CLIMATE AND AGRICULTURE IN CALIFORNIA

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CALIFORNIANS pride themselves on the contrast and variety of their state. The average citizen knows that from the highest point of land in the United States, Mt. Whitney, it is possible to look down into the lowest, Death Valley; that one can spend his winter week-end either skiing in the Sierras or golfing near the coast; that on a midsummer day one can drive within two or three hours from dry scorching heat in the interior valley to a seashore definitely cool and probably foggy, or can wait for night to fall and bring with it comfortable temperatures. These contrasts find professional expression in the fact that Russell (R. J. Russell: Climates of California, *University of California Publications in Geography*, Vol. 2, 1926, pp. 73–84) and Thornthwaite (C. W. Thornthwaite: The Climates of North America, *Geographical Review*, Vol. 21, 1931, pp. 633–655; The Climates of the Earth, *ibid.*, Vol. 23, 1933, pp. 433–440) each distinguish eleven types of climate within the boundaries of the state. On Thornthwaite's basis of classification (not identical with Russell's), only ten additional types can be found elsewhere in the world's temperate zones. No other state of the Union offers so wide a range: even the vast expanse of Texas contains only five climates, and large states like Alabama, New York, Iowa, and North Dakota only two.

Contrast and variety also characterize the agriculture of California. Here the subtropical lemon can be seen growing in the next field to the sugar beet that flourishes in Michigan or Denmark; the warmth-loving olive within a few miles of the apple that will survive New England winters; moisture-loving rice beside drought-resisting barley and grain sorghums. The characteristic cultivated plants and trees of the temperate and subtropical zones, whether wet or dry, are mingled in the agriculture of California. Here are found also, and in substantial numbers, all of the important draft animals and the productive animals and birds outside of the tropics—horses, cattle, swine, sheep, goats, hens, turkeys, ducks, and geese.

Baker has said of California: "No other state compares with it in variety of crops." (O. E. Baker: Agricultural Regions of North America. Part VIII. The Pacific Subtropical Crops Region, *Economic Geography*, Vol. 6, 1930, pp. 166–190, 278–308.) He remarked further that the Census gives reports for California on the production of every grain crop, every kind of hay, every vegetable, every fruit, and every other crop grown and reported upon in the United States with the trifling exceptions of horseradish, kumquats, pineapples, mangoes, sugar apples, sapodillas, sugar cane, maple syrup, castor beans, chufas, ginseng, peppermint, and teasels. And even some of these are absent only in the sense that census officials find them so unimportant as not to warrant counting the acreages.

Another aspect of variety in Californian agriculture is the presence within the state of thirteen dominant types of farming, broadly distinguishable one from the other on the basis of proportional contribution of different farm products to the farmer's income. There are only twenty such dominant types of farming in the United States; no other state boasts more than ten; and most

states have only four or five. (See map: Type-of-Farming Areas in the United States, 1930, by U. S. Bureau of Census, Department of Commerce, in coöperation with Bureau of Agricultural Economics, Department of Agriculture.)

CLIMATIC DIVERSITY

It is natural to ascribe the diversity of Californian agriculture to the diversity of climate, and to regard this diversity of agriculture as notably exceptional among the agricultures of the world.

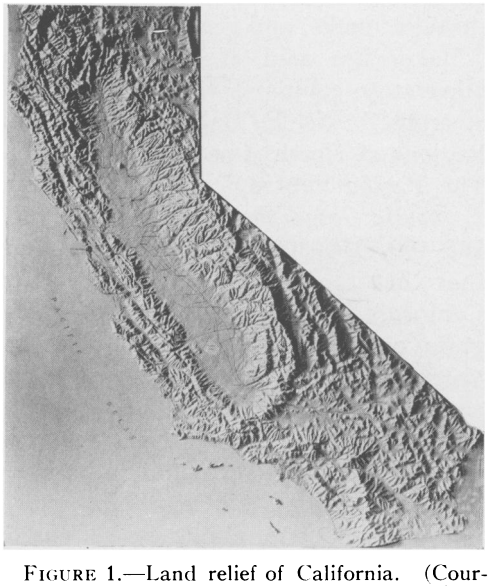

FIGURE 1.—Land relief of California. (Courtesy of Department of Geology, Stanford University. Model by N. F. Drake.)

