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Push to the Desert

The pressure of agriculture on California's arid lands illustrates the law of diminishing returns.

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One-third of the land surface of the earth has a dry climate, and these lands comprise the largest area of any of the climatic regions. It is not surprising, then, that with the present rapid increase in populations, the densely populated areas of the world are pressing ever more intensely on the margins of the dry lands. Most considerations of such pressure have emphasized Southeast Asia, North Africa, and the Middle East, where population densities are extremely high and living standards are correspondingly low. But the crowding of agriculture and populations on the rims of the dry regions is no longer uncommon in the more economically advanced and less densely populated countries, such as the United States and the Soviet Union. In the United States, for example, while cropland area has remained fairly static in most sections of the humid East since 1920, it has significantly increased in the drier West. Population has also grown more rapidly in the West.

The focal point of these "pressures" on the dry lands of the United States is California. One can appreciate this more fully if he considers that this state currently leads all others in rate and amount of population increase, in farm production and expenditure, and in irrigation, and yet has a sizable portion of the driest section of North America. The growth of irrigation farming in California therefore provides us with an excellent example of pressure on arid lands in an area where living standards are uniformly high and agricultural technology is well advanced—a situation quite in contrast to that in most countries of the world where dry conditions are encountered.

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Extent of California Dry Lands

Drought, in varying degrees, is common to almost all agricultural land in California (Fig. 1). Since croplands, or potential croplands, correspond generally to the lowlands, it is relatively simple to denote them by geomorphic terms (Fig. 2). The San Joaquin Valley and the Southeast Desert are the driest and, simultaneously, the largest of the California lowlands. These areas also include about 60 percent of the irrigable area of the state. Despite the difference in the terms used to describe their land forms both areas are definitely deserts from the standpoint of moisture deficiency, being classified as "arid" by Thornthwaite (*1*). Not quite as dry are the "semiarid" portions: the northern tip and eastern piedmont of the San Joaquin Valley, the Central Coastal Valleys between San Francisco and Santa Barbara, and the South Coastal Valleys. The Sacramento Valley and the Northeast Interior Basins and Valleys are even less dry ("dry subhumid") but still belong to the moisture-deficient group. Unfortunately, the last two regions named include only about 20 percent of the irrigable land in the state.

Only the several small lowlands of the North Coastal Valleys ("moist subhumid" or "humid") are judged to have sufficient moisture for agriculture. But these areas contain just 3 percent of the total agricultural land in the state, which, it is estimated, can eventually be irrigated if all the water available is utilized. Thus, even here, water supplies supplemental to the normal water supply are considered desirable, for even in the most humid portions of California drought conditions are approached for at least 2 months during the summer.

Areal Expansion of Irrigation

Beginnings of irrigation: 1848–1870. Some historians of agriculture still disagree on the question whether it was the early California miners-turned-farmers or the Mormons of Utah who introduced modern irrigation to the West. In any case, there is no question but that the forty-niners were the first group of any size to initiate "American" irrigation farming on a serious scale in California. Whereas the irrigation sites of the early missions were established along the central and southern California coast, most of the first irrigation projects of the "Anglos" were in the interior: the Sierra Nevada streams were tapped to water small, scattered croplands located principally along the eastern margins of the Sacramento Valley; like the irrigation projects of the missions, the projects of the Americans were developed only in semiarid areas. Only in the late 1800's and around the turn of the century did irrigation farming seriously invade the drier areas of the San Joaquin Valley and southeastern California.

Historical circumstance, rather than severity of drought, was actually the determining factor in the choice of initial locations for irrigation developments in California. The Spaniards considered primarily ease of access to coastal locations and the necessity for establishing centers from which political and religious control could be effectively exercised, whereas the American settlers concentrated their first irrigation projects close to the rapidly expanding markets provided by the gold-field populations. By 1870 other irrigated patches had developed, notably in the small northeastern semiarid portion of the San Joaquin Valley and in the South Coastal Valleys. To be sure, several centers of irrigation,

Table 1. Amounts of irrigated and irrigable land in California, 1889–1954. All figures except those in the last column are from statistics published by the U.S. Bureau of the Census. The division of acreage among the coastal (South Coastal Valleys) and interior (Southeast Desert) portions of Los Angeles, San Bernardino, and Riverside counties for 1889, 1899, 1939, and 1954 was determined from "Water utilization and requirements of California" [*Calif. State Water Resources Board Bull. 2* (1955), vol. 1, pp. 193, 211]; from "Memorandum report on water conditions in Antelope Valley" [Calif. Div. of Water Resources Publ. (1955), pp. 13, 18]; and from the agricultural commissioners' reports for Los Angeles, San Bernardino, and Riverside counties, respectively. Lack of readily available statistics made apportionment for the year 1919 more difficult, and only rough estimates of acreage were made. Maximum irrigable acreage was computed from *Calif. State Water Resources Board Bull. 2* and from L. R. Wohletz and E. E. Dolder, *Know California's Land* (State Printing Office, Sacramento, 1952).

Region	Irrigated area (10^3 acres) in years indicated					Maximum irrigable area (10^3 acres)
	1889	1899	1919	1939	1954	
San Joaquin Valley	469	749	2,059	2,490	3,739	6,749
Southeast Desert	46	41	539	516	674	4,000
Sacramento Valley	107	122	598	797	1,280	2,852
Northeast Interior Basins and Valleys	214	240	252	297	294	1,321
Central Coastal Valleys	9	57	200	351	490	1,215
South Coastal Valleys	153	227	554	594	495	1,024
North Coastal Valleys	4	6	11	23	79	552
Total	1,002	1,442	4,213	5,068	7,051	17,713

