Reconsideration," *Journal of Political Economy*, Vol. 101, No. 1, 1993.

REFERENCES

- Adams, R.L. *Farm Management Notes for California*. University of California Associated Students' Store, Berkeley, 1921.
- Andrews, Frank. "Marketing Grain and Livestock in the Pacific Region," Bureau of Statistics, Bulletin 89, 1911.
- Blanchard, Henry F. "Improvement of the Wheat Crop in California," USDA Bulletin No. 178, 1910.
- Brewer, William H. "Cereal Report," U.S. Census of 1880, *Agriculture*, Vol. 3, 1883.
- Buchele, Wesley and Graeme Quick. *The Grain Harvesters*. American Society of Agricultural Engineers, St. Joseph, 1978.
- Burns, J. "A Pioneer Fruit Region," *Overland Monthly*, 2nd Series, Vol. 12, No. 67, 1888.
- California Committee to Survey the Agricultural Labor Resources. *Agricultural Labor in the San Joaquin Valley: Final Report and Recommendations*. Sacramento, March 15, 1951.
- California Cotton Journal*, April, 1926.
- Caterpillar Tractor Company. *Fifty Years on Tracks*. Caterpillar Tractor Company, Peoria, 1954.
- Cleland, Robert Glass and Osgood Hardy. *March of Industry*. Powell, Los Angeles, 1929.
- Committee on Agriculture, Nutrition, and Forestry, U.S. Senate. "Farm Structure: A Historical Perspective on Changes in the Number and Size of Farms," April, 1980.
- Critz, José Morilla, Alan L. Olmstead and Paul W. Rhode, "'Horn of Plenty': The Globalization of Mediterranean Horticulture and the Economic Development of Southern Europe, 1880-1930," *Journal of Economic History*, Vol. 59, No. 2, June 1999.
- Domar, Evsey "The Causes of Slavery or Serfdom," *Journal of Economic History*, Vol. 30, No.1, March, 1970.
- Economist*, November 28, 1914.
- Electrical Times*, January 2, 1948.
- Farm Implement News*, 1888.
- Fisher, Lloyd H. *The Harvest Labor Market in California*. Harvard University Press, Cambridge, 1953.
- Gardner, Kelsey B. and Irwin W. Rust. *Sunkist Growers, Inc.: A California Adventure in Agricultural Cooperation*. USDA Farmer Cooperative Service, Circular 27, 1960.
- Margaret Gordon, *Employment Expansion and Population Growth*. UC Press, Berkeley, 1954.
- Hecht, Rueben W. and Glen T. Barton. *Gains in Productivity of Labor*. USDA Technical Bulletin No. 1020. Washington, D.C.: USDA, Dec. 1950.
- Higgins, F. Hal. "John M. Horner and the Development of the Combine Harvester," *Agricultural History*, Vol. 32, 1958.
- Hodgson, Robert. "California Fruit Industry," *Economic Geography*, Vol. 9, No. 4, 1993.
- Hoffman, Elizabeth and Gary D. Libecap. "Institutional Choice and the Development of U.S. Agricultural Policies in the 1920s," *Journal of Economic History*, Vol. 51, No. 2, June 1991.
- Hopkin, Dr. John A. and Dr. Robert C. Kramer. *Cattle Feeding in America*. Bank of America, San Francisco, February 1965.
- Los Angeles Times*, *Farm and Tractor Section*, May 8, 1921.
- Musoke, Moses S. and Alan L. Olmstead. "The Rise of the Cotton Industry in California: A Comparative Perspective," *Journal of Economic History*, Vol. 42, No. 2, June 1982.
- Olmstead, Alan L. and Paul W. Rhode. "An Overview of California Agricultural Mechanization, 1870-1930," *Agricultural History*, Vol. 62, No. 3, 1988.
- . "Induced Innovation in American Agriculture: A Reconsideration," *Journal of Political Economy*, Vol. 101, No. 1, 1993.
- . "The Agricultural Mechanization Controversy of the Interwar Years," *Agricultural History*, Vol. 68, No. 3, Summer 1994.