But the climates are not strikingly diverse within the principal agricultural area of California where the crops are grown. Indeed, they resemble a theme with variations. The "agricultural area" includes the flat and rolling lands with soil suitable to plow. Almost all of this agricultural area lies within the great interior valley of the Sacramento and San Joaquin rivers; the smaller intermontane valleys of the Coast Range particularly those of Sonoma, Napa, Santa Clara, and Salinas; the coastal plains around Eureka, Santa Cruz, San Luis Obispo, Los Angeles, and San Diego; and, inland, the Imperial Valley in the south and in the northeast the broken plateau of Modoc and Lassen counties. The great interior valley is much the largest of these subdivisions of the agricultural area.

The agricultural area is in general characterized by a climate variously called "Mediterranean," or "dry subtropical," or "subhumid to semi-arid, mesothermal, with deficiency of rain in summer." Its salient features are moderate to scanty annual rainfall; a long frost-free season; and a seasonal distribution of precipitation such that the great bulk of it comes in the late autumn and winter, and little or none in late spring and summer.

Among twelve cities scattered throughout the agricultural area (excluding the interior northeastern plateau and the Imperial Valley), the range of annual rainfall is from an average of only 8.3 inches at Hanford in the southern stretch of the great interior valley, to 39.0 inches at Eureka on the northwestern coast. As Figure 2 shows, the growing season (average frost-free period) is long. Among the twelve cities referred to, it ranges from 204 and 205 days respectively at Santa Rosa and King City in coast-range valleys, one north and one south of San Francisco, to 359 days at Los Angeles on the southwestern coast and 305 days both at Sacramento in the north-central part of the interior valley and at San Jose at the southern extremity of San Francisco Bay. The growing season tends to be shortest in the intermontane valleys of the Coast Range. Winter temperatures practically everywhere preclude snow and permit late autumn sprouting and some degree of winter

growth of natural grasses or sown grains.

The rainiest four months at all twelve points are December-March; the driest, either May-August or June-September. Only two of the twelve stations get as much as an inch of rain in any month of the five-month period May-September; these two are Eureka and Santa Rosa in the northwestern portion of the state. Drought therefore prevails for nearly half of the year; and late in April over most of the agricultural area the green-clad countryside begins to turn brown, to remain so until November or December. In the hottest month of the droughty summer season, maximum temperatures (see Figure 2) may average nearly 100 degrees Fahrenheit, especially in the interior valley; but the intermontane valleys of the Coast Range, and particularly the coastal plains, are cooler. In the interior valley itself the nights are much cooler than the days, as is suggested by comparison of the monthly averages of daily maximum and of daily minimum temperatures shown in the chart.

CHARACTERISTICS OF CLIMATE

Broadly similar climates are found elsewhere in the world. Like the climate of the agricultural area of California, they center around the 35th degree parallel in each hemisphere, lie on western exposures of continental land masses, and merge into true desert climates on their equatorial fringes. The largest land mass covered by this general type of climate borders the Mediterranean Sea—whence the common name. This is the climate roughly of the southern portions of Spain, Italy, and Greece; of the western fringe of Asia Minor; of the northern portions of Tunis, Algeria, and Morocco. It is the climate of central Chile west of the Andes; of the southern tip of Africa; and of the westward-facing southern coastlands of Australia.

Figure 3 summarizes climatological data (monthly average precipitation and temperatures) at eight cities located within the four climatic areas akin to that of the agricultural area of California, and also for two points in California—Santa Cruz on the coast, relatively moist and cool, and Merced in the interior valley, relatively dry and hot. The annual precipitation at two of these eight foreign cities exceeds that at Santa Cruz (but is below that of Eureka); in all of them it is higher than at Merced. In most of the foreign