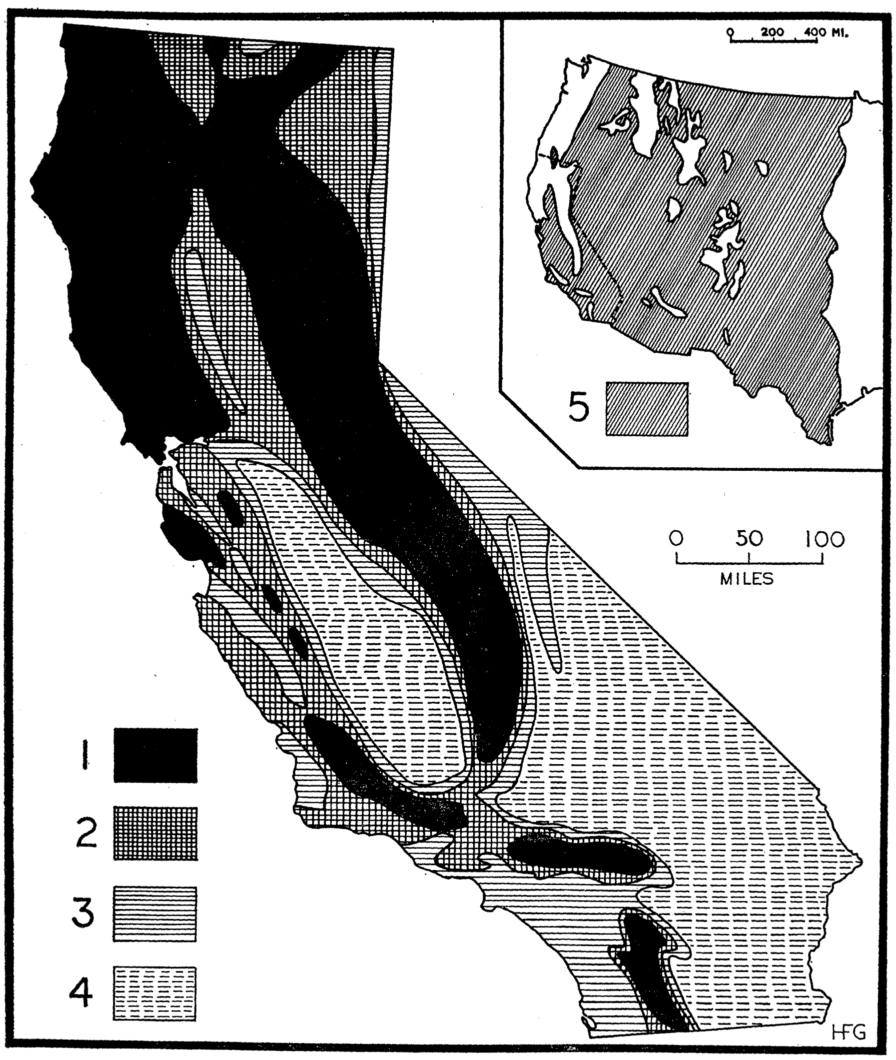

Fig. 1. Moisture regions of California: (1) areas of sufficient moisture; (2) dry subhumid areas; (3) semiarid areas; (4) arid areas; (5) moisture-deficient area of the West. [Generalized after Thornthwaite (1)]

remnants of the older mission enterprises, still existed at this time and were dispersed along the central and southern California coast from the San Francisco Bay region to San Diego. At no time, however, were these projects very large. Irrigation in California in 1870 involved only about 60,000 acres, yet this was many times the largest acreage the missions had ever watered. In no year, apparently, did the mission-cultivated acreage exceed 5000 to 10,000 acres, and much of that acreage was never irrigated.

Major expansions: 1870–1880. Extensive development of irrigation in California dates from the period 1869–1870, when the Central Pacific Railroad extended its tracks through the San Joaquin Valley. More land was then opened up to settlers, and, for the first time, relatively fast and dependable transportation was established between California and her rapidly expanding eastern markets. Soon all the major streams emanating from the Sierra Nevada became important centers for diversion of water onto the expanding croplands of the eastern and northern margins of the San Joaquin Valley. The first large irrigation system was constructed in 1871: a 40-mile-long canal was built to tap the San Joaquin River west of Fresno for irrigating lands northwest of the city. This project was followed by extensive canal construction in other portions of the San Joaquin Valley, again principally in the eastern half. Irrigation expansion also moved apace in the coastal lowlands of southern California. Thus, in the decade 1870 to 1880, there was not only sizable expansion of the irrigated acreage of the state but also an increasingly greater concentration of irrigation activity in the drier lands. The San Joaquin Valley forged ahead of the Sacramento Valley, and even semiarid coastal southern California began to challenge the Sacramento Valley in extent of irrigated lands (Table 1).

New irrigation activity during this period was by no means restricted to the Sacramento and San Joaquin valleys and the South Coastal Valleys. An increasing number of the scattered small lowlands in the mountains north and northeast of the Sacramento Valley were being "put to the ditch" (Fig. 3). Actually, it was not until around the turn of the century that such important irrigation farming areas as the Sacramento Valley and the coastal areas of southern California even equalled this northeastern section, the Northeast Interior Basins and Valleys complex. Such remarkable early development for a section of relatively limited lowland was more apparent than real, however. In addition to the lower temperatures, which precluded planting of the more intensively cultivated crops peculiar to most of the other dry lands in California, there was the problem of a much shorter growing season, which eliminated any possibility of double cropping, another feature now common to most of the dry-land regions where temperatures are milder.

Irrigation had already begun, too, at this early date in the southeastern desert region. But most of the irrigated cropland of the region was concentrated in the relatively cool Owens Valley, in the extreme northern portion. The rest of the southeastern desert corner of California was still largely a void on the agricultural map. Irrigation was expanding also, at a very moderate rate, in the parallel valleys of the coastal ranges between the San Francisco Bay and the Los Angeles areas. Even in the lowlands north of the Bay region—the only cultivable lands in California where moisture is not critically deficient—modest amounts of land were being added to the total acreage under irrigation. By 1880, the total irrigated acreage in California had increased sixfold over that of 1870, and 292,885 of the 350,000 irrigated acres were in the Sacramento and San Joaquin valleys and the South Coastal Valleys (*2*). Most of the land was in cereals and alfalfa, with only a small portion of it in orchards and gardens.

This was the period, too, of "irrigation colonies." Numerous settlements had already sprung up, at Riverside, Redlands, Pasadena, Pomona, and other southern California sites, while the Fresno area was a population center in the San Joaquin Valley. These "colonies" were usually not rigidly organized groupings. Some consisted of a few acquaintances; some were groups of people from certain localities in the eastern states and Europe; and still others were individual families brought together from everywhere by general advertising and promotional propaganda. The dominance of such groupings in the early history of irrigation in California, in contrast to the more individual undertakings of settlers in the humid lands of the United States, partly reflected the greater need for cooperation in the face of increasing environmental (that is, climatic) adversity (*3*). Even today, a major part of the irrigated area in California is under the administration of group organizations (irrigation districts).

Challenging the desert: 1880–1920. The progressive extension of the frontiers of irrigation farming into the drier portions of California during the period 1870 to 1880 was more than matched in succeeding decades. The San Joaquin Valley, as early as 1889, had almost half the state's irrigated acreage (Table 1). Second in importance at this date were the semiarid South Coastal Valleys, which, however, had not quite a third as much irrigated cropland as the San Joaquin Valley. The acreage in the Sacramento Valley, in turn, was exceeded by that in both these regions. The tardy growth of irrigation in the Sacramento Valley explains in part the increasing emphasis during this period on irrigation farming in the drier portions of California. Rainfall was relatively more plentiful in the Sacramento Valley, and therefore the valley did not require as much artificial watering. Areas of good soil in the semiarid and arid lands, especially in the San Joaquin Valley, are larger, because there is less leaching. And, perhaps most important, temperatures were higher in the more southerly valleys, thus speeding growth and making possible a greater and more varied agricultural production. Fruits, which require more water than field crops and thrive