- . "The Red Queen and the Hard Reds: Productivity Growth in American Wheat, 1800-1940," *Journal of Economic History*, Vol. 62, No. 4, December 2002.
- Pacific Rural Press, April 2, 1927.
- Parker, William. "Agriculture," *American Economic Growth: An Economist's History of the United States*. Lance Davis et al., Editors. Harper and Row, New York, 1972.
- Rhode, Paul W. "Learning, Capital Accumulation, and the Transformation of California Agriculture," *Journal of Economic History*, Vol. 55, No. 4, December 1995.
- Rogin, Leo. *The Introduction of Farm Machinery in its Relation to the Productivity of Labor in the Agriculture of the United States During the Nineteenth Century*. University of California Publications in Economics, Vol. 9, University of California Press, Berkeley, 1931.
- Rosenberg, Nathan. *Inside the Black Box: Technology and Economics*. Cambridge University Press, Cambridge, 1982.
- Shaw, G.W. "A Preliminary Progress Report of Cereal Investigations, 1905-07," *California Agricultural Experiment Station Circular No. 28*, January 1907.
- . "How to Increase the Yield of Wheat in California." California Agricultural Experiment Station Bulletin No. 211. Berkeley, California Agricultural Experiment Station, 1911.
- Shear, S.W. *Prune Supply and Price Situation*. California Agricultural Experiment Station Bulletin No. 462. Berkeley, 1928.
- Stroykowitch, Wélimir. *Recherches physiologiques sur la prune, et étude les méthodes à employer pour l'amélioration de l'industrie prunière en Serbie*. Nancy. Imprimerie Universelle Marcel Vagner, 1910.
- Teague, Charles. *Fifty Years A Rancher: The Recollections of Half a Century Devoted to the Citrus and Walnut Industries of California and to Furthering the Cooperative Movement in Agriculture*. Ward Ritchie, Los Angeles, 1944.
- Tufts, Warren. "Rich Pattern of California Crops," In *California Agriculture*, Claude B. Hutchison, Editor. University of California Press, Berkeley, 1946.
- USDA. Technical Bulletin No. 1020, pp. 38, 98.
- U.S. Bureau of the Census. *Tenth Census of the United States 1880*. Agriculture, Vol. 3, 1883.
- . *Tenth Census of the United States 1880*. Vol. 6, Cotton Production, Part 2--Eastern, Gulf, Atlantic, and Pacific States, 1884.
- . *Twelfth Census of the United States 1900*. Agriculture.
- . *Fourteenth Census of the United States 1920*. Agriculture, Vol. 5.
- . *Fifteenth Census of the United States 1930*. Agriculture, Vol. 11, Part 3--The Western State, 1932.
- . *Fifteenth Census of the United States 1930*. Agriculture, Vol. 4
- . *Sixteenth Census of the United States 1940*. Agriculture, Vol. 1, Part 6, 1942.
- . *U.S. Census of Agriculture 1959*. California, Vol. 1, Part 48.
- . *U.S. Census of Agriculture 1959*. General Report, Vol. II, Statistics by Subject, 1961.
- . *U.S. Census of Agriculture 1959*. General Report, Vol. II, Statistics by Subject, 1962.
- . *1980 Census, Population*, Vol. 1.
- . *1980 Census of Population*, California, Vol. 1, Part 6.
- . *1990 Census*, "Labor Force Status and Employment Characteristics: 1990 Data Set: 1990 Summary Tape File 3 (STF 3) —Sample data."
- . *1990 Census of Population*, California, Section 1.
- . *2000 Census*, "Industry by Sex—Percent Distribution: 2000 Data Set: Census 2000 Summary File 3 (SF 3) —Sample Data" downloaded at <http://factfinder.census.gov>.
- U.S. Census Office. *Compendium of the Ninth Census 1870*.
- U.S. Department of Agriculture. *Agricultural Report*. 1869.
- . *Agricultural Report*. 1875.
- . *Monthly Crop Report*. 1918.

----- . *Statistics Bulletin 218*. 1957.

----- . *Agricultural Statistics*. 1995.

----- . http://www.nass.usda.gov/census/census97/volume1/us-51/us1_01.pdf.

----- . http://www.nass.usda.gov/census/census97/volume1/ca-5/ca1_01.pdf.

U.S. Dept. of Commerce. *Regional Employment by Industry, 1940-1970*.

U.S. Patent Office. *Subject-matter Index of Patents for Inventions Issued by the United States Patent Office from 1790 to 1873, inclusive*. 1974.

U.S. Weather Bureau. *Climatology of California, Bulletin L*. 1903.

Wickson, Edward. *California Fruit*. Pacific Rural Press, San Francisco, 1900.

Wik, Reynold. *The Mechanization of Agriculture and the Grain Trade in the Great Central Valley of California*. Pioneer Museum Project Grant Proposal, 1974.