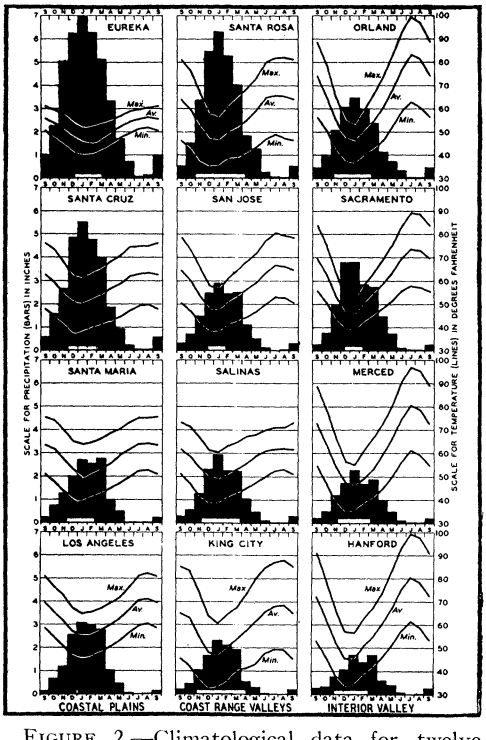

FIGURE 2.—Climatological data for twelve stations in the agricultural area of California. Vertical black bars represent monthly average precipitation; horizontal white bars, average span between first and last killing frost; successive solid lines, monthly means respectively of daily maximum, daily average, and daily minimum temperatures. (Long-term averages from U. S. Weather Bureau, *Climatic Summary of the United States*, Sections 15–18.)

points, winter temperatures are higher than those at Merced, but summer temperatures are not so high except at Athens and Beirut. At most of the foreign points, the seasonal distribution of rainfall differs from the characteristic Californian distribution in three respects: the month of heaviest rainfall is November or December (in the Southern Hemisphere, June) rather than December or January; the rainy season extends a little later into the spring, May rainfall being somewhat more abundant than in California; and the drought season of June-September is not quite so dry. Tentatively, the generalization may be ventured that characteristically, both the seasonal rise of temperature and the seasonal decline of precipitation from January (July in the Southern Hemisphere) to the late spring are on the whole more rapid in California than in most other climates similar in general type.

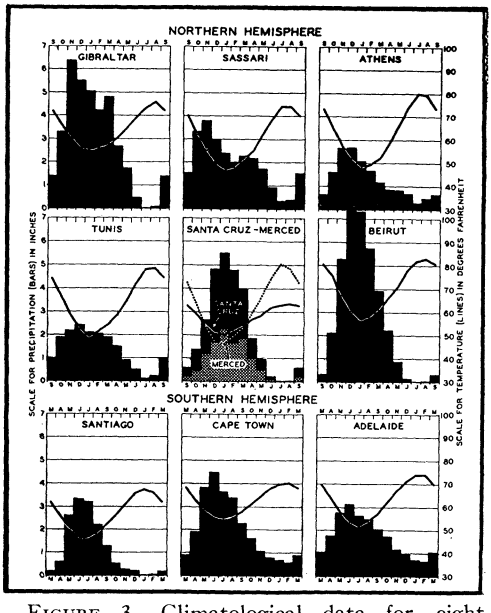

FIGURE 3.—Climatological data for eight foreign stations in regions of Mediterranean climate, and for two stations in California. Vertical bars represent long-term monthly average precipitation; horizontally running lines monthly means of daily average temperatures which in turn are usually means of daily maximum and daily minimum. (Foreign data from *Smithsonian Miscellaneous Collections*, Vol. 79 [1927]; for source of California data see Figure 1.)

Within these sister climates, the range of agricultural products is very much the same as in California. These are lands where irrigated agriculture mingles with dry farming. Over wide stretches they are warm enough for rice, citrus fruits, and cotton, if irrigated, but cool enough for irrigated sugar beets. They are dry enough, but in wide areas not too dry, for unirrigated wheat and barley, which in the stretches that approach deserts are commonly grown in rotation with fallow so as to conserve moisture. They are eminently well suited to grapevines, olives, apricots, plums, and almonds, which grow well in the moister reaches unirrigated, and in the drier stretches under irrigation. Perhaps the most typical unirrigated crops are wheat, barley, beans, grapes, apricots, almonds, and olives.

Without irrigation, the Mediterranean climate generally is not well adapted to growth of grass, leguminous hay, rice, corn, grain sorghums, cotton, tobacco, or root crops like potatoes, sugar beets, and turnips. Only in the restricted regions that are *both* warm and wet is it adapted to citrus fruits. In general, all of these crops require a longer time to grow and more moisture in their growing season than the Mediterranean climate provides. The weeks are few between the cool winter when plant growth must at best be slow, and the onset of drought in the late spring or early summer. In this respect, California is perhaps the least favored of the Mediterranean climates.