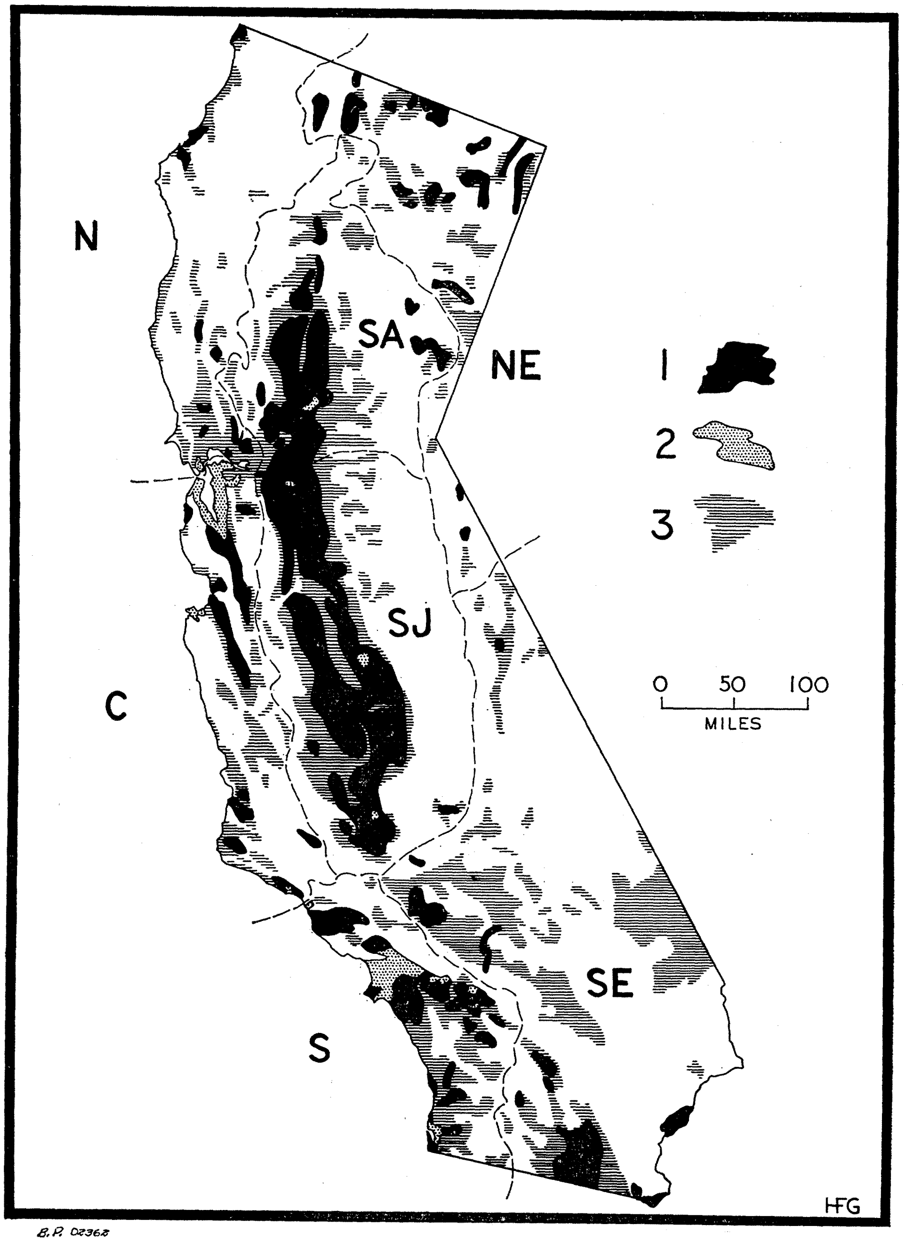

Fig. 2. Irrigation in California: (1) Irrigated land, (2) urban area, (3) irrigable land. Major lowland complexes: *N*, North Coastal Valleys; *C*, Central Coastal Valleys; *S*, South Coastal Valleys; *SA*, Sacramento Valley; *SJ*, San Joaquin Valley; *NE*, Northeast Interior Basins and Valleys; *SE*, Southeast Desert. [After L. R. Wohletz and E. E. Dolder, *Know California's Land* (State Printing Office, Sacramento, 1952) and *Calif. State Water Resources Board Bull. 2*]

better in the milder areas, were becoming an important part of California's production in the period 1880 to 1890. The direct connection of southern California with the East in 1881, by the Southern Pacific Railroad and the coming of railroad refrigeration in 1888 further stimulated agricultural production and thus the growth of irrigation, to the benefit of the southern half of the state.

The position of the Imperial Valley up to the turn of the century best illustrates an important agricultural problem in California: in the north, more moisture but less level land for cropping and a shorter growing season; in the south, more potential cropland and longer growing seasons but greater drought. Except for a narrow coastal strip in southern California, the areas where there are the longest periods between killing frosts are the Imperial Valley and other southerly portions of the Southeast Desert. This advantage is heightened by the higher temperatures of the interior. But this section is also the driest in California, and in the nation. An example is Brawley, an important marketing center in the Imperial Valley, which receives an average annual rainfall of just over 2 inches. Also, unlike the situation in either the Central Valley or coastal southern California, no major streams flow into the Southeast Desert from nearby mountains. Instead, the area is in the rain shadow of both the Sierra Nevada and the southern California coastal ranges.

But there remained the Colorado River to the east. The story of the tapping of the Colorado in 1901, via a canal that cut through over 80 miles of forbidding desert terrain, is now history, but the tremendous change in the irrigation status of the Southeast Desert is still manifest. From a position, in 1900, of inferiority, from the standpoint of acreage under irrigation, to every other major section of the California dry lands, it rose after World War II to equal, in acreage under irrigation, the South Coastal Valleys, and it seriously challenged the Sacramento Valley even earlier (Table 1). Prior to the irrigation of the Imperial Valley, most of the irrigated acreage had been in the northern and higher, or Mohave, portion of the Southeast Desert, where the growing season was not quite as long and the danger of winter frosts was greater.

Meanwhile, great additions were being made to the other principal irrigation areas of the state. Only in the Northeast Interior Basins and Valleys did expansion lag. The expansion in the Sacramento Valley was clearly evident by 1920 when this area surpassed the South Coastal Valleys in acreage under irrigation—this despite continuing impressive increases by the latter as well. The 1920 agricultural census also revealed moderately impressive growth in irrigation in the Central Coastal Valleys. Much of this land was formerly dry-farmed, but the better yields brought by irrigation, as well as by increasing the planting of tree crops, made big increases in irrigation farming inevitable. While the major growth of irrigation farming in the Southeast Desert during the early 1900's was in the Imperial Valley, other smaller oases were showing signs of development in this same period. Most important were the Antelope Valley (the westernmost extension of the Southeast Desert), the Mohave River Valley (east of the Antelope Valley), the Coachella Valley (north of the Imperial Valley), and two small sections along the Colorado River—the Palo Verde and Bard Valleys.

Advance and retreat: 1920–1954. The irrigation farming area has continued to grow in the Southeast Desert since the opening of the Imperial Valley. This increase becomes even more significant when compared with the situation in the South Coastal Valleys. Since World War II, the cropland area around Los Angeles has been slowly but steadily declining before the tremendous growth of the city and its numerous satellite urban centers. This marks the first time that modern irrigation farming in a major agricultural region of California has not registered an increase (Table 1). A partial result of this decline has been a further stimulus to cropland expansion in the immediately adjacent Southeast Desert region. The same situation has developed to a smaller degree in the San Francisco Bay Area conurbation; this has also resulted in increasing dependence on the oases (*4*).

An even weightier counterbalance to the acreage losses in coastal southern California was the remarkable advance in irrigation farming in the San Joaquin Valley. Between 1920 and 1954 the Sacramento and San Joaquin valleys gained a total of approximately 2.4 million acres of irrigated acreage—well over half again as much as the total irrigated area in the state in 1900. Three-fourths of this growth was in the drier west side of the San Joaquin Valley. Prior to even as late as the middle 1930's, most of the west side of the valley was termed a "desolate wasteland of jack-rabbits and sagebrush, with a limited amount of grazing for cattle and sheep" (*5*). The well-developed portion of the valley, largely the eastern third, had access to the major streams of the Sierra Nevada. The greatest concentration of the good soils of the valley was also there. Here, then, were the early sites of agriculture in the San Joaquin Valley, and, in fact, this section remains the core of many of the agricultural industries in the valley today.

Lying next to the lower coastal ranges on the western side of the valley, where there are fewer and smaller streams, the west side was unable to support much intensive agriculture worthy of the name. All was not "desolate wasteland," however. In the northern and middle portions of this area, where both the amount and the effectiveness of precipitation are a little greater, dry grain farming was practiced (*6*). In the late 1920's the perfecting of the deep-well turbine pump, plus high farm prices, made it economically practicable, for the first time, to tap the deeper connate water supplies of the west side of the valley. But the greatest surge was to come after World War II, the same period in which irrigation acreage began to decline in the coastal lowlands of southern California. Western Fresno County was the center of this growth; there irrigated acreage rose phenomenally from 90,000 in 1945 to 520,000 in 1951 (*7*).