From the agricultural point of view, the Mediterranean climate, without irrigation, is not highly productive. The span is too short between the winter season when annual plants can make

little growth and the practically rainless summer season when growth must cease. This prevents cultivation of the productive slow-maturing annual plants, and also tends to hold down the per-acre yield of some of the rapidly-maturing and less productive annual plants. (For example, the postwar average yield per acre of wheat within Mediterranean regions of substantial size very rarely equals 15 bushels, and often falls below 10 bushels. See M. K. Bennett and Helen C. Farnsworth: World Wheat Acreage, Yields, and Climates, *Wheat Studies*, Vol. 13, 1937, tabulations on pp. 303–308.) Steeply declining rainfall accompanied by rising temperatures in the period between sowing and harvest is not favorable to yields of such plants. Nitrogenous fertilizers, as in all dry climates, are not effective in enhancing yields, though phosphates are of vital importance in the phosphate-deficient soils of Australia. Rotations that exclude fallow are difficult to develop. The peculiar virtue of the Mediterranean climate unmodified by irrigation is, in its moderately moist stretches, the advantages it affords for grapes and a rather wide range of fruits and nuts. Among these advantages are relative infrequency of hail or of strong winds, and the dry sunny summer that facilitates curing of fruits

Wherever irrigation is feasible in the Mediterranean climates, it is possible to expand the range of crops grown to include both those of moisture-loving subtropical types like the citrus fruits, rice, and cotton, and the moisture-loving temperate-zone types like corn, alfalfa, sugar beets, and tender vegetables. The subtropical types, however, naturally tend to be grown in the warmer parts of any Mediterranean climate, the temperate-zone types in the cooler parts. Irrigation also widens the geographical spread of vines, fruits, and

FIGURE 4.—Snow pack in the Sierras: Stored water for irrigation. (Courtesy of California State Chamber of Commerce.)

nuts in any Mediterranean climate by supplying moisture to carry them through the summer drought. In the warmer stretches, irrigation also permits the production of two or three crops of rapidly-maturing vegetables from a field in one year.

CONCENTRATION OF AGRICULTURE

Thus Californian agriculture is not distinguished from the agriculture of other regions with the Mediterranean type of climate by the variety or range of its products. First and foremost it is distinguished by a far different concentration within the range—a concentration due fundamentally to the wider prevalence of irrigation.

At present the area of California farms is about 30.5 million acres. More than two-thirds of it is woodland and pasture. Somewhat less than the third that remains may be called cultivated land. Of this cultivated land, covering about 8.7 million acres, nearly a fourth is usually unproductive—either in fallow, or idle because it is not planted or because the planted crops fail. Over a third of the cultivated land is used for crops of intensive or semi-intensive types, those involving much labor and capital and little land. Among the

intensive are counted the grapes, fruits, nuts, vegetables, sugar beets, and cotton; among the semi-intensive, the alfalfa, rice, and corn. The residue of the cultivated land, about two-fifths of it, is used for crops of extensive type, involving much land and little labor or capital. Barley occupies the largest area of these extensive crops; then follow hay and forage of diverse kinds, including small grains cut for hay; then wheat cut for grain; then field beans and peas. The land from which crops are harvested is divided almost equally between that producing semi-intensive and intensive crops on the one hand (crops that may conveniently be called "non-extensive"), and on the other hand that producing extensive crops. (Acreage data mainly as given in *Census of Agriculture* for 1934.)

This approximately equal division of crop land between extensive and non-extensive uses distinguishes Californian agriculture from the agriculture of all other regions of Mediterranean climate. In Algeria, the intensive and semi-intensive crops occupy only about a fifth as much land as the extensive crops; in Australia still less. Even in Italy as a whole, only two-thirds as much land is devoted to the intensive and semi-intensive crops as to the extensive; and the proportion is lower in the southern half of Italy where the climate more closely resembles that of California. (Based on acreage data from *International Yearbook of Agricultural Statistics, 1937–38.*)

Because of the emphasis upon intensive and semi-intensive crops, Californian agriculture has often been called exceptionally productive. And so it is with reference to value of agricultural products per acre of farm land available for crops (including the land idle and fallow), and with reference to regions with similar climates. Since intensive crops tend to be valuable crops, it may be inferred even without the pertinent statistics that the relative importance of these intensive crops in California as compared with other regions of similar climates indicates a relatively high productivity of Californian agriculture in terms of per-acre values of product. The inference is all the more justified because California farmers produce intensive crops of remarkably fine quality.

Yet it would overstate the case to say that Californian agriculture is more productive than any other regardless of climate. In terms of income from sales of produce per acre of land available for crops, for example, Florida ranks on a par with California, New England ranks a little higher, and New Jersey nearly 50 per cent higher—reflecting broadly still greater emphasis on intensively cultivated valuable agricultural products. (Based on official estimates of gross income from farm production by states, 1934 and 1935 (*Agricultural Statistics, 1937*), divided by summations of census data on land available for crops plus areas in orchard and vineyard.) Presumably Denmark, Germany, and northern France would also rank above California.

It would be unwise to guess how Californian agriculture compares with others in productivity of another kind—the net income per farm family expendable for family living. This is a complex question, and much depends upon the amount of land operated by a farm family.

CHARACTER OF AGRICULTURE

The agriculture of California is commonly further characterized as specialized, commercialized, and mechanized. The farmers tend to specialize on one or two marketable products or groups of allied products. Most citrus growers

produce nothing but citrus, most prune growers practically nothing but prunes and apricots, a great many barley farmers nothing but barley and wheat, and so on. Relatively rare in California are farmers who, like most of the Danes, sell as long a list of products as milk, eggs, pigs, grain, and sugar beets. The so-called "general farm" so common in many states is not a type of farming found among the thirteen in California. The agriculture of California is commercialized in two senses: individual farmers produce for sale and rarely for household consumption, so that the subsistence type of farming is so rare as not to be listed; and the state as a whole ships much of its farm output to other states and foreign countries. Mechanization is highly developed. Tractors, trucks, combines, pumps, seed-drills, milking machines are familiar instruments, to mention only some of the larger and more expensive ones. Some farmers even sow rice by airplane.

It can further be said truthfully that Californian agriculture is highly organized and notably progressive. Farmers group themselves into coöperative associations, and are alert to adopt improvements of crop varieties and of agricultural practice.

But Californian agriculture does not stand out as definitely more specialized, commercialized, mechanized, organized, or progressive than the agricultures of *all* other regions of similar climate. In these respects the agriculture of Australia is similar, though the agricultures of the Mediterranean littoral and central Chile are very different, and South Africa stands in an intermediate position. The features that sharply differentiate Californian agriculture from that of *all* regions closely similar in climate are its emphasis upon the non-extensive crops, and its associated high productivity in terms of value of product per acre of land available for crops.

These in turn rest mainly upon the ratio of irrigated crop land to total crop and fallow land. Nowhere else within the Mediterranean climates of the world is there a block of nearly 9 million acres of arable land with somewhere around two-thirds of it irrigable from water-works already constructed. (In 1930, the irrigation enterprises of the state were estimated to be capable of supplying water to 6.8 million acres (*Statistical Abstract of the United States, 1937*, p. 569). Not all of this acreage, however, was necessarily part of the 8.7 million acres of cultivated land.) Over 3.5 million acres of crops were grown on irrigated land in California in 1934, out of a total acreage of harvested crops of 6.6 million acres.

FIGURE 5.—Harvesting unirrigated barley by combine, typical of foothill country. Fallow in background. (Courtesy of Pacific Rural Press, San Francisco.)