Future Growth of Irrigation Farming

Directional trends. The growth of irrigation agriculture in both the San Joaquin and Sacramento valleys appears assured for at least the near foreseeable future. Much of this expansion antedated the Central Valley project, which is only now just beginning to show its benefits in a major way. Much land also remains to be reclaimed, the only immediate principal obstacle being availability of water. It is hoped that the problem of the now falling water table in the San Joaquin Valley (especially on the west side) will not become critical before construction of the planned additional irrigation facilities in the Central Valley project is completed and proposals for the Feather River project mature. Certainly there appears to be no indication, either, of a halt in the rise in irrigation farming in the Southeast Desert. Extrapolations of the curve for population growth in coastal southern California indicate that there will be even greater losses of agricultural land in that area in the future. While yield intensities may

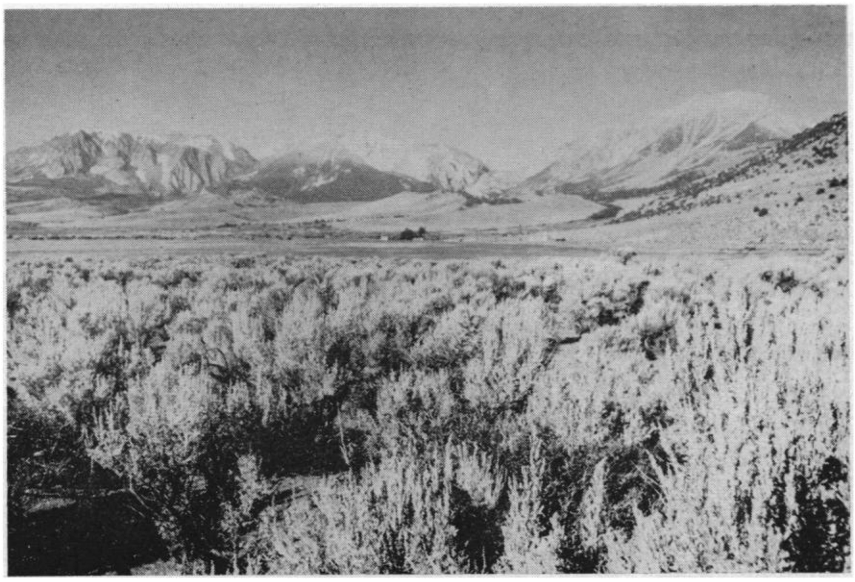

Fig. 3. Irrigated basin in the Mono Lake region. The sagebrush area in foreground is irrigable; the land on the lower grass slopes of the Sierra Nevada in the distance, just beyond irrigated flats, may be irrigable.

temporarily mask this increasing decline in the amount of irrigated cropland, the trend seems unmistakable: an increasing dependence on the desert for satisfaction of local and national food needs.

Relatively unnoticed in the impressive showing of the Central Valley and the Southeast Desert during the last half century has been the surge of the Central Coastal Valleys. In 1954 this region had about equalled the South Coastal Valleys in area under irrigation. As in the case of the Southeast Desert region, such increases were greatly stimulated by the losses of agricultural land to urban use in both the San Francisco Bay and Los Angeles areas; but the Central Coastal Valleys do not appear to have as good a prospect as the Southeast Desert for continued expansion of irrigation farming, in part because of the more restrictive terrain, but more because of the far greater potentialities of the Central Coastal Valleys for urbanization. The region is situated between the two main metropolitan centers of the state and has the seeds of further urbanization within its own area in the several towns of the central California coast.

Two movements, therefore, characterize areal trends in California's irrigation farming: (i) an increasingly southerly shift, further emphasizing the dominance of central and southern California; (ii) an easterly shift, from the coast to the interior—so far not as impressive as the first trend in actual acreage involved but with perhaps much more significance for the future. In both cases, the movements have created increasing pressure on the drier lands of the state.

Urban and agricultural land pressures. The pressures on the dry lands are both agricultural and urban in nature. In coastal southern California, the rapidly growing metropolitan complex has been a major factor in augmenting the pressure on the adjacent desert and will undoubtedly continue to be one in the future. In no other portion of the Western Hemisphere does so large an urban center impinge on arid land margins. Although local environmental and economic variations complicate the picture, there is a rough areal sequence in type of land use between the Los Angeles urban core and the outer (northern and eastern) margins of southern California: immediately adjacent to the built-up area is the most intensive type of agriculture in the region, irrigation farming; next is an area with a more extensive type of cropping, dry farming; on the peripheries of the ecumene, cropping disappears and only a very extensive type of livestock raising (in some areas, not even this) is pursued. This sequence may be ascribed in some part to the effect of increasing transportation costs for agricultural products as the distance between the main urban market and outlying producing centers becomes greater. The increased cost of land as the city area is approached is an even more important cause of this progression. Higher land rents, a result more of urban than of agricultural demands, stimulate an increase in agricultural intensity. This increase in intensity is reflected, in semiarid and arid lands especially, by the introduction and expansion of irrigation.

As the urban center grows, the circumferential land-use areas tend to migrate in the same direction. Thus, while irrigated lands have retreated before rapidly growing Los Angeles, they in turn have expanded at the expense of dry-farming sections. This outward movement has been much less noticeable for the dry-farming areas, although their character is modified through the substitution of more intensively cultivable crops (for example, vegetables in place of grain) as the irrigated sections approach. Also, to be sure, another factor modifies somewhat this pattern of areal and temporal changes in land use types: the effect of out-of-state markets. Most of the initial expansion in irrigated citrus acreage in the Los Angeles area, for example, was due to demands of the Eastern states, not those of Los Angeles. Yet, present shifts in acreage devoted to citrus fruits and other specialty crops with national markets also indicate the effect of urban encroachment as high-priced orchard and vegetable land is abandoned to the growing metropolitan area and more distant and less intensively cultivated agricultural land is sought for new plantings. The more recent greatly increased demands of the Los Angeles market and their effect on land-use change in the "rural-urban fringe" should not be overlooked, either. The increase in requirements for fruits and vegetables of this market has further promoted the outward expansion of the more intensive irrigation farming at the cost of dry farming and other less intensive types of farming (*8*).

There thus exist, actually, not just one but several land-use pressures, each affecting the other, the total effect being an advance of agriculture into the unutilized dry regions. The trend toward development of a ringlike pattern of land-use types surrounding an urban core illustrates von Thünen's law of land-use intensity, stated well over a hundred years ago (*9*). This trend applies not only to the principal urban area of Los Angeles and to the surrounding agricultural area but also, on a smaller scale, to Los Angeles' numerous satellite cities and their environs within coastal southern California. Such items as irregular terrain, microvariations in climate, availability or nonavailability of water, and the economic "pull" of urban expansion along radial transportation routes make the actual picture a complex one. But, again, this does not basically alter the picture of an over-all *tendency* toward a concentric pattern of land use.