The growth of this irrigated area is the major factor that has changed California within half a century from a region of predominantly extensive agriculture like Australia today, not notably productive, to a relatively productive region where semi-intensive and intensive agriculture is strongly emphasized. Fifty years ago, in 1888, the state had three million acres in wheat, led all other wheat states except

Minnesota, and exported large quantities. Today the wheat acreage of California is only a fourth to a third of what it was 50 years ago, and wheat is imported regularly. Extensive types of agriculture have lost ground to intensive types, and irrigation was the principal instrument. (See E. D. Fagan: Some Theoretical Factors in the Migrations of the Wheat Belt in the United States, *The Balance Sheet* [Cincinnati, Ohio], September 1929, Supplement, pp. 3–7.) It is difficult even to imagine how different Californian agriculture would be if there were no irrigation. Enough, perhaps, is suggested by the facts that California farmers now harvest about 1.5 million acres of rice, cotton, alfalfa, sugar beets, and citrus fruits, of which practically none would be grown without irrigation; this is between a fourth and a fifth of the total acreage in harvested crops; and in addition there are hundreds of thousands of acres now planted to vegetables, vines, and various tree crops which could not be used for those crops without irrigation.

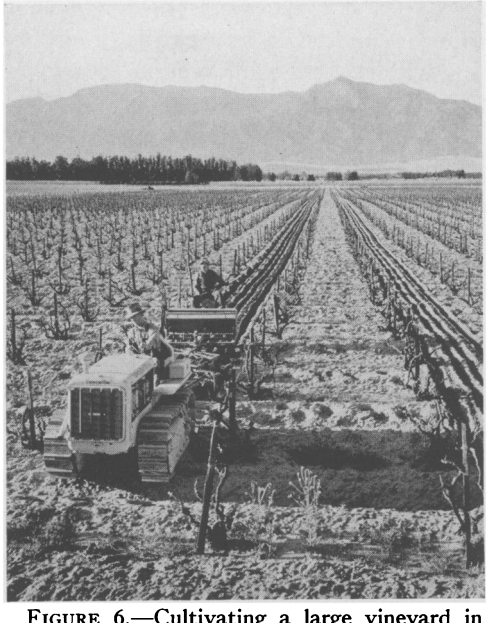

FIGURE 6.—Cultivating a large vineyard in southern California, typical of San Joaquin vineyard districts. (Courtesy of Pacific Rural Press, San Francisco.)

Irrigation in California is both by dam and ditch in specially formed irrigation districts, and by well and pump on individually owned establishments. Particulars as to importance of the two types are not available. In the great interior valley, however, irrigation is mostly by dam and ditch, utilizing water impounded on the western slope of the Sierras and derived both from direct run-off after rains and from run-off due to melting of the heavy winter snow-pack in spring and summer. Much less land is irrigated in the Sacramento than in the San Joaquin basin. The former has abundant unused water supplies, and new reserves following construction of an enormous dam near Reading in the upper Sacramento Valley will enlarge water supplies far to the south in the San Joaquin region. The Imperial Valley in extreme southern California draws irrigation water mainly from the Colorado River. In the intermontane valleys of the Coast Range and on the coastal plains, irrigation is mostly from wells, though around Los Angeles mountain water is also used. Water levels tend to decline in many or most of the coastal valleys and plains, and costs of lifting tend to increase. In order to achieve maximum replenishment of underground water, many cheap catchment dams have recently been erected in foothill country. They are so managed that winter rains, instead of running out to sea, are caught and fed slowly into stream-beds, there seeping underground.

Undoubtedly the great development of irrigation in California in part represents natural advantages—high mountains flanking a great expanse of agricultural area, with heavy precipitation in the mountains and a considerable fraction of it stored by nature in the

form of snow. It is probably true that no other large agricultural area in Mediterranean climates has a hinterland of mountain equally favorable for development of irrigation projects. But the favorable natural environment does not fully suffice to explain why irrigation is relatively so conspicuous in California; something depended upon economic prospects for profitable use of land once brought under irrigation.

THE AGRICULTURAL PROSPECT

Irrigation works, whether by dam and ditch or by well and pump, represent investment of capital. This investment required motivation. The obvious motivation was that men expected to receive a return when they placed investments in Californian irrigation—at least interest at current rates, amortization of capital in the course of time, perhaps something more. In many particular instances the investors were probably disappointed. But it is worth while to try to understand why so many people should have expected to receive good returns from investment in irrigation works in California.

A dominant factor in their expectations was anticipation of a market for fruits and vegetables wide enough to absorb increasing quantities at remunerative prices. Without the emergence of such a market particularly in the eastern part of the United States but also in western Europe and in California itself, Californian agriculture could not have followed its historical trend; and investors in irrigation works in California would not have been justified in expecting reasonable returns from their investment.