Figure 4 (right) is a schematic illustration of these patterns of varying land-

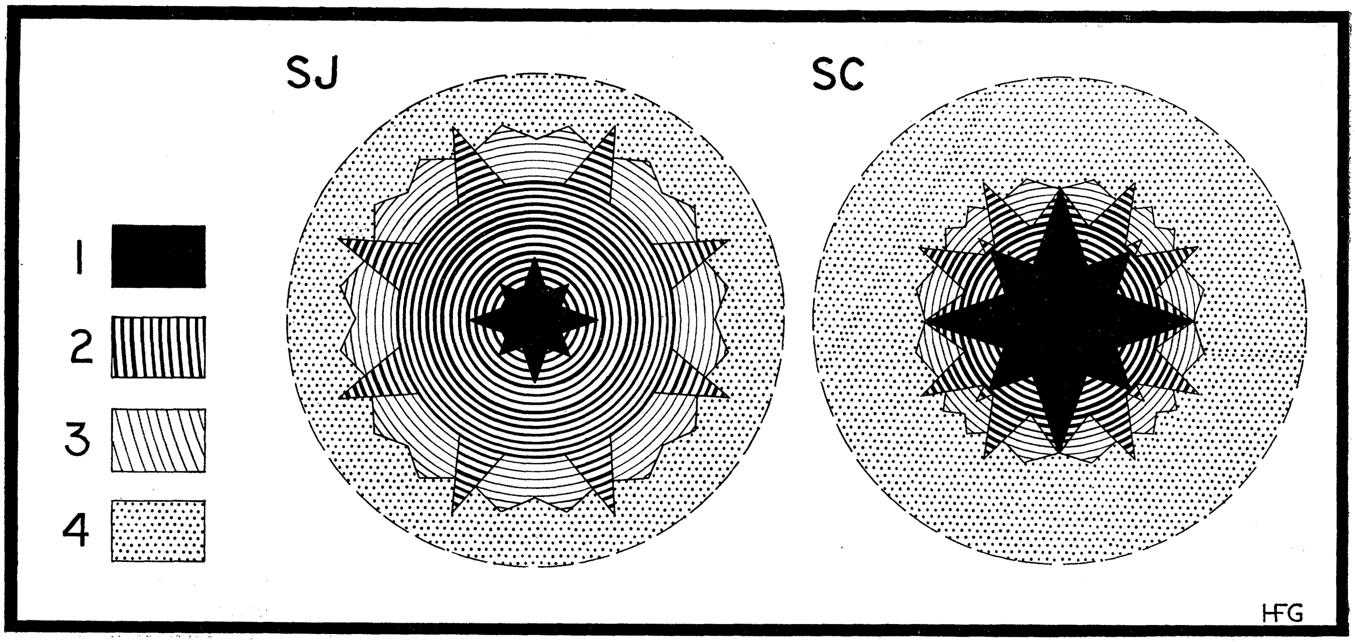

Fig. 4. Schematic diagram of spatial patterns of land-use pressure tendencies: (1) urban areas; (2) irrigation-farming areas; (3) dry-farming areas; (4) extensive livestock-raising areas (desert). *SJ,* San Joaquin Valley; *SC,* Southern California.

use intensity in the light of such tendencies. The wedges indicating urban use indicate the attraction of communication lines, along which the city expands (*10*). The freeways have been especially effective in this regard in the Los Angeles and San Diego areas. The channeling effect of the numerous valleys of coastal southern California may also be noted in these pronglike extensions. In some areas, irrigation farming also shows this tendency to put forth lone radial extensions, often penetrating the more peripheral and drier zones where no dry farming can intervene between the irrigated land and the surrounding "raw land."

Irrigation agriculture also tends to parallel the above-mentioned urban prongs where rapid transportation routes to markets exist. The more recent gains in irrigation farming in the Southeast Desert region of southern California are not contiguous to the irrigated areas of the coastal lowlands to the west. However, a sizable portion of the post-World War II increase in agricultural production in the irrigated Imperial, Coachella, and Palo Verde valleys has been due to the same pressures that have brought about the changes in types, and in areal patterns, of land use in the Los Angeles area: increases in urban markets and the need for new cropland to substitute for that lost to urban encroachment (*8*).

Urban pressures on the California dry lands are much less forceful in the San Joaquin and Sacramento valleys. A schematic diagram (Fig. 4, left) similar to that drawn for southern California but based on conditions in the San Joaquin Valley shows that irrigation agriculture is not only the most extensive but the dominant land-use pressure in the valley. This is further evidence that the San Joaquin Valley is the leading center of agricultural production (Table 1). Dry-farming areas on the outer margins of the irrigated area are also larger in the San Joaquin Valley than they are in southern California, and they embrace considerable areas along most of the valley periphery (Figs. 2 and 5). But, as in the southern portion of the state, sizable wedges of irrigation farming occasionally invade the more truly arid areas where dry farming is impossible. Aridity is not the only factor that restricts dry farming, by the way. Undeveloped land in or near irrigation-project areas usually increases markedly in value. Thus, just as urban influences on land valuations tend ultimately to discourage agriculture, the impact of irrigation farming on land prices tends to encourage intensive agriculture.

According to recent estimates, the San Joaquin Valley has somewhat less land available for future irrigation than the Southeast Desert (Table 1 and Fig. 2). While the proportion of urban land and the rate of urban growth are much smaller than in southern California or the San Francisco Bay area, urbanism in the San Joaquin and Sacramento valleys should not be underestimated. Such cities as Sacramento, Stockton, Fresno, and Bakersfield are still well ahead of the national growth average for centers of their size, and increasing loss of agricultural land on the city borders is a problem for them as well as for the two principal California metropolitan areas (*11*). However, the numerous advancing prongs of the Central Valley cities have had little effect on the outer margins of the irrigation-farming areas; this is quite in contrast to the situation in the southern California lowlands, where the ratio of urban area to cropland is noticeably greater.

That these tendencies toward peripheral expansion of both urban and agricultural lands will continue is fairly certain. And there is likewise little doubt that the land-use pressures on the dry lands in southern California will be increasingly attributable to urban growth, while advances on the arid sections of the San Joaquin Valley will remain largely agricultural in nature for some time to come. In southern California, for instance, the coastal urban mass has already, in some places, expanded into desert lands *ahead* of agriculture. These "suburbs in the sun" differ from the earlier settlements in the Southeast Desert in that, for establishment of the latter, a local agricultural base was considered an essential prerequisite (*12*). That there will be in the future a continuous urban area stretching from Los Angeles to San Diego and from the Pacific to the Los Angeles coastal ranges seems now a matter of certainty rather than merely an overoptimistic prediction by southern Californians. A similar development is in prospect for the San Francisco Bay region, where several of the valleys ringing the bays are undergoing rapid urbanization.

Availability of Water

Certainly the tremendous expansion of population and cropland at the expense of the California dry lands would not have been possible without a plentiful supply of water. California shares with the Pacific Northwest, middle Chile, Peru, and northern India the good fortune of having its dry lands in close juxtaposition to a very humid watershed. This areal relationship in California appears even more intimate when viewed locally: While the Sacramento and San Joaquin valleys are, in general, fairly intensively irrigated today, it is on the eastern sides of both lowlands that irrigation is most widespread—the areas closest to the Sierra Nevada and its numerous streams. The South Coastal Valleys likewise have for a long time owed a major share of their ground-water supplies to the encircling ranges of southern California. The correlation between dry lowland and mountain watershed along the margins of the Southeast Desert is now less evident than it was before irrigation water was imported into the more interior Imperial and Coachella valleys. Yet the underground reservoirs of water along the eastern foot of the Sierra Nevada and the Los Angeles ranges, while limited, have supplied several locally important irrigation farming areas, the most important being the previously mentioned Antelope Valley.

Such a simple geographical relationship as this, however, masks several other considerations affecting the availability of water, some of which may be of even greater significance to the future expansion of irrigation farming than just *physical* availability. These other "availabilities" are principally four in number: economic, political, areal, and technological. In actuality, none of these can be considered alone in viewing the current water problems of any particular irrigation-farming area, and only a few examples of their significance can be noted here.