At least until the onset of world-wide economic depression in 1929, there was good reason to anticipate emergence and long-term growth of a remunerative market for the valuable, expensive, intensively-grown crops of California. The fundamental influences were obscurely felt and recognized, if not often fully and clearly expressed, by investors and farmers themselves. In those days people generally had a vague faith in the future of the country, even of the world. If that faith meant anything tangible, it meant belief in a persistent trend toward increasing per-capita consumption of goods and services, often called a rising standard of living. The belief rested on experience. It was easy to see that many peoples of the world and particularly those of the United States actually were consuming more goods and services per capita than they had done a decade or two or three before. It was even easy to perceive, with a little reflection, that the rising standard of living rested on persistently increasing efficiency of the manifold processes of

FIGURE 7.—Irrigating a pear orchard in the Santa Clara valley. (Courtesy of Berton Crandall, Palo Alto.)

production in industry, agriculture, and commerce.

If persistently increasing efficiency of production throughout the economic world could be assumed, then an investor in irrigation in California might have argued as follows: "The future will witness rising standards of living at home and in many places abroad. When standards of living rise generally, food standards rise also; people can and will reduce their consumption of cheap foods like bread and potatoes, and increase their consumption of all sorts of more expensive foods, including fresh and canned green vegetables and fresh and canned and dried fruits. The people will do this because they like to, and also because they will be able to afford to see the doctor oftener, and he will tell them to do it. There will also be more and more people. Therefore there is a good reason to anticipate a reasonable return on investment of money in Californian irrigation that will produce these expensive items. And there is all the more reason to do so if, as in the past, improvement continues in the speed and safety of transporting these things to markets two thousand miles or more away."

This may not have been the precise chain of reasoning openly expressed by any particular investor; but prudent long-term investors very probably acted upon reasoning of much the same drift. They had faith in the growth of a remunerative market for the expensive agricultural products that could be grown under irrigation in California.

The whole structure falls apart if one cannot pre-suppose persistently increasing efficiency of economic processes, which is sometimes described as rising effectiveness of labor. Without this presumption, standards of living, and standards of food consumption involving wider use of expensive perishable foods,

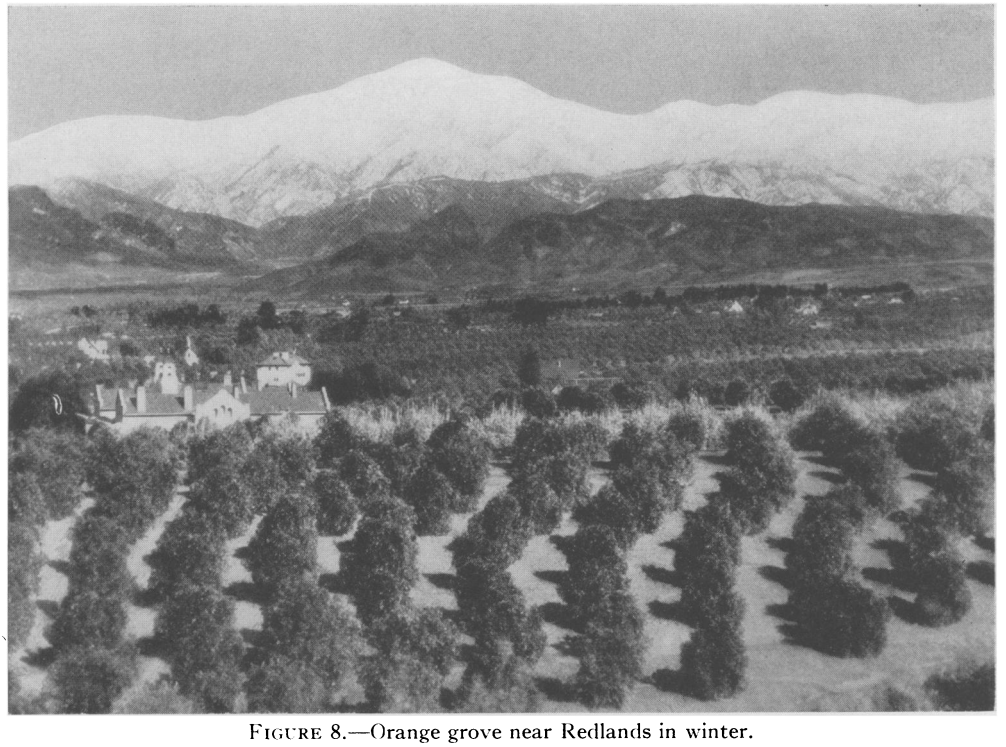

FIGURE 8.—Orange grove near Redlands in winter.

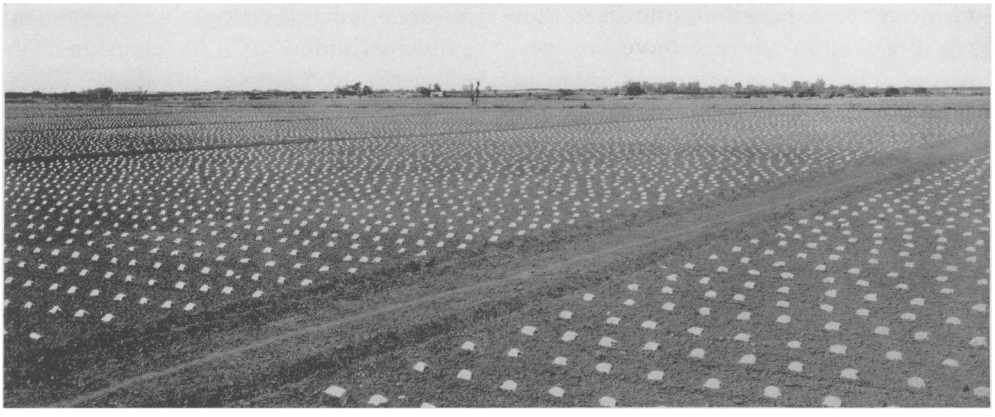

FIGURE 9.—Irrigated cantaloupe field in Imperial Valley in late winter; young plants protected. (Courtesy of California State Chamber of Commerce.)

are not likely to continue to rise. And if one cannot pre-suppose continued growth of population, the growth of a remunerative market for expensive perishable products is likely to be slowed up for this reason alone, even though standards of living rise while total population remains stable or declines.

The investor in Californian irrigation may well stand perplexed today, and indeed has had reason to view the future with uncertainty for nearly a decade. For the basically important assumptions no longer seem altogether safe. The experts in demography anticipate stability or decline of population either shortly or within a few decades, both in the United States and in many countries of Western Europe. The world is widely engaged either in destruction of capital in warfare, or in diversion of capital to uses (armaments) that in the long run do not promote the consumption of goods and services by the masses of people. Barriers to trade, which in themselves hamper international division of labor and therefore the general productivity of labor, are perhaps more prominent than they have been since the early days of the industrial revolution. Nations have tended internally—the United States among them—to substitute planned direction of economic activity for the free flow of capital and labor to the occupations which individuals might choose. The case in favor of such planning and direction, sometimes involving downright regimentation, remains to be proved by experience. It is not proved by the developments in Russia, Germany, or Italy.

If the agriculture of California is to retain or further emphasize the features that now distinguish it from the agricultures of regions with sister climates, that doubt needs to be resolved. The agricultural distinction of California does not rest fundamentally upon the climate, but upon the actions of men. Climate is passive or permissive; economic forces, largely man-made, are active and determining. It is not at all absurd, in the present state of the world, to say that the agricultural distinction of California might be lost within not many decades. Whether or not it will be lost probably depends as much upon the maintenance of a remunerative market as upon any other single influence. Today perhaps more than ever before, it is a major concern of forward-looking Californians to try to differentiate between the manifold national

and international economic policies that have been adopted or are under discussion. To put the matter bluntly, a world and a nation characterized by peace, free trade, and free competition is peculiarly important to Californians, because that is the sort of world that in the long run develops widening and remunerative markets for the expensive Californian agricultural products.

Note: Adapted with minor alterations from a paper presented to the Symposium on Climate and Man, Pacific Division of the American Association for the Advancement of Science, San Diego, California, June 21, 1938.