Economic and political availability. A common misconception about the California water problem is that the combination of agricultural, industrial, and domestic demands will eventually exceed the water reserves of the state. The latest engineering reports state that there is *within* the state water above and beyond the needs of a prospective population of 40 million and for a potential irrigated agricultural area twice as large as the present irrigated acreage (*13*). Yet, the distance between some of those watersheds which are as yet relatively untapped and the particularly water-deficient lowlands is great enough to make the matter of financing a serious obstacle, even in such a rich state as California. The best example of this difficulty to date has been the relationship between Los Angeles, the major center of capital in the state, and neighboring southern California cities in the region's attempt to obtain Colorado River water.

Prior to 1928, Los Angeles, with its larger supply of water, was able to expand and build up its financial reserves at a much greater rate than were the surrounding urban centers. This in turn enabled the city to obtain even greater supplies of water, culminating in construction of the major Owens Valley Aqueduct. The result of this spiral of expansion was the crippling of the growth of other cities and towns, many of which were forced to request annexation to Los Angeles rather than face water starvation, especially in times of prolonged drought.

Continued urban expansion forced Los Angeles to look next to the Colorado River, a project which was to be even more costly than the Owens aqueduct and which would require not only additional capital from other southern California cities but their political support as well. Capital and political support were even more critical for the smaller cities, of course. The result was the organization of the Metropolitan Water District of Southern California, in 1928, an organization that now includes almost all of the cities of southern California and that fosters new water developments but allows these cities new freedom in their individual development (*14*). Thus, a further stimulus to urban expansion in southern California was provided —a movement which, as noted before, has encouraged the expansion and outward migration of irrigation farming on the urban margins.

The fact that most major water projects in California in the last 25 years—with the exception of the Central Valley project—have been initiated by, and constructed for use by, urban areas emphasizes the new and growing financial and political problems that stem from the problem of availability of water: the conflict between the water demands of agricultural and urban users. Although about 90 percent of the water used in California is used for irrigation, a major part of the capital needed for future water projects is controlled by urban interests. And this financial control is obviously increasing, at a time when the contemplated costs of such projects are at levels never before attained. Combined with capital control is the growing political power of the urban areas.

The proposed Feather River project is the best example to date of the effect of this growing twofold dominance. A

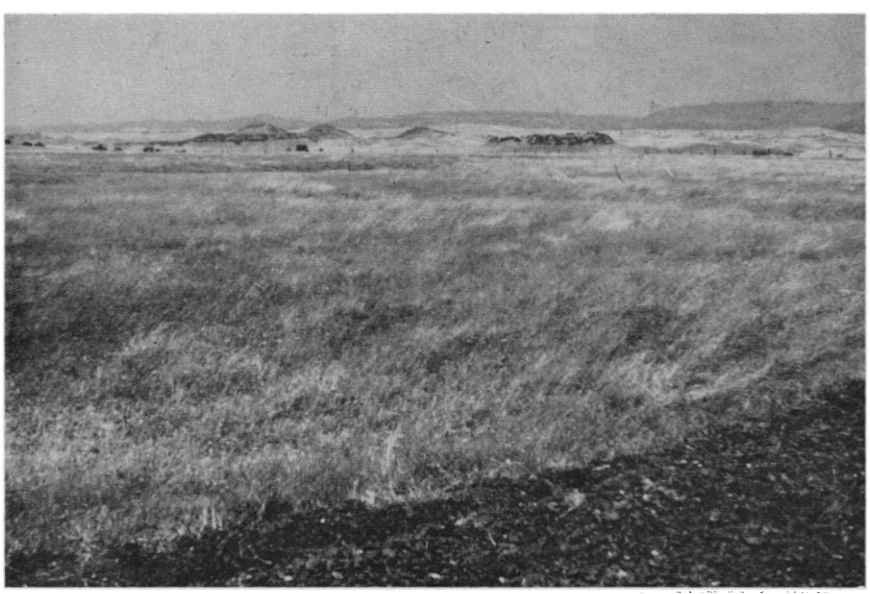

Fig. 5. Dry-farmed grain on the eastern margin of the middle San Joaquin Valley with Sierra Nevada foothills in the background.

major obstacle so far has been the refusal of the Metropolitan Water District of Southern California to agree to the plan until a firm guarantee of a permanent supply of water is made to southern California. The Central Valley proponents of the project, especially those from the San Joaquin Valley, have protested against this delay, since the falling water table is of much more immediate concern to the farmers of the valley than to the urban populations of southern California, which currently receive adequate water from the Owens-Mono and Colorado aqueducts. A similar delay has been encountered in the legislature for the past two years. Thus, although 60 percent of the water of the Feather River project would go to the dominantly agricultural Central Valley, the actual construction still rests on the consent of financially more powerful urban southern California. Here again are reflected the urban pressures on the expanding irrigation-farming frontier in southern California, which may be contrasted to the more purely agricultural character of the pressures on the irrigation frontier in the Central Valley. The advancing margin of irrigated lands in the Southeast Desert region, in fact, might well be labelled a "frontier of substitution"—that is, expansion on the desert periphery to compensate for losses in coastal southern California.

Indirectly related to the problem of economic availability of water is the problem of sufficiency of markets for the products of California's irrigation farming. There has been much argument in the past over the raising of crops in western irrigated areas which compete with similar crops raised in the humid East at much less cost. The California dry lands fortunately lie largely in areas of subtropical climate which permits cultivation of many crops which are normally lacking in the East, either during the more rigorous winters or throughout the year. There is, in addition, the rapidly growing population of both California and the nation, as well as the high level of prosperity, to create new food demands.

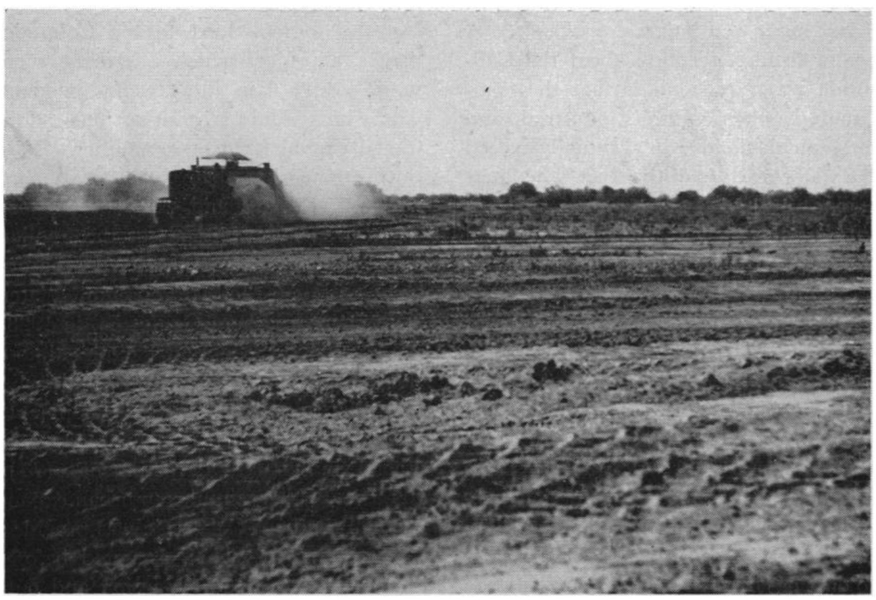

Fig. 6. Leveling of "raw land" in the Buena Vista Lake area, western San Joaquin Valley, prior to irrigation.

Fig. 7. Natural pasture on a sloping fan surface in the southwestern corner of the San Joaquin Valley, with apex of fan and coastal ranges in the background.

Areal availability. If it is assumed that water is economically available for all irrigable areas in California, the areal extent of those lands may be considered to be the ultimate determinant of how far the irrigation-farming frontiers shall advance. California has a sizable amount of both irrigated and irrigable land. It has long led the other states in expansion of irrigated land and contained, in 1954, better than one-third of the total irrigated land in the 11 western states in which most of the American dry lands are located (*15*). Its proportion of the national irrigated acreage is only slightly less impressive—24 percent.

The truly arid regions of California—the San Joaquin Valley and the Southeast Desert regions—together contained approximately 20 percent of the total irrigated area in the period 1949–1954. The San Joaquin has easily led all other single areas in the United States in advancement of irrigation farming into dryland margins (Fig. 6). Well over 2 million acres had already been irrigated by the time the Central Valley project was first beginning to show results and even before the west side expansion had started. The latter, incidentally, represents the largest single block of acreage to be put under irrigation in the United States since World War II, 1.2 million acres (*16*).

The statistics for irrigable area are even more encouraging. Sixty percent of the 17 million acres in the West which are capable of being irrigated lie within the boundaries of California. This amount is fairly well distributed among the principal irrigation-farming areas of the state. But it is again the San Joaquin Valley and the Southeast Desert which are the most favored (Fig. 7). The two regions include over 6 million (60 percent) of the total 10,837,600 acres of irrigable land (Table 1).

Qualifying this simple comparison of irrigated and irrigable land is the fact that a great proportion of the latter is of poorer agricultural quality than the former. It was natural that much of the best California soil would be utilized for irrigation farming first. Many of the best soil regions were directly in the paths of the early settlers (for example, the Los Angeles and Sacramento-Stockton areas); many were also supplied with surface water which was considered adequate for early irrigation-farming demands (for example, Los Angeles and the eastern San Joaquin Valley.

Since the western side of the San Joaquin Valley and several sections of the Southeast Desert region are today, from the standpoint of size, the areas where advances in irrigation are most likely to be made, it is interesting to note that some of the most serious soil problems that will be encountered in future attempts at irrigation farming are concentrated in these regions. This is especially the case in the Southeast Desert, where the extremely sandy soil and low water table are expected to exact a much greater toll in water than is the case in plots of comparable size in other agricultural areas of the state.

A further handicap is the widely dispersed and fragmented distribution of the best soil areas, which makes it economically infeasible to irrigate many sections. In consequence, the Southeast Desert has by no means the advantage over the drier portions of the San Joaquin and Sacramento valleys that comparative figures for acreage of irrigable lands indicate (Table 1). It is a reclamation tragedy of the first order that the Southeast Desert, which has the largest amount of land available for irrigation of any area in California, as well as one of the longest growing seasons, has more potential irrigation problems, exclusive of the problem of water supply, than any other area (*17*) (Fig. 8).

Better quality of soil, as well as larger supplies of water, make the west side of the San Joaquin Valley a decidedly better risk than the Southeast Desert. As noted before, this is the most important area of expanding irrigation in California at present. But, in comparison with the problems of the east side of the San Joaquin Valley, the problems which make the west side still a pioneer region stand out. Most of the great agricultural expansion in the drier western two-thirds of the valley has been in field crops. In contrast are the more numerous orchards and vineyards of the better developed east side; such crops are generally more valuable than barley, wheat, and flax, which, with cotton, are the principal rotation crops. While cotton is currently the most profitable crop in the San Joaquin Valley, it is the lack of more intensive rotation partners which largely prevents the west side of the valley from attaining the agricultural maturity of the eastern half. An important factor in this difference in crop emphasis is the high boron content of the soil and water of the west side. More fruit plantings are now being made, and while yields seem to compare favorably on the whole with those of the older fruit lands of the San Joaquin, the quality is not exceptional.

The poorer soil quality and smaller water supply of the west side of the San Joaquin Valley and the Southeast Desert, with their large areas of irrigable lands, have made these regions areas of large farms as well. The average farm on the west side of the San Joaquin Valley is about 4000 acres, while in Imperial County, the largest single concentration of farms in the Southeast Desert region, over half of the units are 1000 acres or larger. Although it is generally agreed that the prevalence of large landholdings materially retarded early irrigation de-

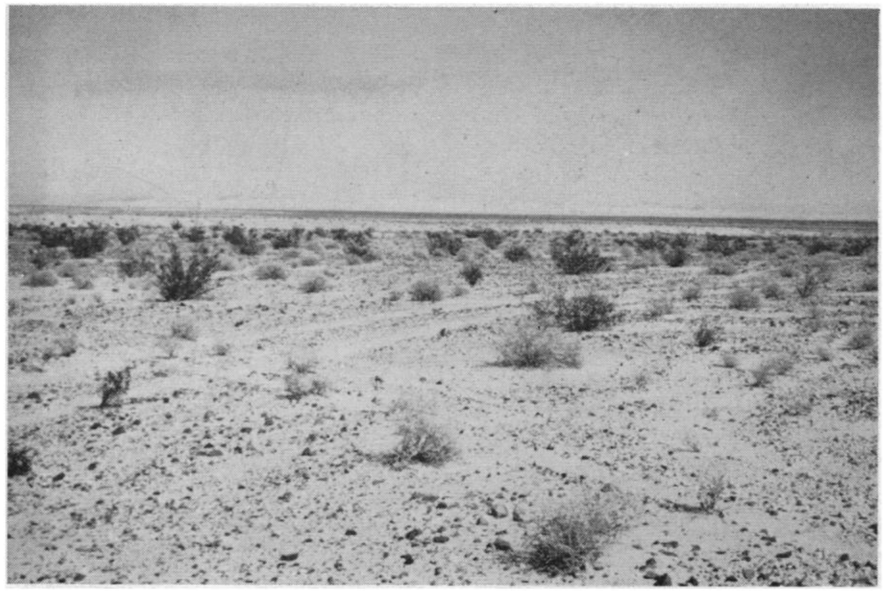

Fig. 8. "Raw land" of West Mesa area in the Southeast Desert, on the western side of the Imperial Valley. Extensive sand dunes may be seen on the horizon.

Fig. 9. "Mound" terrain in the drier west side of the Sacramento Valley. The chances of damage to the soil profile are great if ditch irrigation, with prior leveling, should be introduced.

Fig. 10. Hill lands on the western margin of the Sacramento Valley, where sprinkler irrigation appears to give promise of good results. The irrigated valley floor appears in the foreground, and peaks of the coastal ranges may be seen beyond the hills.

velopment of such areas as the San Joaquin and Sacramento valleys, it is quite doubtful that the drier areas like the west side of the San Joaquin Valley could have been irrigated much earlier, especially without causing great losses in income. In fact, several large landowners (and very often land companies) suffered financial reverses in attempting irrigation reclamation as early as the late 1800's in the drier portions of the San Joaquin Valley.

General farming practices on the typical west-side farm today, make mandatory a minimum of 1000 acres for economic operation. Water must be pumped from average depths of 400 to 450 feet. But even an annual pumping bill of $7500 for a section of land is exceeded by the costs of both cotton picking and fertilizers. To realize on the investment in pumping equipment, irrigation must be continued almost throughout the year. This, in turn, requires a greatly enlarged cropping acreage in the winter to compensate for reduced irrigation demands during that season. Moreover, an average of a quarter to a third of the farm is kept in fallow. This reduces the demands for water somewhat and is believed to be a help in reducing the harmful effects of boron. Increasing costs, due to recurrent investment in more and newer farm equipment, further contribute, as in other areas of the United States, to the growing economic need for larger farms. Land-leveling and soil-conditioning operations will add considerably more to future reclamation costs and perhaps even slow the over-all advance of irrigation farming. So far, much of the newly irrigated land of the San Joaquin Valley has been converted pasture and dry-farmed land, whereas an increasing amount of "raw land" will have to be conquered in the future. The operator of a large farm faces even greater difficulties in the Southeast Desert, where water and soil restrictions are so severe that a sizable portion of the region is now under Bureau of Reclamation withdrawal regulations.

Technological Availability. While such farming procedures as deep-well pumping, large-scale use of machinery, land leveling, and soil fertilization have increased costs for the irrigation farmer, they have also made for great benefits. Improved irrigation techniques have made water available to larger and larger areas, as well as in greater amounts. Improved methods for use of water have also been promoted. The result has been impressive gains, both in acreage and in yield, in agricultural production.

If, as is maintained by Webb, the windmill and barbed wire deserve much credit for the agricultural opening of the Great Plains (*18*), then certainly the pump and, more recently, the sprinkler can be said to have played similar roles in the progress of irrigation farming in the California dry lands. Though the first irrigation developments utilized surface water, it was not until the underground supplies were used extensively that irrigation farming began to expand in a major way, notably in the San Joaquin Valley and the South Coastal Valleys. Also, it was the deep-well turbine pump which made it economically possible to lift water from great depths, thereby paving the way for the first great development in irrigation cultivation in the west side of the San Joaquin Valley.

Sprinkler irrigation systems, first developed in the East over 50 years ago, have become especially popular since World War II with the introduction of improvements such as quick coupling and aluminum tubing. Sprinklers are more efficient than furrows, and, by increasing the permissible slope limit for irrigated tree farming to around 30 percent, have made possible the utilization of terrain formerly considered too rough for successful agricultural development (Figs. 9 and 10). Comparison of 1939 and 1955 estimates of the amount of land

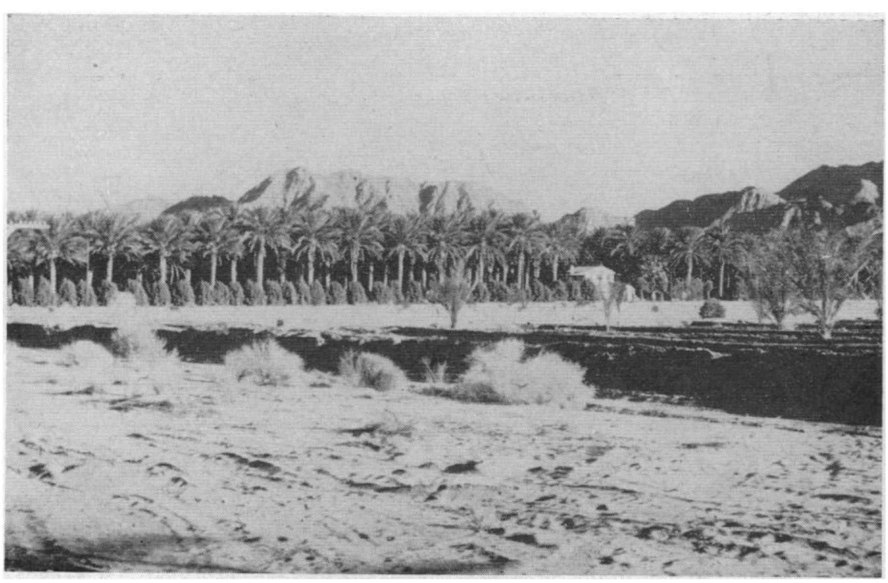

Fig. 11. Date groves on a sloping alluvial fan surface in the Coachella Valley, with more recent plantings in the right foreground.

that will ultimately be irrigated shows, for the Central Valley alone, an increase, based primarily on this consideration, of approximately 1.4 million acres (*19*). Land leveling, an absolute requirement for ditch irrigation, is not as vital if sprinklers are used. This fact has been of especial benefit in the western San Joaquin Valley, where well-developed soil profiles can often be irreparably damaged by even the most judicious leveling—quite a different situation from that in the Southeast Desert, where soils are younger. Sprinkler irrigation systems also offer the possibility of making financially feasible the irrigation of some of the small, dispersed plots of irrigable soil, as in the Southeast Desert. Sprinkler irrigation is thus one of the best examples of a situation where increasing technological development (when it occurs in conjunction with good markets) instead of relieving pressure on undeveloped agricultural lands actually increases it.

But sprinklers are not a panacea. While initial installation costs are low compared with those of a fixed system of irrigation, continuing overhead charges are higher. Soils with very low water-absorption rates can often be better watered by the furrow method. Where soils are too permeable, longer sprinklings will cause loss through deep percolation. Evaporation rates are also quite high. In addition, sprinkling is most effective only at prescribed pressures (*20*).

The utility of water has been enhanced even further by numerous other technological improvements. Crop yields have been greatly boosted by such advances as more and better machinery, greater use of fertilizers, better soil conservation practices, improved varieties of plants, improved strains of animals, and improvements in production, processing and marketing methods. California now maintains a commanding lead among the states in expenditures for machinery and fertilizer. Increases in yield have noticeably delayed the full impact of the diminution in acreage devoted to agriculture on farm production in rapidly urbanizing areas. A case in point is that of the South Coastal Valleys region, which, since 1945, has lost more agricultural land to urban and industrial uses than any other section of the state but, at the same time, has led all other areas in the expansion of agricultural production for local needs. Almost 70 percent of the fresh fruit and vegetable supplies for the two great urban centers of California still comes from the immediate coastal area, where urbanization of agricultural land has been most extensive.

Importation of water, made possible through an extensive and complicated system of canals, pipelines, dams, and pumping stations, is promising to be, for irrigation in California, what it has been for the Los Angeles and San Francisco Bay urban areas. This is again especially true for the drier areas; the Imperial and Coachella valleys are now supplied by the Colorado River, and the southern and western margins of the San Joaquin Valley are getting increasingly large quantities of water from the Central Valley project as it nears completion (Fig. 11). The Feather River project promises to irrigate even more of the Central Valley, as well as portions of the western margins of the Southeast Desert.

But the project also points up the increasing costs of water so obtained, to which the agricultural economy is much more sensitive than the urban. Greater need *and* higher water charges will result in the diversion to urban use of most of the Feather River water to be made available for the South Coastal Valleys, although this may in turn release to farm lands some additional Colorado River water now being reserved for future urban requirements.

Current costs of sea-water reclamation make the use of sea water for irrigation farming even less likely. Although there has been much recent publicity about impending success in efforts to demineralize water at prices that would make this process economically feasible, it should be remembered that "economically feasible" means at prices which only industrial and urban users seem able to bear. Also hindering any extensive use of reclaimed sea water would be the costs of the pumping equipment necessary to get the water over the coastal ranges to the San Joaquin Valley and the Southeast Desert. Extensive use of atomic power for pumping is still in the theoretical stage. Yet, extensive use of reclaimed sea water by the cities would undoubtedly release an abundant supply of Colorado River and Sierra Nevada water, now consumed to a large degree by the cities, to the agricultural regions.

Desalinization of brackish water offers some hope for increasing the water supply for irrigation farming. The salt content of such water is, on the average, only about one-tenth that of sea water. Since brackish waters are common in both the San Joaquin and the Imperial valleys, importation (that is, pumping) costs would also be considerably lower than those incurred in any scheme for recovery of sea water. A more currently realizable water reclamation plan appears to be that of sewage reclamation. Cost estimates show that charges for such water would be only about one-sixth of the charges for reclaimed sea water. A small element of health hazard would still exist, however, if sewage water were improperly treated.

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